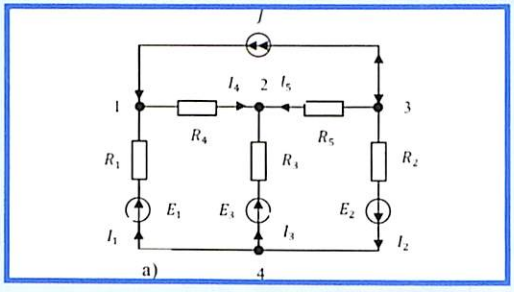
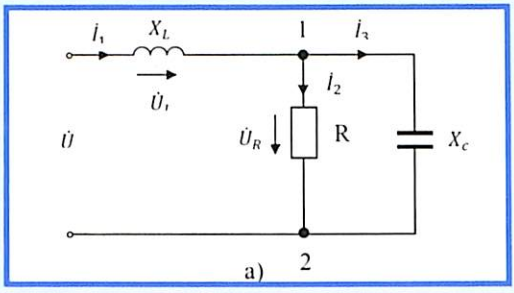
M. IBADULLAYEV, A. TOVBOEV, A. YESENBEKOV

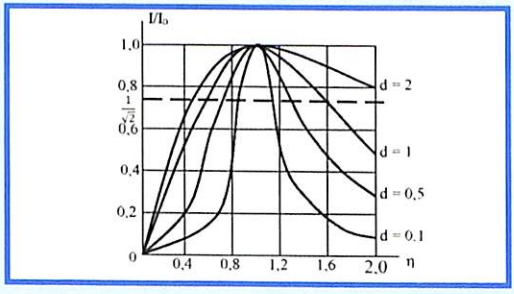
NAZARIY ELEKTROTEXNIKA

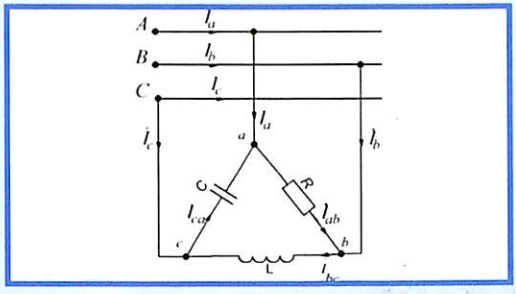
MASALA VA MASHQLAR TO‘PLAMI

I - QISM









O‘ZBEKISTON RESPUBLIKASI
OLIY VA O‘RTA MAXSUS TA’LIM VAZIRLIGI

M. IBADULLAYEV, A. TOVBOEV, A. YESENBEKOV

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I - QISM

Oliy va o‘rta maxsus ta’lim vazirligi tomonidan Oliy o‘quv yurtlarining elektroenergetika, elektrotexnika, radiotexnika va boshqa yo‘nalish talabalari uchun o‘quv qo‘llanma sifatida tavsiya etilgan.

«O‘zbekiston xalqaro islom akademiyasi»
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Toshkent – 2020

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Taqrizchilar:

G‘aipov T.Sh. *–texnika fanlari doktori, “Elektr stansiyalari, tarmoqlari va tizimlari” kafedrasi mudiri, professor.*

Oripov N.M. *– texnika fanlari doktori, Toshkent temir yo’llari muhandislik instituti professori.*

Ushbu o‘quv qo‘llanma oliy o‘quv yurtlarining elektroenergetika, elektrotexnika, elektromexanika, avtomatika, radiotexnika va boshqa yo‘nalishlarida ta’lim olayotgan bakalavr talabalar uchun tavsiya etilib, shuningdek magistr, doktorant va soha mutaxassislari ham foydalanishlari mumkin.

O‘quv qo‘llanma O‘zbekiston Respublikasi Oliy va o‘rta maxsus ta’lim vazirligining 2020-yil 30-iyundagi 359-sonli buyrug‘iga asosan nashr etishga ruxsat berilgan.

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Fanni o’rganishda qoidaga qaraganda misollar foydaliroq bo’ladi.
Isaak Nyuton.

Muqaddima

Mamlakatimiz sanoatining salohiyatini rivojlanishida elektroenergetika sohasining ahamiyati beqiyos bo‘lib, uning ilmiy-nazariy asosi bo‘lmish nazariy elektrotexnikasiz tasavvur qilib bo‘lmaydi.

Umuman olganda, elektrotexnika hamma zamonaviy elektrotexnik soha yo‘nalishlari (energetika, avtomatika, elektronika, radiotexnika, aloqa, telekommunikatsiya, informatika va hokazo) uchun fundamental fan tarmog‘i hisoblanadi.

O’zbekiston Respublikasi oliy va o’rta maxsus ta’lim vazirligi tomonidan tasdiqlangan o’quv dasturiga asosan «Nazariy elektrotexnika» fanidan ma’ruza amalyot darsi va labarotoriya ishlari rejalashtirilgan bo’lib, talabalar nazarya qismidan olgan bilimlarini chuqurroq o`zlashtirish uchun amaliyot darsida mustaqil masala yecha bilish, hisob grafik ishlarini bajarish va test savollarini yechish natijasida amaliy ko’nikmalarga ega bo’lishadi.

Ushbu o‘quv qo‘llanma «Nazariy elektrotexnika» fani dasturi asosida tuzilgan bo‘lib, chiziqli elektr zanjir qismiga doir talabalar mustaqil yechish uchun misol va masalalar berilib na’muna sifatida yechimlari ko’rsatilgan hamda nazariy bilimlarini sinab ko;rish uchun savollar ham berilgan.

Har bir bobga oid fanning nazariy qismidan elektr zanjirni hisoblash uchun zarur bo‘lgan qonun-qoidalar, atamalar, formulalar, tenglamalar, analitik, grafik, kompleks usullar, vektor ifodalari va hisoblash usullari bo‘yicha qisqacha asosiy tushunchalar o‘z ifodasini topgan.

O‘quv qo‘llanma elektroenergetika, elektrotexnika, elektromexanika, elektrotexnologiya, avtomatika, radioelektronika, telekommunikatsiya va axborot texnologiya soha yo‘nalishlari bo‘yicha ta’lim olayotgan bakalavr talabalarga mo‘ljallangan bo‘lib, undan soha mutaxassislari, magistr va doktorantlar ham foydalanishlari mumkin.

O‘quv qo‘llanma talabalarga amaliy mashg‘ulot darsini o‘zlashtirishda mustaqil masalalar yechish, hisob-grafik ishini bajarish, test savollarini yechish va nazariy bilimlarini amalda sinab ko‘rishlarida yordam bo‘ladi degan umiddamiz. Mualliflar o‘quv qo‘llanmani nashga tayyorlashda yordam bergan bakalavr talabasi S. K. Matkarimovga samimiy minatdorchiligini bildiradi.

1. O‘ZGARMAS TOK ELEKTR ZANJIR

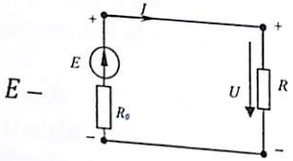
1.1. Umumiy tushunchalar

1. **O‘zgarmas tok** – vaqt bo‘yicha o‘zgarmas bo‘lib

$$I = \frac{q}{t}\ (\frac{Kulon}{sek} = A)$$

O‘zgarmas tok manbalari: o‘zgarmas tok generatori, akkumulator, galvanik elementlar, foto-elementlar, termopara, pyezodatchik va hokazolar elektr yurituvchi kuch (EYK) manbai hisoblanadi.

Amalda mexanik, kimyoviy, issiqlik, shamol, yorug‘lik va boshqa xildagi energiyani elektr energiyasiga aylantirish bilan **elektr manbai** hosil qilinadi. Hosil qilingan elektr energiyasini iste’molchilarga uzatish liniyasi, kabel simlari va elektromagnit to‘lqin orqali yetkaziladi. Bunday bog‘lanishni elektrotexnikada **berk elektr zanjir** deyilib, quyidagi sxema ko‘rinishida ifodalash mumkin.



E – I – tok

U – istemolchi kuchlanishi

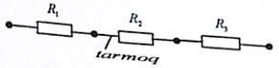
manba EYK

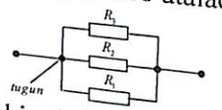
R – iste’molchi qarshiligi.

R_0 – manba ichki qarshiligi

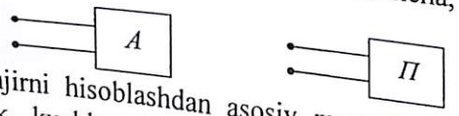
Iste’molchilarda elektr energiyasi boshqa xildagi energiyaga o‘zgartiriladi (mexanik, issiqlik, yorug‘lik, kimyoviy va hakozolar).

Elektr zanjirlar tarmoqlangan va tarmoqlanmagan bo‘lib, iste’molchilarni birlashtiruvchi simlar **tarmoq** (shoxobcha) va uchtadan ko‘p shoxobchani birlashtiruvchi nuqtalar – **tugun** deb ataladi.





Ikki qutbli elektr zanjir ***aktiv*** yoki aksincha, ***passiv*** bo‘lishi mumkin.



Elektr zanjirni hisoblashdan asosiy maqsad, iste’molchilar foydalanyotgan tok, kuchlanish va sarf bo‘ladigan elektr energiyasi quvvatini hisoblab topishdan iborat bo‘lib, Om va Kirxgof qonunidan foydalaniladi.

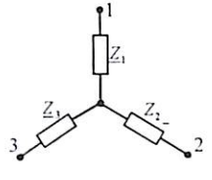
Passiv elektr zanjir parametrlari o’zaro ketma-ket, parallel, aralash yoki murakkab sxemalar ko’rinishida ulanishi mumkin:

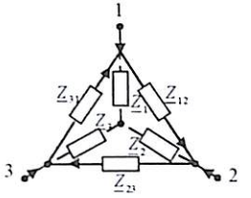
Masalan: a) zanjirning R qarshiligi sxemada ketma-ket ulangan bo’lsa, (ekvivalent) umumiy qarshiligi: $R_{ekv} = \sum_{n=1}^{n=\infty} R_n$ –ya’ni **qarshiliklari qo’shiladi**:

b) parallel ulangan holda ekvivalent qarshilik $G_{ekv} = \frac{1}{R_{ekv}} = \sum_{n=1}^{n=\infty} G_n$ bo’lib, **o’tkazuvchanliklari qo’shiladi**:

c) qarshiliklar o’zaro uchburchak (rasm) yoki yulduzcha shaklidagi sxemalarda ulangan yoki aksincha bo’lsa ekvivalent qarshiliklarini topishda quyidagi formulalardan foydalanish mumkin. Yulduzcha va uchburchak tarzida ulangan tarmoqlarni o‘zaro almashtirish (ekvivalent parametrlar):

a) uchburchak shaklida ulangan qarshiliklarni yulduzcha shaklida almashtirish tenglamalari:





$$Z_1 = \frac{Z_{31}\cdot Z_{12}}{Z_{12}+Z_{31}+Z_{23}};\quad Z_2 = \frac{Z_{12}\cdot Z_{23}}{Z_{12}+Z_{23}+Z_{31}};\quad Z_3 = \frac{Z_{23}\cdot Z_{31}}{Z_{12}+Z_{23}+Z_{31}};$$

b) yulduzcha shaklidan uchburchak shakliga almashtirish tenglamalari:

$$Z_{12} = Z_1 + Z_2 + \frac{Z_1 \cdot Z_2}{Z_3};\quad Z_{23} = Z_2 + Z_3 + \frac{Z_2 \cdot Z_3}{Z_1};$$

$$Z_{31} = Z_3 + Z_1 + \frac{Z_1 \cdot Z_3}{Z_2};$$

d) Murakkab sxemalardagi ekvivalent qarshiliklarni hisoblashda ketma-ket soddalashtirish usulidan foydalaniladi.

2. Elektr kuchlanish yoki **potensiallar farqi** deb, elektr maydon E (manba) ta’sirida biror musbat q zaryadning l masofaga ko‘chirilishida bajarilgan ishga aytiladi va ***Volt*** da o‘lchanadi.

$$U_{ab} = \frac{A}{q} = \int_a^b Edl = \varphi_a - \varphi_b\ (V) \qquad (1.1)$$

Masalan: R – qarshilikdagi kuchlanish potensiallar ayirmasiga yoki manba kuchlanishiga teng:

Bunda:

$\varphi_a - \varphi_b = U_{ab} = IR$; yoki $\varphi_b - \varphi_a = U_{ba} = E$; $U_{ba} = -U_{ab}$

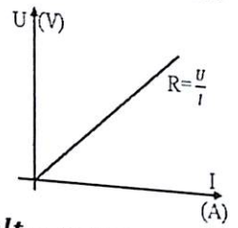
3. Elektr zanjir uchun Om qonuni.

Aktiv ***R*** qarshiligi bo‘lgan zanjirning bir qismi uchun Om qonuni:

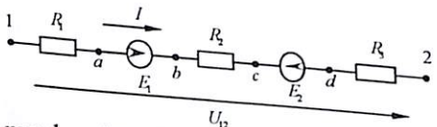
$$U_{ba} = U = RI\ (V) \text{ yoki } I = \frac{U}{R}\ (\text{A}) \qquad (1.2)$$

Bundan:

$$R = \frac{U}{I}(\text{Om}) \text{ yoki } g = \frac{1}{R} = \frac{I}{U}\left(\frac{1}{Om} - \text{ Simens}\right) \qquad (1.3)$$



U holda qarshilik ***volt – amper*** xarakteristikasi $I = f(U)$ chiziqli o‘zgaradi.



Elektr zanjirga manba ulangan holda butun zanjir uchun Om qonuni quyidagicha tenglama bilan ifodalanadi. Potensiallar tenglamasiga asosan:

$$\varphi_d = \varphi_2 + R_3 I\ ,\ \varphi_c = \varphi_d + E_2, \varphi_v = \varphi_c + R_2 I, \varphi_a = \varphi_v - E_1, \varphi_1 = \varphi_a - R_1 I$$

yoki:

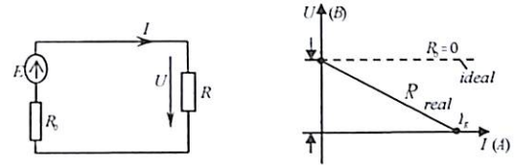
$$\varphi_1 = \varphi_2 + R_1 I + E_1 + R_2 I - E_2 + R_3 I, \varphi_1 - \varphi_2 = U_{12}$$
$$U_{12} = (R_1 + R_2 + R_3)I + E_1 - E_2$$

Bundan:

$$I = \frac{E_1 - E_2 + U_{12}}{R_1 + R_2 + R_3} = \frac{E_1 - E_2 + U_{12}}{\sum R_{um}} \qquad (1.4)$$

4. Elektr manbalar ekvivalent o’xshashlik sxemalari.

Amalda elektr zanjir tashqi *Volt-Amper* xarakteristikasi $U(I)$ quyidagicha ifodalaniladi:



Ushbu zanjirdan o‘tuvchi tok: $I = \frac{E}{R_0 + R}$ yoki: $U = RI$

Kirxgof 2-qonuniga asosan:

$$R_0 I + RI = E \quad \text{yoki} \quad U = E - R_0 I \qquad (1.5)$$

$Volt - Amper$ xarakteristikasidan, ya’ni (1.5) tenglamadan: $E = const$ va $R_0 = const$ xarakteristikasi to‘g‘ri chiziqli bo‘lib, kuchlanish manbai tashqi xarakteristikasini $U(I)$ ifodalaydi:

a) salt holatda: $R = \infty, I = 0$ bo‘lib: $U = U_0 = E$ (1.6)

b) qisqa tutashtirilganda: $R = 0, U = 0$ bo‘lib: $I = I_K = \frac{E}{R_0}$ (1.7)

$R_0 = 0$ bo‘lganda esa ideal kuchlanish manbai bo‘lib:

$U = E = const$

Ushbu sxemani iste’molchi qarshiligiga nisbatan boshqa ko‘rinishga keltirish mumkin. Buning uchun (1.5) tenglamadan manba ichki qarshiligi R_0 ga bo‘lib yuborilsa:

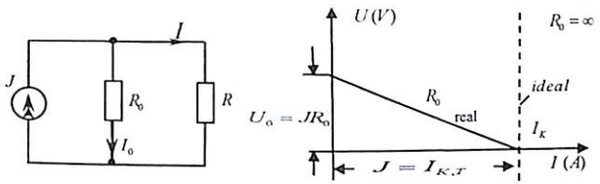
$$\frac{U}{R_0} = \frac{E}{R_0} - I \qquad (1.8)$$

(1.7) tenglamaga asosan:

$$I_K = \frac{U}{R_0} = J \ va\ \frac{U}{R_0} = I_0 \quad \text{yoki} \quad I_0 = \dot{J} - I \qquad (1.9)$$

Bundan: $\dot{J} = I_0 + I$ **tok manbai** bo‘ladi, yoki: $I = \dot{J} - \frac{U}{R_0}$ (1.10)

(1.10) tenglamaga asosan tok manbai (energiya) ekvivalent sxemasi va tashqi xarakteristikasi quyidagicha ifodalanadi:



Tok manbai tashqi xarakteristikasi:

a) salt holatda: $R = \infty, I = 0$ yoki $j = I_K = \frac{U}{R_0}$;

$$U = U_0 = I_K R_0 = E$$

b) qisqa tutashuvda: $R = 0;\ U = 0$ yoki $I = I_K = j = \frac{U}{R_0}$.

Agar $R_0 = \infty, (g_0 = 0)$ bo'lsa, ideal tok manbai bo'ladi: $j = I = const$.

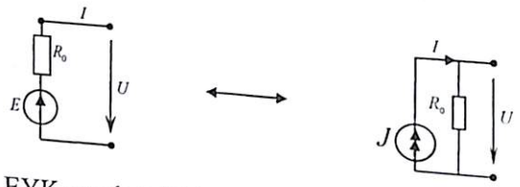
Natijada elektr zanjirni hisoblashda ideal EYK manbaini ekvivalent tok manbaiga almashtirish yoki aksincha amalga oshirish mumkin bo'ladi.

Masalan: berilgan sxemada EYK manbai $E = 12\ V$ ichki qarshiligi $R_0 = 2\ Om$. Tok manbaining ekvivalent sxemasi tuzilsin:

Yechish. Om qonuniga asosan tok manbai qiymatini aniqlaymiz:

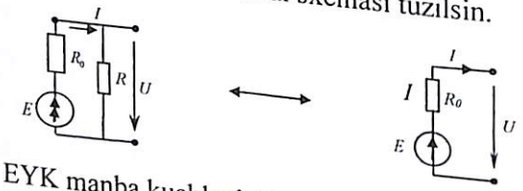
$$j = \frac{E}{R_0} = \frac{12}{2} = 6\ A$$

Ekvivalent sxemasi quyidagicha ifodalanadi:



Bunda EYK manbai E bilan tok manbai j yo'nalishi bir xil bo'ladi hamda ekvivalent sxemaga almashtirilganda tashqi qarshilik qiymati o'zgarmaydi. Ammo quvvat har xil bo'lishi mumkin.

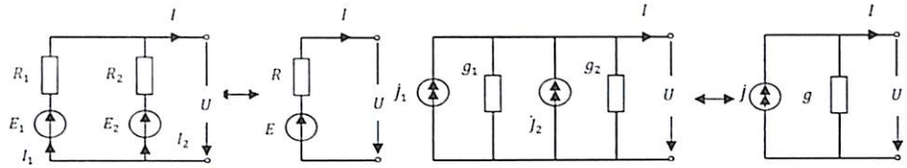
Masalan. Elektr sxemada tok manbai $J = 10A$, ichki qarshilik $R_0 = 3\ Om$ bo'lganda ekvivalent EYK manbai sxemasi tuzilsin.



Yechish. EYK manba kuchlanishi $E = J\ R_0 = 10 \cdot 3 = 30\ V$

Eslatma: Keyinchalik ekvivalent sxemaga o'tishda manba ichki qarshiligi yoki o'tkazuvchanligini iste'molchilar tashqi qarshiligi yoki o'tkazuvchanligi bilan hisobga olamiz ($R_0 = 0,\ g = 0$). EYK manba bilan tok manbaini yoki aksincha almashtirilganda tashqi qarshilikga ta'siri bo'lmaydi, lekin manbadan chiquvchi elektr quvvat turlicha bo'lishi mumkin.

Masalan: Ikkita $EYUK$ bo'lgan parallel zanjirni, yoki tok manbaidan iborat zanjirlarni ekvivalent sxema bilan almashtiramiz:



a) $E = \frac{E_1 y_1 + E_2 y_2}{y_1 + y_2};\ z = 1 : y_1 + y_2$ b) $J = J_1 + J_2 \quad g = g_1 + g_2$

Bunda: $I = \frac{E}{R} = \frac{E_1 + E_2}{\sum R}$ $yoki\ I = I_1 + I_2 = E_1 g_1 + E_2 g_2 = \sum Eg$

$g = \frac{1}{R} - o'tkazuvchanlik.$ Demak $EYUK$ manba bilan tok manbai bo'lgan sxemalarning ekvivalent o'xshashlik tenglamasi:

$$E = \frac{J}{g} = \frac{J_1 + J_2}{g_1 + g_2} = \frac{E_1 g_1 + E_2 g_2}{g_1 + g_2} = \frac{\sum_{k=1}^{n} E_k g_k}{\sum_{k=1}^{n} g_k}; \qquad (1.11)$$

qarshilik $R_{um} = \frac{1}{g_1 + g_2}$

5. Elektr zanjirni hisoblashda Kirxgof qonuni.

Kirxgof qonun elektr zanjirni hisoblashda asosiy qonun bo'lib, barcha hisoblash usullarining negizi hisoblanadi.

Kirxgof qonuniga asosan p-tarmoq q-tugundan tashkil topgan elektr zanjirni hisoblab, tarmoqdagi tok uchun $K = p - (q - 1)$ tuzilgan tenglamani yechish bilan bajariladi.

Kirxgof I-qonuni: $\sum_{k=1}^{n} I_k = 0$ – tarmoqdagi toklar algebraik yig'indisi nolga teng.

Kirxgof II-qonuni: $\sum_{k=1}^{n} E_k = \sum_{k=1}^{n} R_k I_k$– kontur EYK algebraik yig'indisi shu konturga kiruvchi qarshilikdagi kuchlanishlarning algebraik yig'indisiga teng.

6. Elektr zanjirlarida quvvat muvozanat tenglamasi.

Elektr zanjirda energiya muvozanatlanishi qonuniga asosan: manba elektr quvvati iste'molchilarda sarf bo'ladigan elektr quvvatga teng bo'ladi.

$$\sum_{k=1}^{n} P_{GEN} = \sum_{k=1}^{n} P_{Manb} \qquad (1.12)$$

yoki $\sum_{k=1}^{m} E_m I_m + \sum_{k=1}^{n} J_n U_n = \sum_{k=1}^{n} I_K^2 R_K = U_k^2 G_k$

Bunda: m – EYK manbalar soni, n – tok manbalari soni k – iste'molchilar soni, U, I – bir xil yo'nalishdagi tok va kuchlanish.

7. Murakkab elektr zanjirlarni matritsa usulida hisoblash.

Murakkab tok zanjirlari uchun Kirxgof va Om qonunlariga asosan tuzilgan tenglamalarni yechishda algebraik matritsa usulini qo'llash hisoblash jarayonini ancha soddalashtiradi, ayniqsa, elektron hisoblash mashinalaridan foydalanilsa oson kechadi.

Masalan: n – konturdan iborat zanjir tenglamasi:

$R_{11}I_1 + R_{12}I_2 + \ldots\ldots\ldots + R_{1n}I_n = E_{11}$

$R_{k1}I_1 + R_{k2}I_2 + \ldots\ldots\ldots + R_{kn}I_n = E_{kk}$

$\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots$

$R_{n1}I_1 + R_{n2}I_2 + \ldots\ldots\ldots + R_{nn}I_n = E_{nn}$

yoki qisqacha: $\sum_{i=1}^{n} R_{ki}I_i = E_{kk}(k = 1 \div n)$

Bunda: I_i-kontur toklar qiymatlari E_i - EYUK qiymatlari

$R_{ki} - parametrlar\ qiymatlari\ \ n - tenglamalar\ soni$

Ixtiyoriy son qiymatlardan iborat (berilgan yoki noma'lum bo'lgan) guruhni matritsaviy ustunli tenglama ko'rinishida ifodalaymiz:

$$I = \begin{bmatrix} I_1 \\ \vdots \\ I_n \end{bmatrix} \quad va \quad E = \begin{bmatrix} E_1 \\ \vdots \\ E_n \end{bmatrix} \quad yoki$$

$$Z = \begin{bmatrix} z_{11} - & z_{12} & \ldots\ldots & z_{1n} \\ -z_{21} + & z_{22} & \ldots\ldots & z_{2n} \\ \ldots & \ldots & \ldots & \ldots \\ -z_{n1} - & z_{n2} & \ldots\ldots & z_{nn} \end{bmatrix}$$

Z –kvadratli matritsa determinant tenglamaga o'xshash bo'lib, zanjir elementlaridan tarkib topgan.

Ushbu kvadrat matritsa Z ni I tok ustuniga ko'paytirsak:

$$Z \cdot I = \begin{bmatrix} Z_{11}I_1 - & Z_{12}I_2 \ldots\ldots & Z_{1n}I_n \\ -Z_{21}I_1 + & Z_{22}I_2 \ldots\ldots & Z_{2n}I_n \\ \ldots\ldots & \ldots\ldots & \ldots\ldots \\ -Z_{n1}I_1 - & Z_{n2}I_2 \ldots\ldots & Z_{nn}I_n \end{bmatrix} = \begin{bmatrix} E_1 \\ E_2 \\ \vdots \\ E_n \end{bmatrix} \quad yoki \quad Z \cdot I = E$$

Tenglamani yechish uchun o'ng va chap tomonini teskari matritsa Z^{-1} ga ko'paytirish natijasida $Z \cdot Z^{-1} = Z^{-1} \cdot Z = 1$ – *birlamchi matritsa* Δ tenglama hosil qilamiz:

$$Z^{-1} = \frac{1}{\Delta}\begin{bmatrix} \Delta_{11} & \Delta_{21} \ldots\ldots & \Delta_{n1} \\ \Delta_{21} & \Delta_{22} \ldots\ldots & \Delta_{n2} \\ \ldots\ldots & \ldots\ldots & \ldots\ldots \\ \Delta_{1n} & \Delta_{2n} \ldots\ldots & \Delta_{nn} \end{bmatrix}$$

Bu oldingi matritsaning determinant Δ - tenglamasi bo'lib, buning Δ_{ik} –algebraik to'ldiruvchisi : $Z^{-1} \cdot ZI = 1I = I = \frac{E}{Z} = E \cdot Z^{-1}$

Demak tok matritsasini hosil qilish uchun $Z^{-1}ni$ E ustuniga ko'paytirish kifoya qiladi:

$$\begin{bmatrix} I_1 \\ I_2 \\ \vdots \\ I_n \end{bmatrix} = \frac{1}{\Delta}\begin{bmatrix} \Delta_{11}E_1 + & \Delta_{21}E_2 \ldots\ldots & + \Delta_{n1}E_n \\ \Delta_{21}E_1 + & \Delta_{22}E_2 \ldots\ldots & + \Delta_{n2}E_n \\ \ldots\ldots & \ldots\ldots & \ldots\ldots \\ \Delta_{1n}E_1 + & \Delta_{2n}E_2 \ldots\ldots & + \Delta_{nn}E_n \end{bmatrix}$$

Bundan kontur tok qiymatlari ustun qatorlariga mos ravishda:

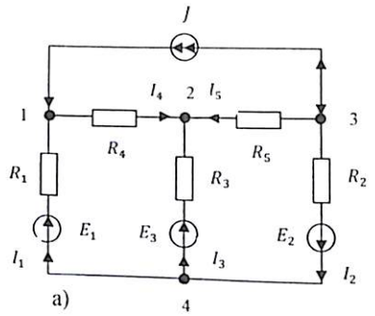
$$I_1 = \frac{1}{\Delta}(\Delta_{11}E_1 + \Delta_{21}E_2 \ldots\ldots + \Delta_{n1}E_n)$$

Tugun kuchlanish usuliga asosan tuzilgan tenglamalari huddi shu ko'rinishdagi matritsaviy usulda yechish bilan tarmoq toklarini topish mumkin.

$g \cdot U = I$ Kirxgof qonunlariga asosan tuzilgan tenglamalarni yechishda ham matritsa usulidan foydalanish mumkin. Bunda kvadrat matritsa I-qatori Kirxgof qonuniga asosan toklar ustuniga mos elementlar 0,+1 yoki -1 deb olinadi. Keyingi ustunlari Kirxgofning II qonuni asosida tuzilgan tenglama mos tarmoq qarshiliklar koeffitsientini ifoda qiladi.

Misol: 5-tarmoq 4-tugun 2-konturdan iborat elektr zanjiri Kirxgof qonunlariga asosan tenglamasini tuzib, matritsa ko'rinishida ifodasini yozing.

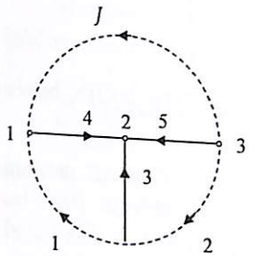
Kirxgof qonunlariga asosan tenglama tuzamiz:



a)

1) $-I_1 + I_4 - J = 0$
2) $-I_3 - I_4 - I_6 = 0$
3) $I_2 + I_5 + J = 0$
4) $I_1R_1 + I_4R_4 - I_3R_3 = E_1 - E_3$
5) $I_3R_3 - I_5R_5 + I_2R_2 = E_2 + E_3$

Matritsa ko'rinishidagi ifodasi:



b) Zanjir topologik sxemasi

$$\begin{bmatrix} -1 & 0 & 0 & 1 & 0 \\ 0 & 0 & -1 & -1 & -1 \\ 0 & 1 & 0 & 0 & 1 \\ R_1 & 0 & -R_3 & R_4 & 0 \\ 0 & R_2 & R_3 & 0 & R_5 \end{bmatrix} \cdot \begin{bmatrix} I_1 \\ I_2 \\ I_3 \\ I_4 \\ I_5 \end{bmatrix} = \begin{bmatrix} J \\ 0 \\ -J \\ E_1 - E_3 \\ E_2 + E_3 \end{bmatrix}$$

1.2. Masalalar yechish va uslubiy ko'rsatmalar

1.1-Masala. Aktiv quvvati $P = 400\,Wt$ va kuchlanish $U = 220\,V$ elektr dazmolga uzunligi $l = 10\,m$ teng po'lat sim sarflangan. Po'lat simning kesim yuzasi S va tok zichligi J topilsin. Bunda simning solishtirma qarshiligi $\rho = 0.2 \cdot 10^{-6} om \cdot m$

Yechish: Tok qiymati : $I = \frac{P}{U} = \frac{400}{220} = 1.82\,A$

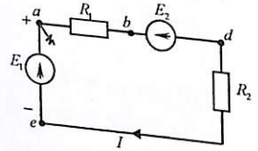
Aktiv qarshiligi : $R = \frac{U}{I} = \frac{U^2}{P} = \frac{220^2}{400} = 121\,om$

Po'lat simning kesim yuzasi : $S = \frac{\rho l}{R} = \frac{0.2 \cdot 10^{-6} \cdot 10}{121 \cdot 10^{-6}} = 0.0165\,mm^2$

Tok zichligi : $J = \frac{I}{S} = \frac{1.82}{0.0165} = 110 A/mm^2$

1.2-Masala. Ketma-ket ulangan elektr zanjirda EYK $E_1 = 4\,V$, $E_2 = 2\,V$, qarshiligi $R_1 = 4\,Om$, $R_3 = 6\,Om$. Tok qiymati va potensiali aniqlanib, diagrammasi tuzilsin.

Yechish. Om qonuniga asosan tokni topamiz:



$$I = \frac{E_1 - E_2}{R_{um}} \frac{4-2}{R_1 + R_2} = \frac{2}{10} = 0{,}2\,A$$

Bunda: $E_1 > E_2$ bo'lganligi uchun tok soat strelkasiga mos yo'nalgan bo'ladi.

Potensiallar farqini aniqlash uchun $\varphi_a = 0$ deb olamiz.

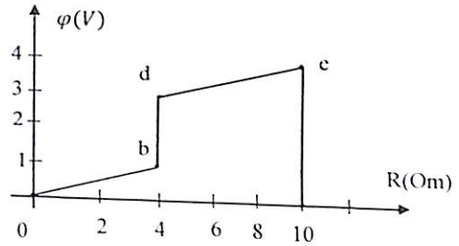
Bunda: $\varphi_b - \varphi_a = R_1 I$ yoki $\varphi_b = \varphi_a + IR_1 = 0 + 0{,}2 \cdot 4 = 0{,}8\,(V)$

φ_d – potensiali: $\varphi_d - \varphi_b = E_2$ $yoki$ $\varphi_d = \varphi_b + E_2 = 2{,}8\,(V)$

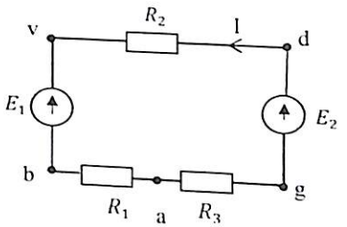
φ_e – potensiali: $\varphi_e - \varphi_d = IR_2$ $yoki$ $\varphi_e = IR_2 + \varphi_d = 0{,}2 \cdot 6 - 2{,}8 = 4\,(V)$

$\varphi_a - \varphi_e = -E_1$ yoki: $\varphi_a = -E_1 + \varphi_e = 4 - 4 = 0$

Potensial diagramma chizamiz.



1.3-Masala. Berilagam sxema parametrlari: $E_1 = 10V$; $E_2 = 30V$; $R_1 = 5\,om$; $R_2 = 3om$; $R_3 = 12om$ bo'lganda potensial diagramma tuzulsin.



Yechish: Tok qiymati Om qonuniga asosan:

$$I = \frac{E_2 - E_1}{R_{1+}R_2 + R_3} = \frac{30 - 10}{20} = 1A$$

$\varphi_{a=0}$ bo'lganda:

$\varphi_b - \varphi_a = IR_1$; $\varphi_b = \varphi_a + IR_1 = 0 + 1 * 5 = 5V$

$\varphi_v - \varphi_b = E_1$; $\varphi_v = \varphi_b + E_1 = 5 + 10 = 15V$

$\varphi_g - \varphi_v = IR_2$; $\varphi_g = \varphi_v + IR_2 = 15 + 1 * 3 = 18V$

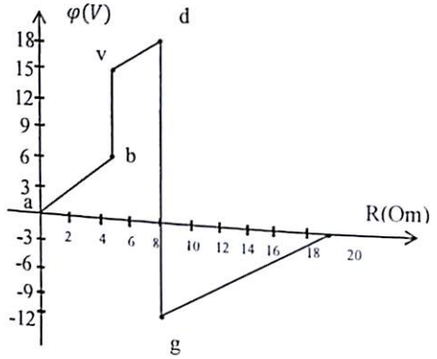
$\varphi_d - \varphi_g = -E_2$; $\varphi_d = \varphi_g - E_2 = 18 - 30 = -12V$

$\varphi_a - \varphi_g = IR_3$; $\varphi_a = \varphi_g + IR_3 = -12 + 1 * 12 = 0$

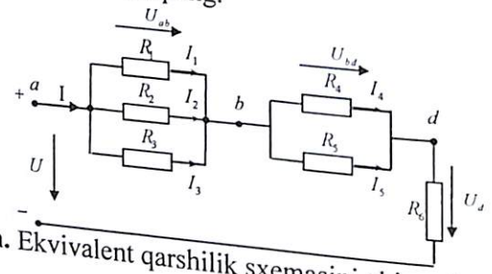
Eslatma: Tugunlardagi kuchlanish manba kuchlanishiga teng.

$$U = \varphi_+ - \varphi_- = E \pm IR_{vm}$$

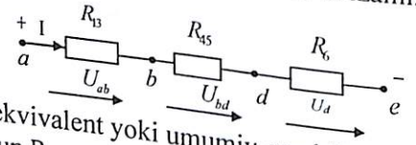
Bu yerda: minus (-) ishora istemolchi ekanligini bildiradi. Plyus(+) ishora generator ekanligini bildiradi .



1.4-Masala. Tarmoqlangan elektr zanjir parametri $R_1 = 40\ Om$, $R_2 = 120\ Om, R_3 = 60\ Om, R_4 = 90\ Om, R_5 = 10\ Om, R_6 = 10\ Om$ bo‘lib, $U = 120\ V$ o‘zgarmas kuchlanishga ulangan. Ekvivalent qarshilik hamda tarmoqdagi tokni aniqlang.



Yechish. Ekvivalent qarshilik sxemasini chizamiz:



Zanjirning ekvivalent yoki umumiy qarshiligini topamiz.
Buning uchun R_{13} va R_{45} qarshilikni parallel holda qo‘shamiz:

$$\frac{1}{R_{13}} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3} = \frac{1}{40} + \frac{1}{120} + \frac{1}{60} = \frac{6}{120}$$

Bundan:

$$R_{13} = \frac{120}{6} = 20\ Om$$

$$R_{45} = \frac{R_4 \cdot R_5}{R_4 + R_5} = \frac{90 \cdot 10}{10 + 90} = 9\ Om$$

Umumiy ekvivalent qarshilik:

$$R = R_{13} + R_{45} + R_6 = 20 + 9 + 11 = 40\ Om$$

Umumiy tokni aniqlaymiz: $I = \frac{U}{R} = \frac{120}{40} = 3\ A$

Tugun potensiali yoki kuchlanishni aniqlaymiz:

$$U_{ab} = I \cdot R_{13} = 3 \cdot 20 = 60\ V; \quad U_{bd} = I \cdot c = 3 \cdot 9 = 27\ V$$

$$U_d = I \cdot R_6 = 3 \cdot 11 = 33\ V$$

Endi tarmoqdagi tokini topamiz:

$$I_1 = \frac{U_{ab}}{R_1} = \frac{60}{40} = 1{,}5\ A$$

$$I_2 = \frac{U_{ab}}{R_2} = \frac{60}{120} = 0{,}5\ A$$

$$I_3 = \frac{U_{ab}}{R_3} = \frac{60}{60} = 1\ A$$

$$I_4 = \frac{U_{bd}}{R_1} = \frac{27}{90} = 0{,}3\ A$$

$$I_5 = \frac{U_{bd}}{R_5} = \frac{27}{10} = 2{,}7\ A$$

Masala yechimini tekshirib ko‘ramiz:

$$U = U_{ab} + U_{bd} + U_d = 60 + 27 + 33 = 120\ V$$

$$I = I_1 + I_2 + I_3 = 1{,}5 + 0{,}5 + 1 = 3\ A$$

Quvvat muvozanati tenglamasiga asosan:

$$P_{manb} = P_{ist} = I_1^2 R_1 + I_2^2 R_2 + I_3^2 R_3 + I_4^2 R_4 + I_5^2 R_5 + I_6^2 R_6 = (1{,}5)^2 \cdot 40 + (0{,}5)^2 \cdot 120 + (0{,}3)^2 \cdot 90 + (2{,}7)^2 \cdot 10 + (3)^2 \cdot 10 = 351\ VT = 360VT$$

Hisoblashdagi xatolik:

$$\gamma = \frac{P_{gen} - P_{ist}}{P_{ist}} \cdot 100\% = \frac{360 - 351}{351} \cdot 100\% = 2{,}7\%$$

1.5-Masala Elektr zanjir parametrlari: $R_1 = R_2 = R_3 = 4\ om$, $R_4 = R_5 = R_6 = 5\ om\ R_7 = 10\ om$ bo’lib, ampermetr $J = 2A$ tokni ko’rsatsa, masalani Om va $Kirxgof$ qonunlariga asosan yechib $E\ (EYUK)$ topilsin.

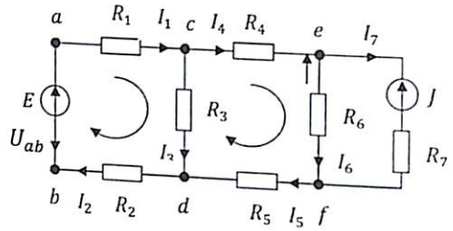
Om qonuniga asosan: $U_{ef} = J \cdot R_7 = 2 \cdot 10 = 20\ V$

Bundan: $I_6 = \frac{U_{ef}}{R_6} = \frac{20}{5} = 4\ A$ $\quad I_4 = I_5 = I_6 + J = 4 + 2 = 6\ A$

Potensial: $U_{ce} = I_4 R_4 = 6 \cdot 5 = 30\ V$; $U_{cd} = I_4 R_4 + I_6 R_6 + I_5 R_5$ yoki $U_{cd} = U_{ce} + U_{ef} + U_{fd} = 30 + 20 + 30 = 80V$

$$I_1 = I_2 = I_3 + I_4 = \frac{U_{cd}}{R_3} + I_4 = \frac{80}{4} + 6 = 26\ A$$

Demak: $E = I_1R_1 + I_2R_2 + I_3R_3 = 4 \cdot 26 + 4 \cdot 20 + 4 \cdot 46 = 368\,V$



Tekshiramiz: $E = U_{ac} + U_{ce} + U_{ef} + U_{fd} + U_{db} = 144 + 30 + 20 + 30 + 144 = 368V$

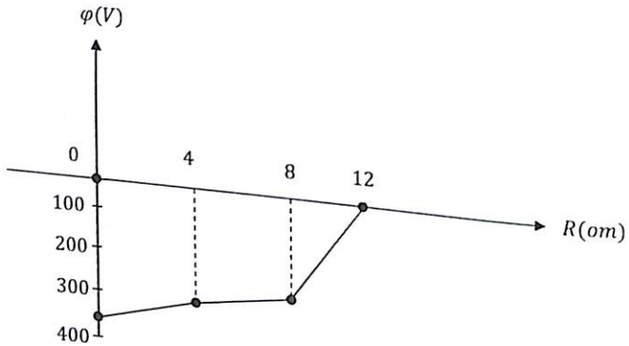
Ushbu zanjirning a, c, d, b – kontur uchun potensial diagrammasi tuzilsin.

Yechish: Agar $\varphi_b = 0$ desak: $\varphi_a = \varphi_b - E = -368\,V$

$\varphi_c = \varphi_a + I_1R_1 = -368 + 104 = -264\,V$

$\varphi_d = \varphi_c + I_3R_3 = -264 + 120 = -144\,V$

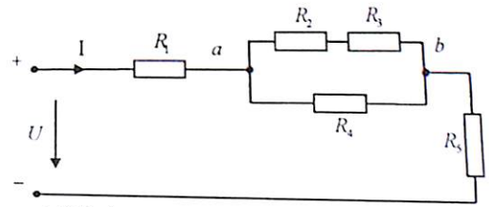
$\varphi_b = \varphi_d + I_2R_2 = -144 + 144 = 0$



Eslatma I – yuqori potensial chiquvchi plusdan , E – yuqori potensial kirishda plus.

1.6-Masala. Aralash sxemada ulangan elektr zanjir parametri: $R_1 = 19\,Om, R_2 = 2\,Om, R_3 = 4\,Om, R_4 = 4\,Om, R_5 = 0{,}6\,Om$ bo‘lib, R_2 qarshilikda $P_2 = 32\,Vt$ quvvat sarflanadi.

Zanjirning tarmoq toki va manba kuchlanishi hamda quvvati aniqlansin.



Yechish. R_2 - qarshilikdan o‘tuvchi I_2 tokni topamiz:

$$I_2 = \sqrt{\frac{P_2}{R_2}} = \sqrt{\frac{32}{2}} = 4\,A$$

a va b potensial kuchlanishni aniqlaymiz:

$$U_{ab} = I_2(R_2 + R_3) = 4(2 + 4) = 24\,V$$

R_4 qarshilikdan o‘tuvchi tok:

$$I_3 = \frac{U_{ab}}{R_4} = \frac{24}{4} = 6\,A$$

Umumiy tok: $I_1 = I_2 + I_3 = 4 + 6 = 10\,A$

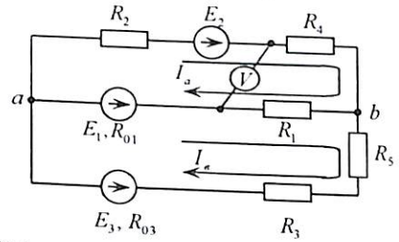
Zanjirning umumiy qarshiligini aniqlaymiz:

$$R_{um} = R_1 + \frac{R_4(R_2+R_3)}{R_4+R_2+R_3} + R_5 = 19 + \frac{4(2+4)}{4+2+4} + 0{,}6 = 19 + 0{,}6 + \frac{24}{10} = 22\,Om$$

Manba kuchlanishi: $U = I_1R_{um} = 10 \cdot 22 = 220\,V$

Manba quvvati: $P = U \cdot I_1 = 220 \cdot 10 = 2200\,VT.$

1.7-Masala. Ikki konturli elektr zanjir manba kuchlanishi: $E_1 = 8\,V, E_2 = 6\,V, E_3 = 36\,V$ qarshiliklari: $R_1 = 3\,Om, R_2 = 1\,Om, R_3 = 2\,Om, R_{01} = 1{,}3Om,$ $R_{03} = 1{,}2\,Om, R_4 = 6\,Om, R_5 = 8\,Om$ konturli tok usuli va tugunlararo kuchlanish usuliga asosan tarmoqdagi tok, voltmetr kuchlanishi va quvvatlar balansi aniqlansin.



Yechish. Mustaqil konturdagi tok I_a, I_b yo‘nalishini belgilaymiz. Kirxgof 2-qonuniga asosan konturdagi tok tenglamasi quyidagicha bo‘ladi:

$R_{11} \cdot I_a - R_{12} \cdot I_b = E_{11} - R_{12} \cdot I_a + R_{22} \cdot I_b + R_{22} = E_{22}$

Bu yerda: R_{11} R_{22} – konturning xususiy qarshiligi.

$R_{11} = R_1 + R_{01} + R_2 + R_4$, $R_{22} = R_1 + R_{01} + R_3 + R_{03} + R_5$

$R_{12} = R_{21}$ – konturlararo qarshilik: $R_{12} = R_{21} = R_1 + R_{01}$

E_{11} va E_{22} – mos konturga aloqador bo'lgan manbaning EYKning algebraik yig'indisi.

Bu holda, agar manba EYK yo'nalishi bilan konturdagi tok yo'nalishi mos bo'lsa, uning ishorasi musbat yoki aksincha, manfiy olinadi.

Bunga asosan: $E_{11} = E_2 - E_1 \quad E_{22} = E_1 - E_3$

Tenglamaga aniqlangan qiymatni qo'yamiz:

$$\begin{cases} (3 + 1{,}3 + 6 + 2) \cdot \mathrm{I_a} - (3 + 3{,}1) \cdot \mathrm{I_a} = 6 - 8 \\ -(3 + 1{,}3) \cdot \mathrm{I_a} + (3 + 11{,}3 + 1 + 1{,}2 + 8) \cdot \mathrm{I_b} = 8 - 36 \end{cases}$$

yoki: $\begin{cases} 12{,}3 \cdot I_a - 4{,}3 \cdot I_a = -2 \\ -4{,}3 \cdot I_a + 14{,}5 \cdot I_a = -28 \end{cases}$

Tenglama Kramer usulida yechiladi:

$$\Delta = \begin{vmatrix} 12{,}3 & -4{,}3 \\ -4{,}3 & 14{,}5 \end{vmatrix} = 178{,}35 - 18{,}49 = 159{,}86$$

$$\Delta_1 = \begin{vmatrix} -2 & -4{,}3 \\ -2{,}8 & 14{,}5 \end{vmatrix} = -29 - 120{,}4 = -149{,}4$$

$$\Delta_2 = \begin{vmatrix} 12{,}3 & -2 \\ -4{,}3 & -28 \end{vmatrix} = -344{,}4 - 8{,}6 = -353{,}0$$

Bundan:

$I_a = \frac{D_1}{D} = \frac{-149{,}4}{159{,}86} = -0{,}93\ A$; $I_b = \frac{D_2}{D} = \frac{-353{,}0}{159{,}86} = -2{,}21\ A$;

Endi tarmoqdagi tokni aniqlaymiz:

$I_1 = I_b - I_a = -2{,}21 - 0{,}93 = -1{,}28\ A$;

$I_2 = I_a = -0{,}93\ A$;

$I_3 = -I_b = 2{,}21\ A$;

I_1 va I_2 tokning minus ishorali bo'lishi, ularning zanjirdagi haqiqiy yo'nalishi, biz qabul qilganga nisbatan teskari ekanligini ifodalaydi.

Tugun potensial usuliga asosan hisoblash.

Tarmoqdagi tokni tugun potensiali orqali ifodalaymiz. Noma'lum potensialni aniqlash uchun tenglama tuzish kerak, ya'ni ixtiyoriy tugun potensiali «ma'lum» yoki «nol» ga teng deb qabul qilinadi. Berilgan sxema ikki tugundan iborat, demak φ_a tugun potensialini «nol», deb qabul qilgan holda tenglama tuzamiz.

$$g_{bb} \cdot \varphi_b = J_b$$

Bu yerda: φ_b– aniqlash kerak bo'lgan tugun potensiali.

g_{bb} – «b» tugunga kiruvchi tarmoqning o'tkazuvchanlik yig'indisi.

J_b– EYK ga ekvivalent bo'lgan tok manbaining algebraik yig'indisi.

Bunda, agar tok manbai yo'nalishi tugunga yo'nalgan bo'lsa, musbat va aksincha manfiy ishora bilan olinadi.

Demak:

$$g_{bb} = \frac{1}{R_2+R_4} + \frac{1}{R_1+R_{01}} + \frac{1}{R_3+R_{03}+R_5};\ \left(\frac{1}{Om}\right)$$

$$J_b = \frac{E_1}{R_1+R_{01}} + \frac{E_2}{R_2+R_4} + \frac{E_3}{R_3+R_{03}+R_5};\ (\mathrm{A})$$

Son qiymatlari qo'yilsa:

$$\left(\frac{1}{2+6} + \frac{1}{3+1{,}3} + \frac{1}{1+1{,}2+8}\right)\varphi_b = \frac{8}{3+1{,}3} + \frac{6}{2+6} + \frac{36}{1+1{,}2+86}$$

yoki: $\varphi_b = 13{,}49\ (V)$

Tarmoqdagi tok:

$I_1 = \frac{-\varphi_b+E_1}{R_1+R_{01}} = \frac{-13{,}49+8}{3+1{,}3} = \frac{-5{,}49}{4{,}3} = -1{,}28$ A;

$I_2 = \frac{-\varphi_b+E_2}{R_2+R_4} = \frac{-13{,}49+6}{2+6} = \frac{-7{,}49}{8} = -0{,}936$ A;

$I_3 = \frac{-\varphi_b+E_3}{R_3+R_{03}+R_5} = \frac{-13{,}49+36}{1+1{,}2+8} = \frac{22{,}51}{10{,}2} = 2{,}206$ A;

1. Voltmetr ko'rsatishini aniqlaymiz:

$U_b = -I_2\ R_4 + I_1 R_1 = -(-0{,}93)\ 6 + (-1{,}28)\ 3 = 1{,}74\ V$

2. Quvvatlar balansi tenglamasiga asosan $P_{man} = P_{ist}$ teng bo'lib, manba quvvati:

$P_{man} = E_1\ I_1 + E_2\ I_2 + E_3\ I_3 = 8\ (-1{,}28) + 6\ (-0{,}93) + 36\ 2{,}21 = -10{,}24 - 5{,}58 + 79{,}56 = 63{,}74\ Vt$

Iste'molchilarda sarf bo'ladigan quvvat:

$P_{ist} = I_1^2 \cdot (R_1 + R_{01}) + I_2^2 \cdot (R_2 + R_4) + I_3^2(R_3 + R_{03} + R_5) = 1{,}28^2 \cdot (3 + 1{,}3) + 0{,}93^2(2 + 6) + 2{,}212(1 + 1{,}2 + 8) \cdot 7{,}045 + 6{,}91 + 49{,}81 = 63{,}76$ Vt

Hisoblashdagi xato:

$$j\% = \frac{|P_{ist} - P_{man}|}{|P_{ist}|} \cdot 100\% = \frac{63{,}76-63{,}74}{63{,}76} \cdot 100\% = 0{,}03\%$$

(1) tenglamaga asosan determinant usuliga asosan tenglama tuzamiz:

$$\Delta = \begin{vmatrix} R_{11} & -R_{12} & -R_{13} \\ -R_{21} & +R_{22} & -R_{23} \\ -R_{31} & -R_{32} & +R_{33} \end{vmatrix} = \begin{vmatrix} 20 & -10 & -5 \\ -10 & 20 & -0 \\ -5 & -10 & 8 \end{vmatrix} = 1900\ (Om)$$

$$\Delta_a = \begin{vmatrix} E_a & -R_{12} & -R_{13} \\ E_в & +R_{22} & -R_{23} \\ E_c & -R_{32} & +R_{33} \end{vmatrix} = \begin{vmatrix} 55 & -10 & -5 \\ 20 & 20 & -0 \\ 10 & -0 & 8 \end{vmatrix} = 11400\ (V)$$

$$\Delta_в = \begin{vmatrix} R_{11} & E_a & -R_{13} \\ -R_{21} & E_в & -R_{23} \\ -R_{31} & E_c & +R_{33} \end{vmatrix} = \begin{vmatrix} 20 & 55 & -5 \\ -10 & 20 & -0 \\ -5 & 10 & 8 \end{vmatrix} = 7600\ (V)$$

$$\Delta_c = \begin{vmatrix} R_{11} & -R_{12} & E_a \\ -R_{21} & +R_{22} & E_в \\ -R_{31} & -R_{32} & E_c \end{vmatrix} = \begin{vmatrix} 20 & -10 & 55 \\ -10 & 20 & 20 \\ -5 & -0 & 10 \end{vmatrix} = 9500\ (V)$$

Konturdagi tokni aniqlaymiz:

$$I_a = \frac{\Delta_a}{\Delta} = \frac{11400}{1900} = 6\ \text{A}$$

$$I_b = \frac{\Delta_b}{\Delta} = \frac{7600}{1900} = 4\ \text{A}$$

$$I_c = \frac{\Delta_C}{\Delta} = \frac{9500}{1900} = 5\ \text{A}$$

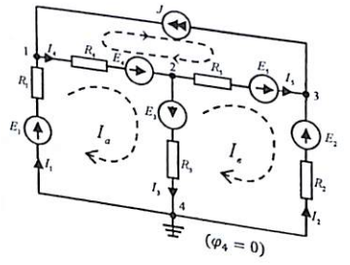
Konturdagi tok orqali tarmoqdagi tokni aniqlaymiz:

$$I_1 = I_a = 6\ A;\ I_2 = I_a - I_B = 6 - 4 = 2\ A$$

$$I_3 = I_b = 4\ A;\ I_4 = I_a - I_C = 1\ A;\ I_5 = I_C = 5\ A$$

1.10-

Masala. Elektr sxema parametri: $R_1 = R_3 = R_5 = 58\ Om, R_2 = R_4 = 40 Om, E_1 = 10\ V, E_2 = 15\ V, E_3 = 10\ V, E_4 = 5\ V,$ $E_5 = 20\ V, J = 2\ A$. Tugun **potensiallar** usuliga asosan tarmoqdagi tokni aniqlab, quvvat muvozanat tenglamasi tuzilsin.



Yechish.

1) tugun potensiallar usuli murakkab elektr zanjirni hisoblashda qulay bo‘lib, Kirxgof va Om qonuniga asosan tugun potensiallari nisbatan tuzilgan tenglamalarni yechish bilan tarmoqdagi tok aniqlanadi. Bunda ixtiyoriy tugun potensialini «nol» ga tenglash bilan tenglamalar sonini $(q - 1)$ kamaytirish mumkin.

Berilgan sxemada 4 ta tugun bo‘lib, to‘rtinchi tugunni «nol» ga tenglaymiz. $(\varphi_4 = 0)$ va Kirxgof 1-qonuniga asosan tugunlar uchun tenglama tuzamiz:

$$\left.\begin{array}{l} 1 - tugun \quad I_4 - J - I_1 = 0 \\ 2 - tugun \quad I_3 + I_5 - I_4 = 0 \\ 3 - tugun \quad J - I_2 - I_5 = 0 \end{array}\right\} \qquad (1)$$

Om qonuniga asosan tok ifodasini tugun potensiallari ayirmasi orqali ifodalaymiz

$$\left.\begin{array}{l} \frac{\varphi_1 - \varphi_2 + E_4}{R_4} - J - \frac{\varphi_4 - \varphi_1 + E_1}{R_1} = 0 \\ \frac{\varphi_2 - \varphi_3 + E_5}{R_5} + \frac{\varphi_2 - \varphi_4 + E_3}{R_3} - \frac{\varphi_1 - \varphi_2 + E_4}{R_4} = 0 \\ J - \frac{\varphi_4 - \varphi_3 + E_2}{R_2} - \frac{\varphi_2 - \varphi_3 + E_5}{R_5} = 0 \end{array}\right\} \qquad (2)$$

Potensial $\varphi_4 = 0$ ekanligini inobatga olib, tenglamani quyidagicha yozamiz:

$$\left.\begin{array}{c} \varphi_1\left(\frac{1}{R_1} + \frac{1}{R_4}\right) - \varphi_2 \frac{1}{R_4} = E_1 \frac{1}{R_4} + J - E_4 \frac{1}{R_4} \\ -\varphi_1 \frac{1}{R_4} + \varphi_2\left(\frac{1}{R_4} + \frac{1}{R_3} + \frac{1}{R_5}\right) - \varphi_3 \frac{1}{R_5} = E_4 \frac{1}{R_5} - E_3 \frac{1}{R_3} - E_5 \frac{1}{R_5} \\ -\varphi_2 \frac{1}{R_5} + \varphi_3\left(\frac{1}{R_4} + \frac{1}{R_2}\right) = E_2 \frac{1}{R_2} + E_5 \frac{1}{R_5} - J \end{array}\right\} \qquad (3)$$

Qarshiliklar parametrini $\frac{1}{R} = g$ o‘tkazuvchanlik parametrlariga almashtirish bilan tarmoq o‘tkazuvchanligni aniqlaymiz:

$$g_1 = g_3 = g_5 = 0{,}2\ sim, g_2 = g_4 = 0{,}25\ sim$$

Tugunlararo tarmoq o‘tkazuvchanligini topamiz:

$$g_{11} = g_1 + g_4 = 0{,}45\ sim,$$

$$g_{22} = g_4 + g_3 + g_5 = 0{,}65\ sim$$

$$g_{33} = g_5 + g_2 = 0{,}45\ sim$$

Tugunlarni bog‘lovchi tarmoqdagi o‘tkazuvchanlikni topamiz:

$$g_{12} = g_{21} = g_4 = 0{,}25\ sim,$$

$$g_{23} = g_{32} = g_5 = 0{,}2\ sim$$

(3) tenglamaning o‘ng tomoni ifodalaridan tugundagi tok qiymatini aniqlaymiz:

$$\left.\begin{array}{l} 1-\text{tugun } I_a = E_1g_1 - E_4g_4 - +J = 2.75\ \text{A} \\ 2-\text{tugun } I_d = E_4g_4 - E_3g_3 - E_5g_5 = -4.75\ \text{A} \\ 3-\text{tugun } I_c = E_5g_5 - E_2g_2 - J = 5.75\ \text{A} \end{array}\right\} \quad (4)$$

(4) tenglamaga tarmoqdagi o‘tkazuvchanlik qiymatini qo‘yib, tugun potensiallar tenglamasini tuzamiz:

$$\left.\begin{array}{c} 0{,}45\varphi_1 - 0{,}25\varphi_2 = 2{,}75 \\ -0{,}25\varphi_1 + 0{,}65\varphi_2 - 0{,}2\varphi_3 = -4{,}75 \\ -0{,}2\varphi_1 + 0{,}45\varphi_3 = 5{,}75 \end{array}\right\} \quad (5)$$

(5) tenglamalar sistemasini yechish bilan tugun potensialli qiymatini topamiz:

$$\varphi_1 = 5{,}25\ V, \varphi_2 = 1{,}6\ V, \varphi_3 = 12{,}08\ V \quad (6)$$

Om qonuniga asosan tuzilgan (2) tenglamadan tarmoqdagi tokni topamiz:

$$\begin{array}{l} I_1 = (\varphi_0 - \varphi_1 + E_1)g_1 = 0{,}95\ A \\ I_2 = (\varphi_0 - \varphi_3 + E_2)g_2 = 0{,}73\ A \\ I_3 = (\varphi_2 - \varphi_0 + E_3)g_3 = 1{,}68\ A \\ I_4 = (\varphi_1 - \varphi_2 + E_4)g_4 = 2{,}96\ V \\ I_5 = (\varphi_2 - \varphi_3 + E_5)g_5 = 1{,}27\ A \end{array} \quad (7)$$

2) quvvatlar muvozanati tenglamasi quyidagicha ifodalanadi:

$$\sum EI + \sum JU = \sum I^2R$$

Berilgan sxema uchun: $E_1I_1 + E_2I_2 + E_3I_3 + E_4I_4 + JU_{13} = I_1^2R_1 + I_2^2R_2 + I_3^2R_3 + I_4^2R_4 + I_5^2R_5$ (8)

Tok manbaga J ulangan konturdagi U_{13} kuchlanishni topish uchun 1-va-3 tugun potensialiga nisbatan tenglama tuzamiz:

$$\varphi_1 - \varphi_3 = U_{13} = -E_4 - E_5 + I_4R_4 + I_5R_5 = -5 - 20 + 5 \cdot 1{,}27 + 4 \cdot 2{,}5 = -6{,}84\ V$$

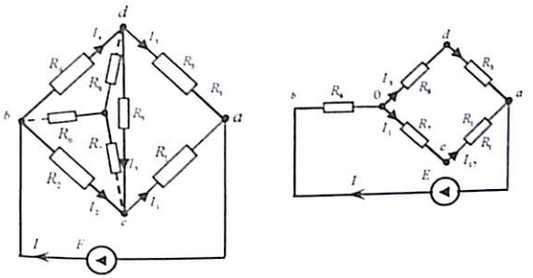
Barcha tok va kuchlanish qiymatlarini (8) tenglamaga qo‘yish bilan quvvat qiymatini aniqlaymiz:

$$10 \cdot 0{,}95 + 15 \cdot 0{,}73 + 10 \cdot 1{,}68 + 5 \cdot 2{,}95 + 20 \cdot 1{,}27 + 2 \cdot (6{,}84) = (0{,}95)^2 \cdot 5 + (0{,}73)^2 \cdot 4 + (1{,}68)^2 \cdot 5 + (2{,}95)^2 \cdot 4 + (1{,}27)^2 \cdot 5$$

Demak, quvvat muvozanati:

$$63{,}8\ VT = 63{,}8\ VT$$

1.11-Masala. Ko‘prik sxemada ulangan elektr zanjir parametri: $R_1 = R_3 = R_5 = 50\ Om, R_2 = R_4 = 4\ Om$ bo‘lib, $E = 30\ V$ o‘zgarmas manbaga ulangan. Uchburchak sxemadan ekvivalent yulduzcha sxemaga o‘tish bilan tarmoqdagi tok va sarf bo‘ladigan elektr tok quvvati aniqlansin.



Yechish.

Berilgan sxemadan b, c, d uchburchak sxema potensialini ekvivalent yulduzcha sxemaga o‘tish ifodasidan foydalanamiz:

$$R_6 = \frac{R_2 \cdot R_4}{R_2+R_4+R_5} = \frac{80 \cdot 120}{320} = 30\ Om$$

$$R_7 = \frac{R_2 \cdot R_5}{R_2+R_4+R_5} = \frac{120 \cdot 120}{320} = 45\ Om$$

$$R_8 = \frac{R_4 \cdot R_4}{R_2+R_4+R_5} = \frac{80 \cdot 120}{320} = 30\ Om$$

Tuzilgan yulduzcha sxemadan qarshilikni ketma-ket va parallel qo‘shish bilan zanjir umumiy qarshiligini aniqlaymiz:

$$R_{um} = R_6 + \frac{(R_3+R_8)(R_1+R_7)}{R_3+R_8+R_1+R_7} = 30 + \frac{210 \cdot 105}{315} = 30\ Om$$

Tarmoqdagi tok: $I = \frac{E}{R_{um}} = \frac{30}{100} = 0{,}3\ A$

Parallel tarmoqdagi tokni aniqlaymiz:

$$R_{17} = I\frac{R_8+R_3}{R_3+R_8+R_1+R_7} = \frac{210 \cdot 0{,}3}{315} = 0{,}2\ A$$

$$R_{38} = I\frac{R_1+R_7}{R_3+R_8+R_1+R_7} = \frac{105 \cdot 0{,}3}{315} = 0{,}1\ A$$

Bu yerda: $R_1 = R_3$ ga teng bo‘lganligi uchun aniqlangan $I_{17} = I_1 = 0{,}2A$ va $I_{38} = I_3 = 0{,}1\ A$ ga teng.

Berilgan sxemaning qolgan tarmoqlaridan o‘tuvchi toklarni aniqlash uchun tugun potensialiga asosan tenglama tuzamiz:

$$U_{bc} = IR_6 + I_1R_7 = 0{,}3 \cdot 30 + 0{,}2 \cdot 45 = 18\ V$$

$$U_{bd} = IR_6 + I_3R_8 = 0{,}3 \cdot 30 + 0{,}1 \cdot 30 = 12\ V$$

$$U_{dc} = U_{bc} - U_{bd} = 18 - 12 = 6\ V$$

Tarmoqdagi tok: $I_2 = \frac{U_{bc}}{R_2} = \frac{18}{80} = 0{,}225$ A, $I_4 = \frac{U_{bd}}{R_4} = \frac{12}{120} 0{,}1\ A$,

$$I_5 = \frac{U_{cd}}{R_5} = \frac{6}{20} = 0{,}05 \text{ A}$$

Masalaning yechimini tekshirib ko‘ramiz.

Bunda: a – tarmoqdagi tok:

$$I = I_1 + I_3 = 0{,}2 + 0{,}1 = 0{,}3\ A$$

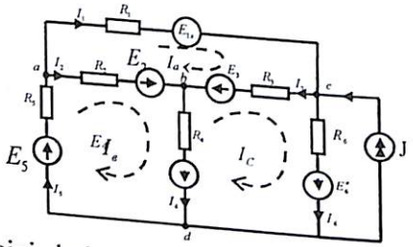
b – tugundagi tok: $I = I_4 + I_2 = 0{,}1 + 0{,}225 = 0{,}3\ A$

Zanjirda sarf bo‘ladigan quvvat:

$$P = UI = I^2 R_{um} = 30 \cdot 0{,}3 = 9\ VT$$

1.12-Masala. Berilgan elektr tok sxemasining parametri: $R_1 = 8\ Om, R_2 = 5\ Om, R_3 = 4\ Om, R_4 = 6\ Om, R_5 = 6\ Om, R_6 = 7\ Om,$ EYK lari: $E_6 = 30V, E_2 = 30\ V, E_3 = 30\ V, E_4 = 40\ V, E_5 = 50\ V$ tok manbai $J = 4A$ va birinchi tarmoqdagi tok $I_1 = 2\ A$ bo‘lib, konturli tok usuliga asosan tarmoqdagi tok, E_{1x} - EYK qiymati va ekvivalent generator usuliga asosan I_2 tarmoqdagi tok aniqlansin.

Yechish.

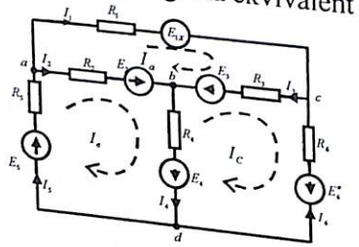


1.Tok manbaini ekvivalent kuchlanish manbai bilan almashtiramiz:

Bunda: $JR_6 = E_6'\ yoki\ E_6' = 4 \cdot 7 = 28\ V$

Demak: $E_6'' = E_6 - E_6' = 30 - 28 = 2\ V$

2. Berilgan sxemani quyidagicha ekvivalent sxemaga keltiramiz.



Konturli tok usuliga asosan konturdagi tok I_a I_b I_c yo‘nalishlari bo‘yicha Kirxgof 2-qonuniga asosan tenglama tuzamiz:

$$\left.\begin{aligned} R_{11}I_a - R_{12}I_b - R_{13}I_c &= E_a \\ -R_{21}I_a + R_{22}I_b - R_{23}I_c &= E_b \\ -R_{31}I_a - R_{32}I_b + R_{33}I_c &= E_c \end{aligned}\right\} \quad (1)$$

Endi konturga kiruvchi qarshilikni aniqlaymiz:

$$R_{11} = R_1 + R_2 + R_3 = 17\ \ Om$$
$$R_{22} = R_2 + R_4 + R_5 = 17\ \ Om$$
$$R_{33} = R_3 + R_4 + R_6 = 17\ \ Om$$

Konturni bog‘lovchi konturlararo qarshilikni aniqlaymiz:

$$\left.\begin{aligned} R_{12} = R_{21} = R_2 &= 5\ Om \\ R_{31} = R_{13} = R_3 &= 4\ \ Om \\ R_{23} = R_{32} = R_4 &= 6\ \ Om \end{aligned}\right\}$$

Konturni tashkil etuvchi EYK ni aniqlaymiz:

$$E_a = E_1X + E_2 - E_3 = (E_1X - 17)\ V$$
$$E_B = E_2 + E_4 + E_5 = 140\ V$$
$$E_C = E_6'' - E_4 - E_3 = -68\ V$$

1– konturdagi tok: $I_a = I_1 = 2\ A$

Aniqlangan qiymatni (1) tenglamaga qo‘yamiz:

$$\left.\begin{aligned} 2 \cdot 17 - 5 \cdot I_b - 4 \cdot I_c &= E_{1X} - 20 \\ -2 \cdot 5 + 17 \cdot I_b - 6 \cdot I_c &= 140 \\ -2 \cdot 4 - 6 \cdot I_b + 17 \cdot I_c &= -68 \end{aligned}\right\} \quad (2)$$

Ushbu tenglamadan noma’lum konturdagi tok (I_b, I_c)ni aniqlaymiz:

yoki:

$$\left.\begin{aligned} 17I_b - 6I_c &= 150 \\ -6I_b - 17I_c &= 160 \end{aligned}\right\}$$

Bu tenglamani Kramer usuliga asosan yechamiz:

$$\Delta_a = \begin{vmatrix} 17 & -6 \\ -6 & 17 \end{vmatrix} = 289 - 36 = 253$$

$$\Delta_b = \begin{vmatrix} 150 & -6 \\ -60 & 17 \end{vmatrix} = 2550 - 360 = 2190$$

$$\Delta_c = \begin{vmatrix} 17 & 150 \\ -6 & -60 \end{vmatrix} = -1020 + 900 = -120$$

Bundan:

$$I_b = \frac{2190}{253} = 8{,}65\ A, \qquad I_c = -\frac{120}{253} = -0{,}475$$

(2) tenglamadan E_{1x} - EYK qiymatini aniqlaymiz:

$$E_{1x} = 54 - 5 \cdot 8{,}65 + 4 \cdot 0{,}475 = 12{,}65\ V$$

Tarmoqdagi tokni aniqlaymiz:

$$I_1 = 2A, \quad I_2 = I_a - I_b = 2 - 8{,}65 = -6{,}65\ A$$
$$I_3 = I_a - I_c = 2 + 0{,}475 = 2{,}475\ A$$
$$I_4 = I_b - I_c = 8{,}65 + 0{,}475 = 9{,}125\ A$$
$$I_5 = I_b = 8{,}65\ A$$
$$I_6 = -I_c = 0{,}475\ A$$

Quvvat muvozanat tenglamasini tuzamiz:

$$I_1^2R_1 + I_2^2R_2 + I_3^2R_3 + I_4^2R_4 + I_5^2R_5 + (I - I_2)R_6 =$$
$$E_1I_1 + E_2I_2 + E_3I_3 + E_4I_4 + E_5I_5 + E_6(I - I_6)$$

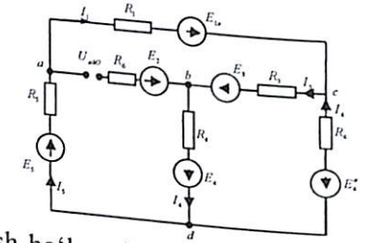
Bundan: $13335.86 \approx 13337\ (VT)$

Hisoblashdagi xatolik 0,02% ga teng.

3. Ekvivalent generator usuliga asosan I_2 tarmoqdagi tokni aniqlaymiz.

Bunda: $I_2 = \frac{U_{abo}}{R_0+R_2}$ (3)

Ekvivalent sxemasini chizamiz:



2- tarmoqda uzilish bo‘lganda elektr sxema ikki tugunli potensial ayirmasi bilan ifodalanib $(\varphi_C - \varphi_B)$ tugunlararo potensiallar ayirmasi tenglamasiga asosan:

$$U_{cd} = \frac{\sum_{m=1}^{n} E_n g_n}{\sum_{m=1}^{n} g_n} = \frac{(E_5+E_{1x})\frac{1}{R_1+R_5} - (E_4+E_3)\frac{1}{R_3+R_4} - E_6''\frac{1}{R_6}}{\frac{1}{R_1+R_5+} + \frac{1}{R_3+R_4} + \frac{1}{R_6}} =$$
$$\frac{\frac{62{,}65}{14} - \frac{70}{10} - 2\frac{1}{7}}{\frac{1}{14}+\frac{1}{10}+\frac{1}{7}} = 8{,}95\ V$$

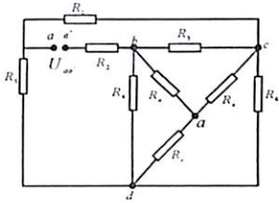
Om qonuniga asosan tarmoqdagi toklarni aniqlaymiz:

$$I_1 = I_5 = \frac{(E_5+E_{1X})-U_{cd}}{R_1+R_5} = (62{,}65 + 8{,}95)\cdot\frac{1}{14} = 5{,}2\ A$$
$$I_3 = I_4 = \frac{(E_3+E_4)+U_{cd}}{10} = \frac{70-8{,}95}{10} = 6{,}1\ A$$
$$I_6 = \frac{E_6''+U_{cd}}{7} = \frac{2-8{,}95}{7} \approx -1\ A$$

Potensial qiymatni aniqlaymiz:

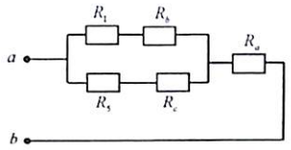
$$\varphi_a = \varphi_d + E_5 + I_5R_5 = 0 + 50 - 5{,}2\cdot 6 = 19{,}3\ V$$
$$\varphi_b = \varphi_d - E_4 + I_4R_4 = 0 - 40 + 6{,}1\cdot 6 = -3{,}37\ V$$
$$\varphi_b' = \varphi_b + E_2 = -3{,}37 - 50 = -53{,}37\ \text{V}$$
$$U_{abo} = \varphi_a - \varphi_b' = 19{,}3 + 53{,}37 = 72{,}67\ V$$

Endi (3) tenglamadagi R_0 – ichki ekvivalent qarshilikni aniqlaymiz. Buning uchun b, c, d potensiallarni birlashtiruvchi qarshilikni uch-burchak sxemadan yulduzcha sxemaga keltirish formulasiga asosan ekvivalent sxemasini chizamiz:



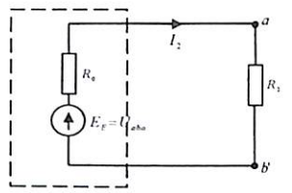
$$R_a = \frac{R_3R_4}{R_3+R_4+R_6} = \frac{24}{17}\ (Om)$$
$$R_b = \frac{R_3R_6}{R_3+R_4+R_6} = \frac{28}{17}\ (Om)$$
$$R_a = \frac{R_4R_6}{R_3+R_4+R_6} = \frac{42}{17}\ (Om)$$

R_c qarshilikni R_5 bilan va R_1 qarshilikni R_b qarshilik bilan qo‘shib ikkita parallel ulangan sxemaning umumiy qarshiligini topamiz:



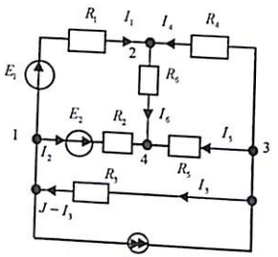
$$R_{um} = R_0 = \frac{(R_C+R_5)(R_b+R_1)}{R_c+R_5+R_b+R_1} + R_a =$$
$$5{,}95\ (Om)$$

Uzilgan 2-tarmoqqa nisbatan ekvivalent sxemasini tuzamiz hamda aniqlangan qiymatni (3) tenglamaga qo‘yish bilan I_2 tarmoqdagi tokni aniqlaymiz:

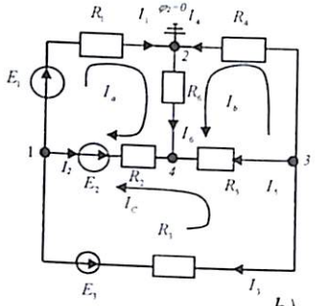


$$I_2 = \frac{U_{abo}}{R_0+R_2} = \frac{72{,}6}{5{,}95+5} = 6{,}65\ (A)$$

1.13-Masala. Murakkab elektr zanjir tarmoqlaridagi qarshilik: $R_1 = R_2 = R_3 = 2\ Om$, $R_4 = R_5 = R_6 = 6\ Om$ va elektr yurituvchi kuch $E_1 = 68$, $E_2 = 12\ V$ bo‘lib, tok manbai $J = 9\ A$ ga teng. Konturli tok va tugun potensiallari usullariga asosan tarmoqdagi tokni aniqlang.



a)



b)

Yechish. a) tok manbaini elektr yurituvchi kuchlar manbai bilan almashtirilgandan keyingi ekvivalent sxema uchun (b) konturli tok usuliga asosan tenglama tuzamiz: $E_3 = J \cdot R_3 = 9 \cdot 2 = 18\ V.$

$$\left.\begin{array}{l} I_a(R_1 + R_6 + R_2) + I_b R_6 + I_c R_2 = E_1 - E_2 \\ I_a R_6 + I_b(R_4 + R_5 + R_6) - I_c R_5 = 0 \\ I_a R_{2-} - I_b R_5 + I_c(R_2 + R_3 + R_5) = E_3 - E_2 \end{array}\right\}$$

yoki:

$$\left.\begin{array}{l} 10I_a + 6I_b + 2I_c = -6 \\ 6I_a + 18I_b - 6I_c = 0 \\ 2I_a - 6I_b + 10I_c = 6 \end{array}\right\}$$

Tenglamalar sistemasini yechish bilan konturdagi tokni aniqlaymiz: $I_a = I_1 = -1{,}5\ A;\ I_b = I_4 = 1a;\ I_c = I_3 = 1{,}5\ A$

Tarmoqdagi tokni aniqlaymiz:

$$I_6 = I_a + I_b = -0{,}5\ A;\ I_5 = I_c - I_b = 0{,}5\ A;$$

$$I_2 = -(I_a + I_c) = 0$$

R_3 qarshilikdagi tok $J - I_c = 9 - 1{,}5 = 7{,}5\ A.$

I_a va I_6 ishorasi tokning haqiqiy qiymati teskari ekanligini ifodalaydi.

b) **tugun potensial usuliga** asosan sxemadan 2-tugun potensialini $\varphi_2 = 0$ deb olamiz.

Bunda:

$$\left.\begin{array}{l} \varphi_1(g_1 + g_2 + g_3) - \varphi_3 g_3 - \varphi_4 g_2 = -E_1 g_1 - E_2 g_2 - E_3 g_3 \\ -\varphi_1 g_3 + \varphi_3(g_3 + g_4 + g_5) - \varphi_4 g_5 = E_3 g_3 \\ -\varphi_1 g_2 - \varphi_3 g_5 + \varphi_4(g_2 + g_5 + g_6) = E_2 g_2 \end{array}\right\}$$

yoki:

$$\left.\begin{array}{l} 3\varphi_1 - \varphi_2 - \varphi_4 = -3 \\ -3\varphi_1 + \varphi_3 - 5\varphi_4 = 36 \\ -3\varphi_1 + 5\varphi_3 - \varphi_4 = 54 \end{array}\right\}$$

Tenglamani yechish bilan tugun potensiallar qiymatini topamiz:

$$\varphi_1 = -9\ \text{V};\ \varphi_3 = 6\ \text{V};\ \varphi_4 = 3\ \text{V}.$$

Bundan, tarmoqdagi toklarni Om qonuniga asosan aniqlaymiz:

$$I_1 = (\varphi_2 - \varphi_1 - E_1)g_1 = (0 + 9 - 6)\frac{1}{2} = 1{,}5\ A$$

$$I_2 = (\varphi_1 - \varphi_4 + E_1)g_2 = (-9 - 3 + 12)\frac{1}{2} = 0$$

$$J - I_3 = (\varphi_3 - \varphi_1)g_3 = (6 + 9)\frac{1}{2} = 7{,}5\ A$$

$$I_4 = (\varphi_3 - \varphi_2)g_4 = (6 - 0)\frac{1}{6} = 1\ A$$

$$I_5 = (\varphi_3 - \varphi_4)g_5 = (6 - 3)\frac{1}{6} = 0{,}5\ A$$

$$I_6 = (\varphi_4 - \varphi_2)g_6 = (3 - 0)\frac{1}{6} = 0{,}5\ A\ .$$

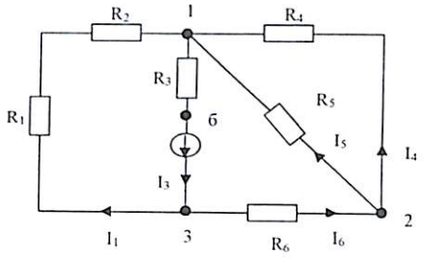
Quvvat muvozanat tenglamasiga asosan:

$$\sum P_{manba} = \sum P_{iste'molchi}$$

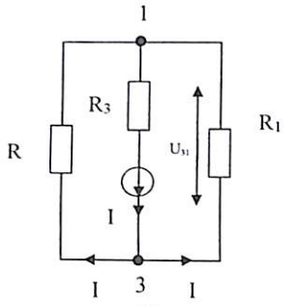
$$E_1 I_1 + E_2 I_2 + E_3 I_3 = I_1^2 R_1 + I_2^2 R_2 + I_3^2 R_3 + I_4^2 \cdot R_4 + I_5^2 R_5 + I_6^2 R_6.$$

Demak: $P_{manba} = 36\ VT = P_{iste'm} = 36\ VT.$

1.14-Masala. Zanjir parametrlari: R_1=R_2=4 Ω R_3=6 Ω R_4=R_5=12 Ω R_6=4 Ω va I_6=2 A ga teng bo'lganda tarmoq toklari topilsin.



a)



b)

Yechim: 1-3 tugun potensiallariga nisbatan ekvivalent qarshilik topamiz:

$$R''_{ekv} = \frac{R_4 \cdot R_5}{R_4 + R_5} + R_6 = 10\ \text{om} \qquad R'_{ekv} = R_1 + R_2 = 8\ \text{om}$$

Bunda ekvivalent sxemasi b - rasm ko'rsatilgan. Shunga nisbatan kuchlanish:

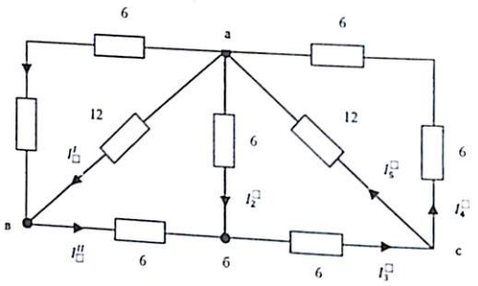
$U_{31} = R''_{ekv} \cdot I_6 = 10 \cdot 2 = 20\text{V}$ demak, $I_1 = \frac{U_{31}}{R'_{ekv}} = \frac{20}{8} = 2{,}5\ \text{A}$

Kirxgofning 1- qonuniga asosan: $I_3 = I_1 + I_6 = 2{+}2{,}5 = 4{,}5\ \text{A}$

2-tugun uchun: $I_6 = I_4 + I_5$ $R_4 = R_5$ bo'lib, tok $I_4 = I_5 = \frac{I_6}{2} = 1\text{A}$

demak $E = U_{31} + R_3 \cdot I_3 = 20 + 6 \cdot 4{,}5 = 47\text{V}$

1.15-Masala. Berilgan elektr zanjir aktiv qarshiliklari va tarmoq toki $I = 1A$ bo'lganda, $U_{аб}$ potensial kuchlanish va tarmoq toklari nimaga teng?



Yechish: a-b potensial orasidagi kuchlanishni topamiz :

$U_{аб}= 1\cdot(6+6) =12V$ Bundan: $I' = \frac{Uаб}{12} = \frac{12}{12} = 1A$

Kirxgofning 1-qonuniga asosan: $I''= I + I'=1+1=2A$

Demak kuchlanish $U_{вб}= I'' \cdot 6= 2\cdot6=12V$

Kirxgofning 2-qonuniga asosan a-b potensial kuchlanish:

$U_{аб}=U_{ав}+ U_{вб}=12+12= 24V$ demak: $I_2= \frac{Uаб}{6} = \frac{24}{6} = 4A$ unda: $I_3 = I''+I_2=2+4=6A$

Qarshilik parametrlari bir xil bo'lganligi uchun $I_4 = I_5 = \frac{I_3}{2} = \frac{6}{2} = 3A$.

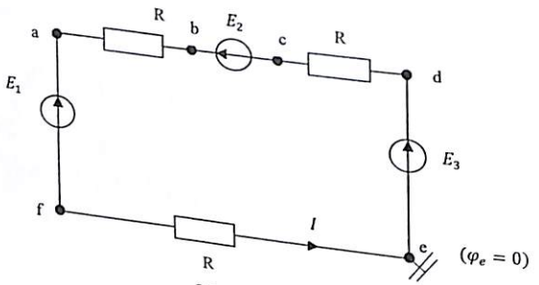
Masalaning yechimini a – tugunga nisbatan tekshiramiz:

$-I - I' - I_2 + I_5 + I_4 = -1 - 1 - 4 + 3 + 3 = 0$

Zanjirda sarf bo'ladigan umumiy quvvat:

$P_{um}= P+ P' + P'' + P_3 + P_4 + P_5 = I^2 \cdot 12 + I^2 \cdot 12 + I''^2 \cdot 6 + I_3^2 \cdot 6 + I_4^2 \cdot 12 + I_5^2 \cdot 12 + I_2^2 \cdot 6 = 12 + 12 + 24 + 216 + 108 + 108 + 96 = 576$ Wt

1.16-Masala Ketma-ket zanjir parametr qiymatlari $R = 2\ om$; $E_1 = E_2 = 20\ V$; $E_3 = 10\ V$; bo'lganda tok I aniqlanib, potensial diagrammasi tuzilsin.



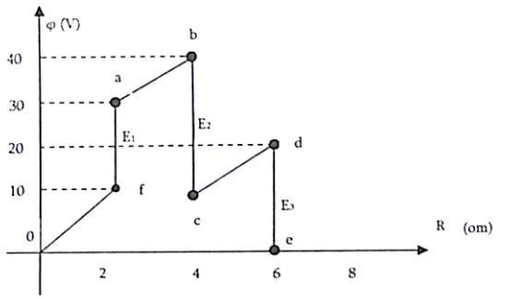
Yechish: Tarmoq toki: $I = \frac{-E_1+E_2+E_3}{3R} = \frac{-20+30+20}{2\cdot3} = \frac{30}{6} = 5A$

Zanjir potensiali $\varphi_e = 0$ deb potensiallar farqini quydagicha ifodalaymiz:

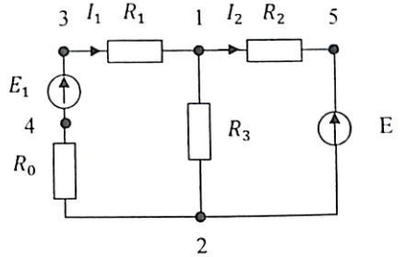
$$\varphi_f - \varphi_e = IR \Rightarrow \varphi_f = 5 \cdot 2 = 10$$
$$\varphi_a - \varphi_f = E_1 \Rightarrow \varphi_a = E_1 + \varphi_f = 20 + 10 = 30$$
$$\varphi_b - \varphi_a = IR \Rightarrow \varphi_b = IR + \varphi_a = 10 + 30 = 40$$
$$\varphi_c - \varphi_b = -E_2 \Rightarrow \varphi_c = -E_2 + \varphi_b = -30 + 40 = 10$$
$$\varphi_d - \varphi_c = IR \Rightarrow \varphi_d = IR + \varphi_c = 10 + 10 = 20$$
$$\varphi_e - \varphi_d = -E_3 \Rightarrow \varphi_e = -E_3 + \varphi_d = -20 + 20 = 0$$

$Izoh$: I –chiquvchi yuqori potensial (+) E – chiquvchi yuqori potensial (-)

Potensial qiymatlarga asosan diagramasini tuzamiz.



1.17-Masala Sxemada avtomobil elektr ta'minot qismidagi generator bilan akkumulyator ulangandagi ekvivalent zanjir parametrlari: $E_1 = 14.4\ V$; $E = 12\ V$; $R_0 = 0.01\ om$; $R_1 = 0.19\ om$; $R_2 = 0.2\ om$; $I_1 = 11A$; $I_2 = 1A$ teng $U_{12} = \varphi_1 - \varphi_2$ potensial kuchlanish topilib, diagrammasi tuzilsin.



Yechish: Kirxgofning 2-qonuniga asosan tenglama yozamiz:

a) $E_1 - E = R_0 I_1 + R_1 I_1 + R_2 I_2 = 14.4 - 12 = 0.01 \cdot 11 + 0.19 \cdot 11 + 0.2 \cdot 2 = 2.4V$

b) 1-2 potensial kuchlanish:

$U_{12} = E_1 - (R_0 + R_1) \cdot I_1 = 14.4 - (0.01 + 0.19) = 12.2\ V.$

Potensial diagramma tuzish uchun $\varphi_2 = 0$ tenglaymiz, bunda;

$\varphi_4 = \varphi_2 - R_0 \cdot I_1 = 0 - 0.01 \cdot 11 = -0.11\ V$

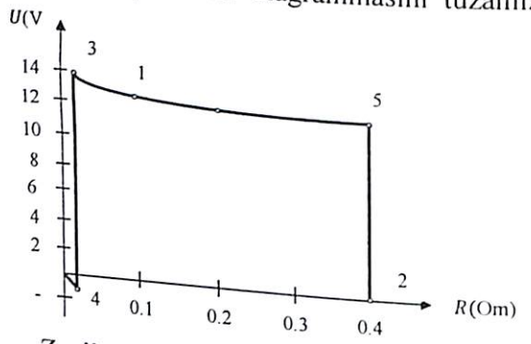
$\varphi_3 = \varphi_4 + E_1 = -0.11 + 14.4 = 14.29\ V$

$\varphi_1 = \varphi_3 - R_1 \cdot I_1 = 14.29 - 0.19 \cdot 11 = 12.2\ V$

$\varphi_5 = \varphi_1 - R_2 \cdot I_2 = 12.2 - 0.2 \cdot 1 = 12\ V$

$\varphi_2 = \varphi_5 - E_2 = 12 - 12 = 0$

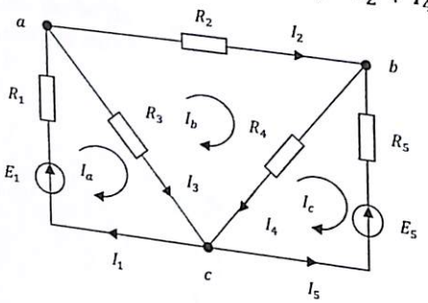
Masshtab tanlash bilan potensial diagrammasini tuzamiz:



1.18-Masala. Zanjir parametrlari: $E_1 = 8\ V$ $E_5 = 12\ V$ $R_1 = R_3 = 1\ om$ $R_5 = 3\ om$ $R_2 = R_1 = 2\ om$ bo'lganda tarmoq toklari matritsa usulidan foydalanib topilsin.

Yechish: Kirxgof qonunlariga asosan tenglama yozamiz:

$a) -I_1 + I_2 + I_3 = 0$ $b) -I_2 + I_4 - I_5 = 0$



$$I_1 R_1 + I_3 R_3 = E_1$$
$$I_2 R_2 - I_3 R_3 + I_4 R_4 = 0$$
$$-I_4 R_4 - I_5 R_5 = -E_5$$

Matritsali ifodasi: $\begin{bmatrix} -1 & 1 & 1 & 0 & 0 \\ 0 & -1 & 0 & 1 & -1 \\ R_1 & 0 & R_3 & 0 & 0 \\ 0 & R_2 & -R_2 & R_4 & 0 \\ 0 & 0 & 0 & -R_4 & -R_5 \end{bmatrix} = \begin{bmatrix} I_1 \\ I_2 \\ I_3 \\ I_4 \\ -I_5 \end{bmatrix} = \begin{bmatrix} 0 \\ 0 \\ E_1 \\ 0 \\ -E_5 \end{bmatrix}$

1)Konturli tok usuliga asosan matritsa tenglama ifodasi:

$$\begin{bmatrix} I_a R_{11} + & I_b R_{12} + & I_c R_{13} \\ I_a R_{21} + & I_b R_{22} + & I_c R_{23} \\ I_a R_{31} + & I_b R_{32} + & I_c R_{33} \end{bmatrix} = \begin{bmatrix} E_{11} \\ E_{22} \\ E_{33} \end{bmatrix}$$

yoki matritsa tenglamaning chap tomonini ikkita matritsaning ko'paytmasi ko'rinishida ajratib yozamiz:

$$\begin{bmatrix} Z_{11} & Z_{12} & Z_{13} \\ Z_{21} & Z_{22} & Z_{23} \\ Z_{31} & Z_{32} & Z_{33} \end{bmatrix} \cdot \begin{bmatrix} I_a \\ I_b \\ I_c \end{bmatrix} = \begin{bmatrix} E_{11} \\ E_{22} \\ E_{33} \end{bmatrix} \quad yoki \quad [Z] \cdot [I] = [E]$$

Endi $[Z]$ matritsa tenglamaning har ikki tomonini $[Z]^{-1}$ ga ko'paytiramiz:

$$[Z]^{-1} \cdot [Z] \cdot [I] = [Z]^{-1} \cdot [E]$$

Bunda $[Z]$ matritsa determinantini $[\Delta_{kn}]$ – algebraik qo'shimcha element bilan to'ldiramiz.

2)Ya'ni $[\Delta_{kn}]$ –matritsani $[Z]$ matritsa determinantiga bo'lamiz:

$$\Delta = \begin{bmatrix} Z_{11} & Z_{12} & Z_{13} \\ Z_{21} & Z_{22} & Z_{23} \\ Z_{31} & Z_{32} & Z_{33} \end{bmatrix}$$

3) $[\Delta_{kn}]$ matritsani ,,Transponirovat'' qilish uchun matritsa qatorlari mos ravishda ustunlari bilan almashtiramiz ya'ni:

$$[Z]^{-1} = \frac{1}{\Delta} \begin{bmatrix} \Delta_{11} & \Delta_{12} & \Delta_{13} \\ \Delta_{21} & \Delta_{22} & \Delta_{23} \\ \Delta_{31} & \Delta_{32} & \Delta_{33} \end{bmatrix}$$

yoki $[Z]^{-1} \cdot [Z] = 1 \quad bo'lib \quad [1] \cdot [I] = [I]$

$$[I] = [Z]^{-1} \cdot [E] \quad yoki \quad \begin{bmatrix} I_a \\ I_b \\ I_c \end{bmatrix} = \frac{1}{\Delta} \begin{bmatrix} \Delta_{11} & \Delta_{12} & \Delta_{13} \\ \Delta_{21} & \Delta_{22} & \Delta_{23} \\ \Delta_{31} & \Delta_{32} & \Delta_{33} \end{bmatrix} \cdot \begin{bmatrix} E_{11} \\ E_{22} \\ E_{33} \end{bmatrix}$$

Kontur toklar I_a , I_b , I_c yo'nalishini soat strelkasi bo'yicha olamiz:

$$\begin{bmatrix} 2 & -1 & 0 \\ -1 & 5 & -2 \\ 0 & -2 & 5 \end{bmatrix} \cdot \begin{bmatrix} I_a \\ I_b \\ I_c \end{bmatrix} = \begin{bmatrix} 8 \\ 0 \\ -12 \end{bmatrix}; \quad \Delta = \begin{bmatrix} 2 & -1 & 0 \\ -1 & 5 & -2 \\ 0 & -2 & 5 \end{bmatrix} = 37$$

$$\Delta_{11}=\begin{bmatrix}5 & -2\\ -2 & 5\end{bmatrix}=21 \qquad \Delta_{12}=\Delta_{21}=\begin{bmatrix}-1 & 0\\ -2 & 5\end{bmatrix}=5$$

Shunga o'xshash: $\Delta_{13}=\Delta_{31}=2,\ \Delta_{22}=10;\ \Delta_{23}=\Delta_{32}=4,\ \Delta_{33}=9$

Demak:

$$[Z]^{-1}=\frac{1}{37}\begin{bmatrix}21 & 5 & 2\\ 5 & 10 & 4\\ 2 & 4 & 9\end{bmatrix};\quad \begin{bmatrix}I_a\\ I_b\\ I_c\end{bmatrix}=\frac{1}{37}\begin{bmatrix}21 & 5 & 2\\ 5 & 10 & 4\\ 2 & 4 & 9\end{bmatrix}\cdot\begin{bmatrix}8\\ 0\\ -12\end{bmatrix}$$

Algebraik matritsalarni ko'paytirish usuliga asosan:

$$\begin{bmatrix}I_a\\ I_b\\ I_c\end{bmatrix}=\frac{1}{37}\begin{bmatrix}21\cdot 8+ & 5\cdot 0- & 2\cdot 12\\ 5\cdot 8+ & 10\cdot 0- & 4\cdot 12\\ 2\cdot 8+ & 4\cdot 0- & 9\cdot 12\end{bmatrix}=\frac{1}{37}\begin{bmatrix}144\\ -8\\ -92\end{bmatrix}=\begin{bmatrix}3{,}9\\ -0{,}216\\ -2{,}49\end{bmatrix}$$

Demak kontur toklar qiymati:

$$I_a=3{,}9A,\quad I_b=-0{,}216\ A,\quad I_c=-2{,}49\ A$$

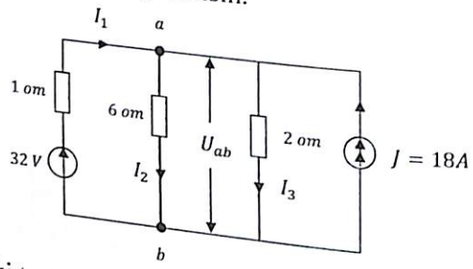
Endi tarmoq toklarini topamiz:

$$I_1=3{,}9\ A \qquad I_2=-0{,}216\ A \qquad I_5=2{,}49\ A$$

$I_3=3{,}9+0{,}216=4{,}116\ A$ $I_4=I_b-I_c=-0{,}216+2{,}49=2{,}38\ A$

a tugunda tekshiramiz: $-I_1+I_2+I_3=-3{,}9-0{,}216+4{,}11\approx 0$

1.19-Masala. Zanjir parametrlari berilgan bo'lganda tarmoq toklari tugun potensiali usuliga asosan yechilsin.



Yechish: Ikki tugun potensiallar usuliga asosan U_{ab} kuchlanishini topamiz:

$$U_{ab}=\varphi_a-\varphi_b=\frac{Eg+J}{g_1+g_2+g_3}=\frac{32\cdot 1+18}{1+\frac{1}{6}+0{,}5}=30V$$

Tarmoqdagi tok: $I_2=\frac{U_{ab}}{R}=\frac{30}{6}=5A,\qquad I_3=\frac{U_{ab}}{R}=\frac{30}{2}=15A$

Kirxgofning I qonuniga asosan:

$$I_1=I_2+I_3-J=5+15-18=2A$$

Quvvatlar muvozanat tenglamasiga asosan:

$$EI_1+J\cdot U_{ab}=I_1^2R+I_2^2R+I_3^2R \qquad yoki \qquad 604=604$$

1.20-Masala. Elektr energiyani iste`molchilarga uzatish liniya kuchlanishi U=230 V ichki qarshiligi $R_0$= 0,2 Om bo`lib, iste`molchi qarshililigi: $R_{ist}$= 0 -2 Omga o`zgarganda elektr quvvati P=f(R/R_0) grafigini chizing.

Yechish. Uzatish liniyadan oqadigan tok:

$$I=\frac{U}{R+R_0}=\frac{U}{R_0}\cdot\frac{1}{\left(1+\frac{R}{R_0}\right)}=\frac{230}{0{,}2\cdot\left(\frac{R}{R_0}\right)+1}=1150\,\frac{1}{1+\left(\frac{R}{R_0}\right)}$$

$\frac{R}{R_0}$ va R qrashilik qiymatlariga nisbatan I-tokni aniqalaymiz.

1-jadval

$\frac{R}{R_0}$	0	0,5	1	2	3	5	10
R(Om)	0	0,1	0,2	0,4	0,6	1	2
I(A)	1150	766	575	383	287	191	104

Tok qiymatlari asosida iste`molchidagi quvvati $P=I^2R$ shunga asosan: P=f($\frac{R}{R_0}$) hisoblab (tabl.2) grafigini tuzamiz.

2-jadval

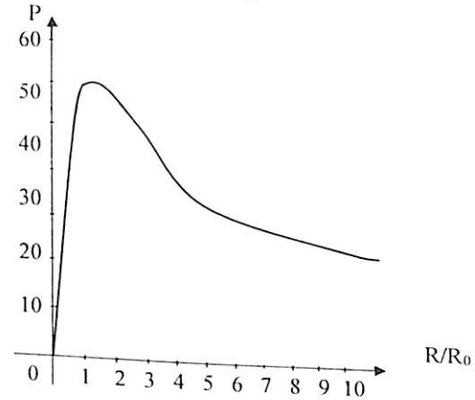
$\frac{R}{R_0}$	0	0,5	1	2	3	5	10
P	0	59	66	59	50	37	22

Foydali ish koeffisienti:

$$\eta=\frac{P_{ist}}{P_1}=\frac{I^2R}{I^2(R_0+\frac{R}{R_0})}=\frac{R}{R_0+\frac{R}{R_0}}=0{,}5\cdot 100\%=50\%$$

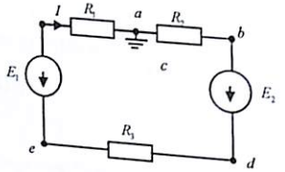
Ya`ni $R=R_0$ bo`lganda iste`molchiga uzatiladigan quvvat

$$P_{ist}=\frac{1}{2}P$$



1.3. Mustaqil yechish uchun masalalar

1.1-Masala. Ketma-ket sxemada ulangan elektr zanjir parametri: $E_1 = 20\ V$, $E_2 = 12V$, $R_1 = 5\ Om$, $R_2 = 6\ Om$, $R_3 = 9\ Om$ ga teng. Tarmoqdagi tok va potensiallari aniqlanib, potensiallar diagrammasi tuzilsin.

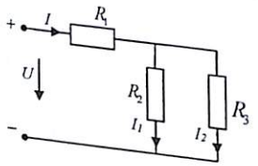


Javob: $I = 0{,}4\ A$, $\varphi_a = 0$, $\varphi_b = 2{,}4\ V$, $\varphi_d = -14{,}4\ V$, $\varphi_e = -18\ V$, $\varphi_c = 2\ V$

1.2-Masala. Parallel sxemada biriktirilgan elektr zanjirning a va b tugun potensiallaridagi kuchlanish $U_{ab} = 60\ V$ bo'lib, kiruvchi tarmoqdagi tok $I = 1{,}5\ A$ va qarshilik $R_2 = 120\ Om$ ga teng. Tarmoqdagi tok qarshiligi va ekvivalent qarshiligini aniqlang.

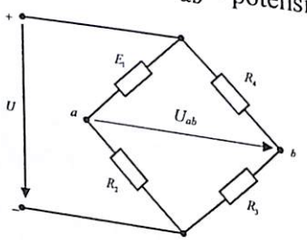
Javob: $R_1 = 60\ Om, R_{ekv} = 40\ Om, I_1 = 1\ A, I_2 = 0{,}5\ A.$

1.3-Masala. Elektr zanjir $U = 60\ V$ kuchlanishga ulanganda $P = 300Vt$ quvvat sarflanadi. Qarshilik parametri $R_2 = 15\ Om, R_3 = 5\ Om$ ga teng bo'lganda, R_1 qarshilik qiymati va tarmoqdagi tokni aniqlang.



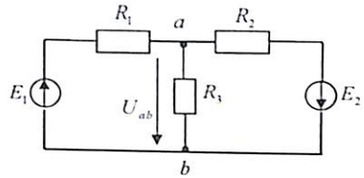
Javob: $R_1 = 8{,}25Om, I_1 = 3{,}75\ A$, $I_2 = 1{,}25\ A, I = 5\ A$,

1.4-Masala. Ko'prik sxemada ulangan zanjir qarshilik parametri $R_1 = 10\ Om, R_2 = 20\ Om, R_3 = 40\ Om, R_4 = 30\ Om$ bo'lib, $U = 210\ V$ kuchlanishga ulangan. U_{ab} – potensial kuchlanishi aniqlansin.



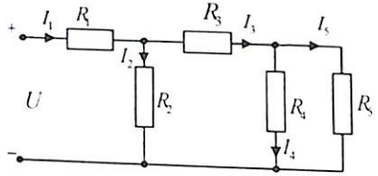
Javob: $U_{ab} = 20\ V$

1.5-Masala. Keltirilgan sxemada $E_1 = 12V$, $E_2 = 24V$, $R_1 = R_2 = 2Om, R_3 = 10\ Om$ bo'lsa, φ_a va φ_b tugunlar orasidagi kuchlanish necha voltga teng.



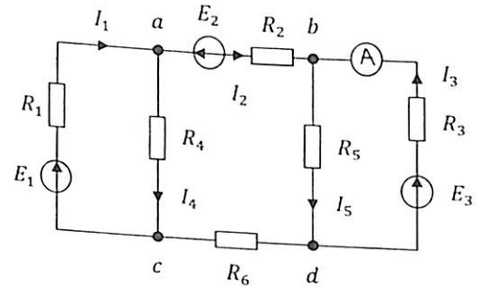
Javob: $U_{ab} = 9\ V.$

1.6-Masala. Aralash sxemada ulangan elektr zanjir parametri: $R_1 = 50\ Om, R_2 = 80\ Om, R_3 = 20\ Om, R_4 = 30\ Om, R_5 = 60\ Om$ bo'lib, to'rtinchi tarmoqdan o'tuvchi tok $I_4 = 0{,}2\ A$ ga teng. Tarmoqdagi tok, zanjir umumiy kuchlanishi va sarf bo'ladigan elektr quvvat aniqlansin.



Javob: $U = 34{,}5\ V, P = 15{,}5\ Vt$

1.7-Masala. Zanjir qarshiliklari: $R_1 = R_2 = R_5 = 2\ om, R_3 = R_4 = 6\ om$, $R_6 = 3\ om$ ga teng bo'lib, $EYUK\ E_1 = 120\ V$, $E_2 = 6\ V$, $E_3 = 80\ V$ va ampermetr $8\ A$ tokni ko'rsatsa, tarmoq toklar $Kirxgof\ va\ Om$ qonunlariga asosan hisoblanib, quvvatlar balans tenglamasi tuzilsin.

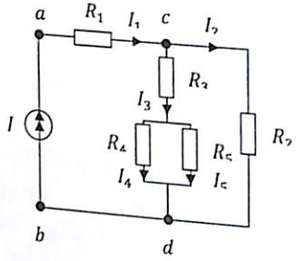


Javob: $I_1 = 21\ A$, $I_2 = 8\ A$, $I_4 = 13\ A$, $I_5 = 16\ A$, $P = 3112\ Wt.$

1.8-Masala. 1.6 masalada berilgan sxema parametri qiymati bo'yicha $U = 50\ V$ kuchlanishga ulangan. I_4 tarmoqdagi tok va sarf bo'ladigan quvvat aniqlansin.

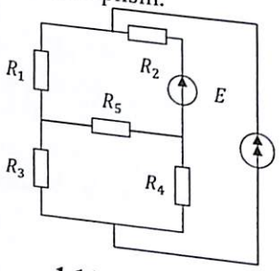
Javob: $P = 32{,}5\ Vt, I_4 = 290\ mA$

1.9-Masala. Zanjir qarshilik parametrlari $R_1 = 12\ om,\ R_2 = 10\ om,\ R_3 = 16\ om,\ R_4 = 40\ om,\ R_5 = 60\ om,$ bo'lib $J = 0{,}1\ A$ tok manbaiga ulangan. Tarmoq toklari, $U_{ab} - kuchlanish$ va sarf bo'ladigan elektr quvvat P –topilsin.



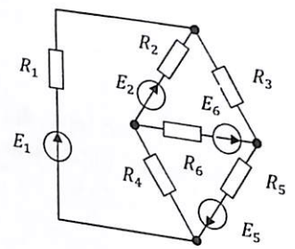
Javob: $I_2 = 0{,}08\ A \quad I_3 = 0{,}02\ A$
$I_4 = 0{,}012\ A\ I_5 = 0{,}008\ A$
$U_{ab} = 2\ V \quad P = 0{,}2\ Wt.$

1.10-Masala. Zanjir parametrlari: $J = 50\ mA,\ E = 60\ V,\ R_1 = 5\ kom, R_2 = 4\ kom,\ R_3 = 16\ kom,\ R_4 = 2\ kom,\ R_5 = 8\ kom.$ Konturli tok usulida tuzilgan tenglama asosida, matritsa usulida tarmoq toklari topilsin.



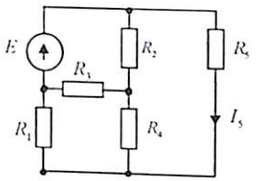
Javob: $I_1 = -30 \cdot 10^{-3} A,\ I_2 = 30 \cdot 10^{-3} A,$
$I_3 = -40 \cdot 10^{-3} A,\ I_4 = 40 \cdot 10^{-3} A,$
$I_5 = 10 \cdot 10^{-3} A,$

1.11-Masala. Zanjir uchun yo'naltirilgan grafik sxema tuzilib, konturli tok usuliga tuzilgan tenglamani matritsa usulida yechish bilan tarmoq toklari topilsin. Berilgan: $E_1 = 2\ V,\ E_2 = 12\ V,\ E_5 = 16\ V,$ $E_6 = 4\ V, R_1 = 8\ om, R_2 = 2\ om, R_3 = R_5 = 4\ om, R_4 = 1\ om,$ $R_6 = 5\ om.$



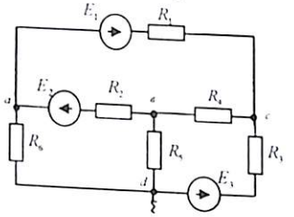
Javob: $I_1 = 1\ A,\ I_2 = 0,\ I_3 = 1\ A,$
$I_4 = 2\ A, I_5 = 1\ A,\ I_6 = 2\ A.$

1.12-Masala. Berilgan elektr sxemaning qarshilik parametri: $R_1 = 4Om,\ R_2 = 6\ Om, R_3 = 3\ Om, R_4 = 2\ Om, R_5 = 2{,}5\ Om.$ EYK $E = 24\ V$. Konturli tok va ekvivalent generator usuliga asosan beshinchi tarmoqdan o'tuvchi I_5 tok aniqlansin.



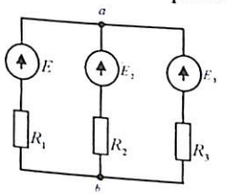
Javob: $I_5 = 2\ A$

1.13-Masala. Berilgan elektr zanjir qarshilik parametri: $R_1 = R_3 = R_6 = 3\ Om, R_2 = R_4 = R_5 = 1\ Om,$ EYK $E_1 = E_2 = E_3 = 48V$. Konturli tok va tugunlararo kuchlanish usuliga asosan tarmoqdagi tok aniqlansin.



Javob: $I_4 = 8\ A, I_1 = 5{,}33\ A,$
$I_2 = 8\ A, I_3 = 13{,}33\ A, I_5 = 0,$
$I_6 = 13{,}33\ A,$

1.14-Masala. Berilgan elektr sxemaning parametri: $E_1 = 40\ V, E_2 = 5V,\ E_3 = 30\ V, R_1 = 5\ Om, R_2 = 1\ Om, R_3 = 3\ Om.$ Ikkita tugun orasida potensiallar kuchlanishi va ustma-ustlik usuliga asosan tarmoqdagi tok aniqlansin.

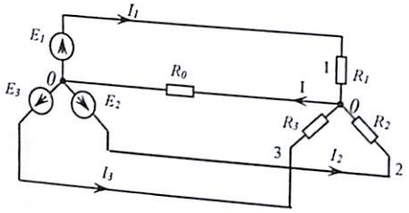


Javob: $I_1 = 5A,\ I_2 = 10\ A, I_3 = 5\ A$

1.15-Masala. Elektr isitgich $U = 220\ V$ kuchlanishga mo'ljallangan bo'lib, $P = 600\ Vt$ elektr sarflaydi. Agar shu elektr isitgich $U = 110\ V$ kuchlanishga ulanganda qancha quvvat sarflanadi.

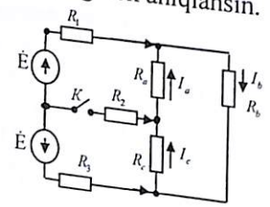
Javob: $P = 150\ Vt$

1.16-Masala. Berilgan sxema parametri: $R_1 = 1\ Om, R_0 = 10\ Om, R_2 = 2\ Om, R_3 = 4\ Om.\ E_1 = 20V, E_2 = 100\ V,\ E_3 = 80\ V$ bo'lganda, tugunlararo kuchlanish usuliga asosan tarmoqdagi tok aniqlansin.



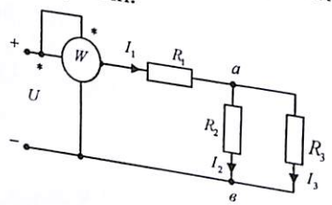
Javob: $I_1 = -3{,}4A,$
$I_2 = 2{,}3\ A, I_3 = 6{,}5\ A,$
$I_0 = 5{,}4\ A, U_{00'} = 54\ V$

1.17-Masala. Berilgan elektr zanjir parametri: $R_1 = R_2 = R_3 = 10\ Om, R_a = 25\ Om, R_b = 50\ Om, R_c = 50\ Om$ bo'lib, $E_1 = E_2 = 120\ V$ o'zgarmas tok manbaga ulangan. Kalit (K) ulangan holat uchun tarmoqdagi tok aniqlansin.



Javob: $I_a = 2{,}4\ A, I_b = -2{,}85\ A,$
$I_c = 1{,}65\ A$

1.18-Masala. Aralash sxemada ulangan elektr zanjir qarshilik parametri: $R_2 = 20\ Om, R_3 = 30\ Om$ bo'lib, $U = 625\ V$ kuchlanishga ulangan. Vattmetr ko'rsatishi $P = 32{,}25\ KVt$ bo'lgan holatda $R_1 -$ qarshilik, tarmoqdagi tok I_2, I_3 va R_2, R_3 qarshiliklarda sarf bo'ladigan quvvat aniqlansin.

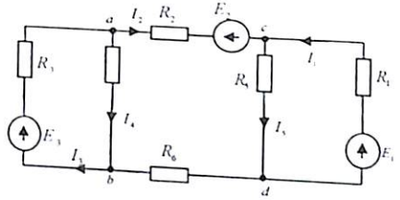


Javob: $I_2 = 3\ A, I_3 = 2\ A,$
$R_1 = 113\ Om, P_2 = 180\ Vt,$
$P_3 = 120\ Vt$

1.19-Masala. 1.16. masalada berilgan sxema sharti bo'yicha $I_1 = 2A, I_2 = -3\ A,\ I_3 = 2\ A$ (tok yo'nalishi strelka ko'rsatishiga mos) bo'lganda E_1 va E_2 manba kuchlanishlari aniqlansin.

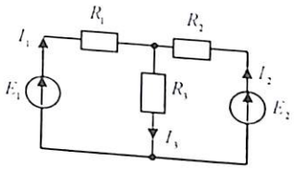
Javob: $E_1 = 100\ V, E_2 = -150\ V$

1.20-Masala. Berilgan elektr zanjirning parametri:
$R_1 = 6\ Om, R_2 = 2Om, R_3 = 2\ Om, R_4 = 6\ Om, R_5 = 2\ Om,$
$R_6 = 6\ Om$, EYK $E_1 = 80V, E_2 = 6\ V, E_3 = 120\ V$ bo'lib, birinchi tarmoq toki $I_1 = 8\ A$ ga teng. Om va Kirxgof qonunga asosan tarmoqdagi tok aniqlansin.



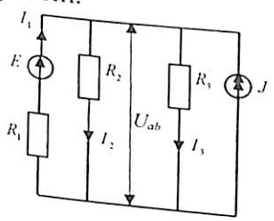
Javob: $I_2 = 8\ A, I_3 = 21\ A,$
$I_4 = 13\ A, I_5 = 16\ A$

1.21-Masala. Elektr zanjir parametri: $R_1 = R_2 = R_3 = 2\ om$, EYK $E_1 = 24V,\ E_2 = 18V$ bo'lganda, Kirxgof qonuni va ustma-ustlik usullariga asosan tarmoqdagi tok hamda sarf bo'ladigan elektr quvvat qiymati topilsin:



Javob: $I_1 = 5A, I_2 = 2A, I_3 = 7A$

1.22-Masala. Elektr zanjir manba qiymatlari: $E = 32\ V, J = 18\ A,$ qarshiligi $R_1 = 1\ Om,\ R_2 = 6\ Om,\ R_3 = 2\ Om$ ga teng. Konturli tok, tugun potensiali va ustma-ustlik usullariga asosan tarmoqdagi tok aniqlansin.

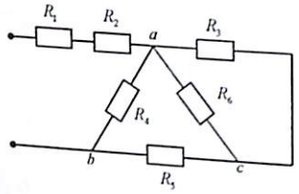


Javob: $I_1 = 2\ A,\ I_2 = 5\ A,\ I_3 = 15\ A.$

1.23-Masala. Elektr tok quvvati $P = 40\ Vt$ bo'lgan 10 ta lampochka har kuni 6 soat yonadi. 30 kun davomida sarf bo'ladigan elektr energiyasi aniqlanib, 1 kVt/soat energiya 135 so'm bo'lganda, bir oylik xarajat hisoblab topilsin.

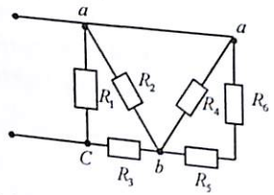
Javob: $W = 72\ kVt/soat,$ sarf puli: 9720 *so'm.*

1.24-Masala. Elektr zanjir qarshiligi $R_1 = R_2 = R_3 = R_5 = 5{,}5\ Om$, $R_4 = 12\ Om$, $R_6 = 3{,}25\ Om$ bo'lganda, umumiy qarshilik R_{um} aniqlansin.



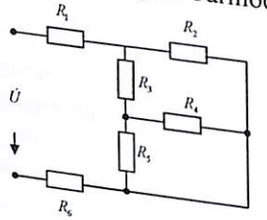
Javob: $R_{um} = 15\ Om.$

1.25-Masala. Elektr zanjir qarshi-ligi: $R_1 = R_4 = 60\ Om$, $R_2 = R_5 = 40\ Om$, $R_3 = 10\ Om$, $R_6 = 80\ Om$ bo'lganda, umumiy qarshilik $R_{(um)}$ aniqlansin.



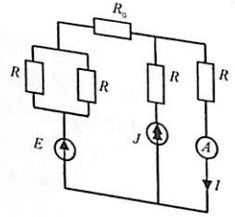
Javob: $R_{um} = 20\ Om.$

1.26-Masala. Elektr zanjir parametri $R_1 = R_6 = 4{,}5\ Om$, $R_2 = 22\ Om$, $R_3 = 7{,}6\ Om$, $R_4 = 24\ Om$, $R_5 = 36\ Om$ bo'lib, $U = 120\ V$ kuchlanishga ulangan. Tarmoqlardagi tokni aniqlang.



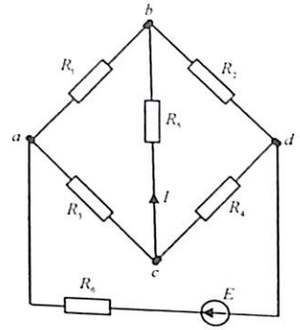
Javob: $I_1 = 6A$, $I_2 = I_3 = 3A$, $I_4 = 1{,}8A$, $I_5 = 1{,}2A$

1.27-Masala. Ekvivalent generator usuliga asosan, elektr zanjir parametri $R = 1\ Om$, $R_0 = 0{,}5\ Om$, $E = 1\ V$, $J = 1\ A$ bo'lganda ampremetr qancha tok ko'rsatadi?



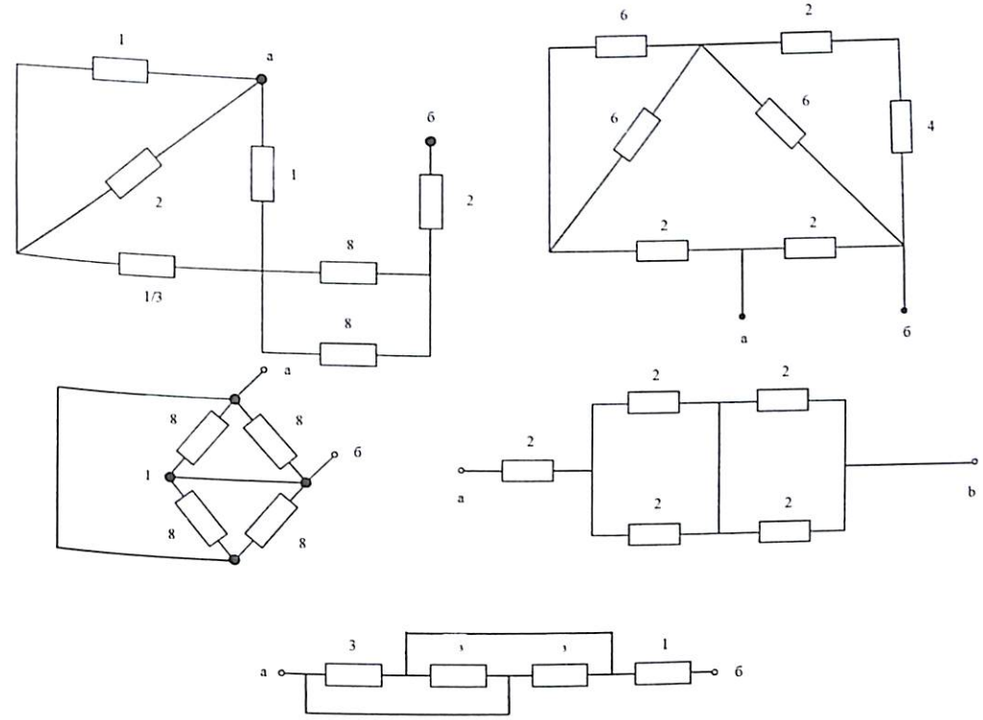
Javob: $I = 1\ A$

1.28-Masala. Ko'prik sxema parametri: $R_1 = 120Om$, $R_2 = 180Om$, $R_3 = 120Om$, $R_4 = 80Om$, $R_5 = 80Om$, $R_6 = 50Om$, EYK $E = 12\ V$. 5-tar-moqdagi tok I aniqlansin.



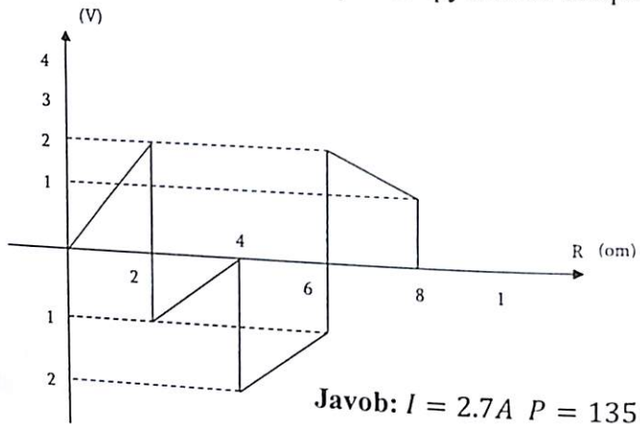
Javob: $I = -0{,}0084\ A$

1.29-Masala. Keltirilgan sxemalar uchun a-б potensialga nisbatan ekvivalent qarshilik topilsin.



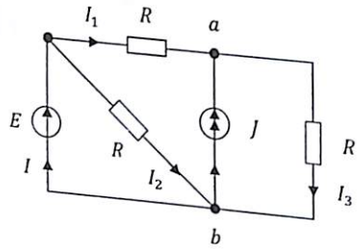
Javoblar: a) 6.5; b) 1.6; v) 2; c) 4; d) 2;

1.30-Masala. Keltirilgan potensial diagramma uchun ekvivalent elektr sxemasi tuzilib, tok va aktiv quvvat qiymatlari aniqlansin.



Javob: $I = 2.7A \;\; P = 135Wt$

1.31-Masala. Zanjir parametrlari: $E = 60\,V \quad J = 2\,A \quad R =$ 10 *om* bo'lganda ekvivalent o'xshashlik sxemasi chizilib, tarmoq toklari topilsin.



Javob: $I_1 = 4\,A, \quad I = 10\,A$

Nazorat savollari

1. Elektrotexnika fani nimani o'rgatadi?
2. O'zbekiston energetikasining rivojlanish tarixidan nimalarni bilasiz?
3. Elektr zanjir qanday qismlardan iborat?
4. O'zgarmas tok manbalarini bilasizmi?
5. EYK va tok manbai nima?
6. Elektr zanjir asosiy elementlari haqida ma'lumot bering.
7. Tarmoqlangan elektr zanjirlarni chizib, tarmoq, tugun, kontur nima ekanligini izohlab bering.
8. Elektr maydon kuchlanganligi nima?
9. Elektr sig'imni izohlab bering va o'lchov birligi nima?
10. Elektr maydonining kuch chiziqlari ekvipotensial sirtga nisbatan qanday yo'nalgan?
11. Sig'imi $C = 0,1\,mkF$ bo'lgan havoli kondensator qoplamalari orasidagi masofa $0,5\,mm$ ga teng bo'lsa, qoplamaning yuzasi (S) qancha bo'lishi kerak?
12. Kuchlanish $U = 1\,kV,$ sig'imi $C = 0,1\,mkF$ bo'lgan kondensatorda qancha miqdorda energiya to'planadi?
13. Kondensatorlarning ketma-ket yoki parallel sxemada ulanishidan maqsad nima?
14. Nuqtaviy zaryadlangan zarrachalarning o'zaro ta'sir kuchi qaysi qonunga asosan aniqlanadi?
15. Potensiallar farqi, kuchlanish nima va o'lchov birligi nimadan iborat?
16. Zanjirning bir qismi va butun zanjir uchun Om qonunini yozing.
17. Elektr zanjiri uchun Kirxgof qonunini ifodalab bering.
18. Elektr tok quvvati, (aktiv quvvat) qanday ifodalanadi va nimada o'lchanadi?
19. Elektr o'lchov asboblari: ampermetr, voltmetr va vattmetr elektr sxemaga qanday ulanadi?
20. Elektr manbai tashqi xarakteristikasini chizing va izoh bering. Qisqa tutashuv va salt holat deganda nimani tushunasiz?
21. Murakkab elektr zanjirni hisoblash usullariga izoh bering.
22. Potensial diagramma nima va u qanday chiziladi?
23. Quvvat balans tenglamasini yozing.

24. Qaysi holatda ekvivalent generator usulidan foydalanish qulay hisoblanadi va qanday amalga oshiriladi?

25. Aktiv va passiv ikki qutbli zanjir nima?

26. Elektr va magnit maydon energiyasi ifodasini yozing.

27. Ikkita potensialdan iborat bo‘lgan sxema uchun tugunlararo usuliga asosan tenglama tuzing.

28. Ustma-ustlik usulini izohlab bering.

29. Yulduzchadan uchburchakga o‘tish va aksincha holat almashtirish formulasini yozing.

30. Ikki qutbli liniyadan iste’molchiga maksimal quvvat uzatish shartini tushuntiring va tenglamasini yozing.

31. Aktiv qarshilik yoki o‘tkazuvchanlik qanday ifodalanadi?

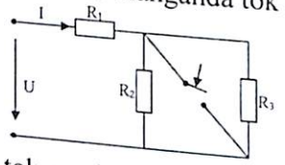
32. Manbaning ichki qarshiligi deganda nimani tushunasiz?

33. Elektr tok energiyasi bajargan ish tenglamasi qanday ifodalanadi?

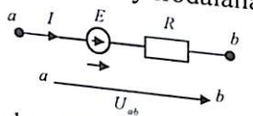
34. Kuchlanishi $24\,V$ bo‘lgan manbaga ikkita qarshilik – $R_1 = 20\,Om$; $R_2 = 28\,Om$ ketma-ket ulangan. Tok necha amperga teng?

35. Ikkita qarshiligi bo‘lgan tok zanjiri parallel ulanganda, umumiy qarshiligini ifodalang.

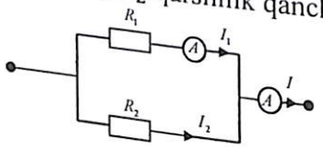
36. Parallel zanjirda K – kalit ulanganda tok qanday o‘zgaradi?



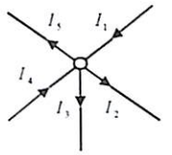
37. Ushbu sxemada tok qanday ifodalanadi?



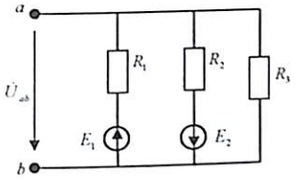
38. Parallel sxemada ulangan zanjirdagi tok $I_1 = 5\,A$, $I = 8\,A$ qarshiligi $R_1 = 3\,Om$ bo‘lganda, R_2 qarshilik qanchaga teng?



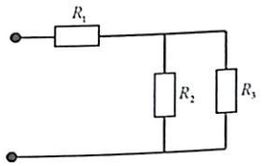
39. Tugun uchun Kirxgof 1-qonuniga asosan tenglama tuzing.



40. Parallel zanjir uchun ekvivalent kuchlanish ifodasiga asosan ekvivalent tok manbai sxemasi chizilsin .



41. Aralash sxemada ulangan zanjir qarshiligi $R_1 = 10\,Om, R_2 = R_3 = 4\,Om$ bo‘lib, $U = 40\,V$ kuchlanishga ulanganda qancha aktiv quvvat sarflanadi?



42. Elektr quvvati $P = 600\,VT$ bo‘lgan issiqlik manbai (pechka) 5 soat davomida qancha elektr energiya sarflaydi?

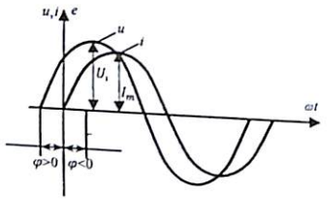
2. SINUSOIDAL TOK ELEKTR ZANJIR

2.1. Asosiy nazariy tushunchalar

Sinusoidal davriy o‘zgaruvchan tok, kuchlanishi va EYK oniy qiymati quyidagi funksiya ko‘rinishda ifodalanadi.

$$i = I_m \sin(\omega t + \varphi_i);\quad u = U_m \sin(\omega t + \varphi_u);$$
$$e = E_m \sin(\omega t + \varphi_u) \qquad (2.1)$$

Grafik ifodasi:



Bunda: $\varphi = \varphi_u - \varphi_i$ – faza farqi

i – sinusoidal o‘zgaruvchan tokning oniy qiymati

I_m – amplituda, yoki maksimal qiymat

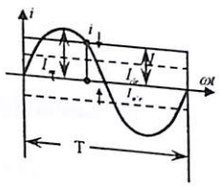
φ_i –boshlang‘ich faza $(grad)$

ω – burchak chastota (rad/sek)

f – chastota (Gs)

T – davr (sek)

Sinusoidal o‘zgaruvchan tokning effektiv yoki ta’sir etuvchi qiymati:



$$I = \sqrt{\frac{1}{T}\int_0^T i^2 dt} = \frac{I_m}{\sqrt{2}} \qquad (2.2)$$

Sinusoidal o‘zgaruvchan tokning yarim davrdagi o‘rtacha qiymati:

$$I_{ur} = \sqrt{\frac{2}{T}\int_0^{\frac{T}{2}} i^2 dt} = \frac{2}{\pi} I_m \qquad (2.3)$$

Sinusoidal o‘zgaruvchan tokning forma va amplituda koeffitsienti:

$$K_f = \frac{I}{I_{o'r}};\quad K_a = \frac{I_m}{I}; \qquad (2.4)$$

Sinusoidal o‘zgaruvchan elektr zanjir uchun Om qonuni:

$$I = \frac{U}{z} = \text{Uy}\,(A); \qquad (2.5)$$

yoki burchak koeffitsientlari: $\cos\varphi = \frac{R}{z} = \frac{g}{y}$; $\sin\varphi = \frac{x}{y} = \frac{b}{y}$;

$$\text{tg}\varphi = \frac{x}{R} = \frac{b}{g};\quad \varphi = \text{arcctg}\frac{x}{y} = \frac{b}{g}; \qquad (2.6)$$

To‘la qarshilik: $Z = \sqrt{R^2 + x^2}\ (Om);$ (2.7)

Ketma-ket ulangan R – aktiv; L – induktiv; C – sig‘im qarshiliklar bo‘lganda, reaktiv qarshilik:

$$X = X_L - X_C = \omega L - \frac{1}{\omega c}\ (Om) \qquad (2.8)$$

Elektr zanjir induktiv xarakterga ega bo‘lganda: $\omega L > \frac{1}{\omega c}$; $\varphi > 0$

Sig‘im xarakterga ega bo‘lsa: $\omega L < \frac{1}{\omega c}$; $\varphi < 0$.

Agarda $\omega L = \frac{1}{\omega c}$ bo’lib $x = 0$ bo‘lsa rezonans holat yuzga keladi

Parallel zanjirning to‘la o‘tkazuvchanligi:

$$y = \sqrt{g^2 + b^2} \text{ bunda } g = \frac{1}{R}; b = b_L - b_C = \frac{1}{x_L} - \frac{1}{x_C}; \qquad (2.9)$$

Ekvivalent parametr o‘xshashlik tenglamalari:

$$g = \frac{R}{z^2}\quad b = \frac{x}{z^2}\quad y = \frac{1}{z}; \qquad (2.10)$$

$$R = \frac{g}{y^2};\quad x = \frac{b}{y^2};\quad z = \frac{1}{y}; \qquad (2.11)$$

Iste’molchi ketma-ket ulangan elektr zanjirlarda ekvivalent qarshilik:

$$R_e = \sum_{k=1}^{n} R_n;\quad X_e = \sum_{k=1}^{n} X_n;\ Z_e = \sum_{k=1}^{n} Z_n \qquad (2.12)$$

Parallel ulangan holda:

$$g_e = \sum_{k=1}^{n} g_n;\quad b_e = \sum_{k=1}^{n} b_n;\ y = \sum_{k=1}^{n} y_n \qquad (2.13)$$

Tok va kuchlanishning aktiv va reaktiv tashkil etuvchilari:

$$U_a = IR = U\cos\varphi;\quad I_a = Ug = I\cos\varphi;$$
$$U_p = I \cdot x = U\sin\varphi;\quad I_p = U \cdot b = I\sin\varphi; \qquad (2.14)$$
$$U = \sqrt{Ua^2 + Up^2};\quad I = \sqrt{Ia^2 + Ip^2};$$

1. Sinusoidal o‘zgaruvchan tokning quvvat ifodasi:

Sinusoidal o‘zgaruvchan tokning oniy quvvati:

$$P = ui[\cos\varphi - cos(2\omega t - \varphi)] \qquad (2.15)$$

Aktiv quvvat:

$$P = U_l \cos\varphi = I_2 R = U_2 g = U I_a = U_a I[Vt, kVt] \qquad (2.16)$$

Reaktiv quvvat:

$$Q = U_I \sin\varphi = I_2 x = U_2 b = U\, I_p = U_p I [Var, kVar] \quad (2.17)$$

To‘la quvvat:

$$S = \sqrt{P^2 + Q^2} = UI = I^2 Z = U^2 y\ [Va, kVa] \quad (2.18)$$

2. Sinusoidal o‘zgaruvchan tok, kuchlanish va EYK:

Faza farqi: $\varphi = \varphi_u - \varphi_i$ (2.19)

3. Sinusoidal o‘zgaruvchan tokning vektor ifodasi yoki vektor diagrammasini tuzishda quyidagilarga e’tibor berish zarur:

a) aktiv qarshilikda tok va kuchlanish vektori ustma-ust tushadi ($\varphi = 0$);

b) induktivlikda kuchlanish vektori $\bar{U}$, tok vektori $\bar{I}$ ga nisbatan 90°farq qilib, oldinga ketadi ($\varphi > 0$);

d) sig‘im qarshilikda kuchlanish $\bar{U}, \bar{I}$ tok vektoriga nisbatan 90° orqada qoladi ($\varphi < 0$).

e) elektromagnit induksiya (o‘z induksiya, o‘zaro induksiya) qonuniga asosan induktivlikda, o‘zgaruvchan tok hosil qiluvchi elektr yurituvchi kuch vektori $\bar{E}$, magnit oqim vektori ϕ nisbatan 90°farq qilib, orqada qoladi ($\varphi = -90°$).

f) induktivlik kuchlanish $\bar{U}_L$ vektoriga nisbatan EYK vektori $\bar{E}$ 180°farq qilib, teng va qarama-qarshi yo‘nalishda ifodalanadi. $\bar{E} = -\bar{U}_L$

2.2. Masalalar yechish va uslubiy ko‘rsatmalar

2.1-Masala. O‘zgaruvchan magnit oqimi $\Phi = 0{,}01 sin 314t\ (vb)$ bo‘lib, chulg’amlar soni $W = 50$ bo‘lganda g‘altak aylanma harakatlanishi natijasida hosil bo‘ladigan EYKni aniqlang.

Yechish.

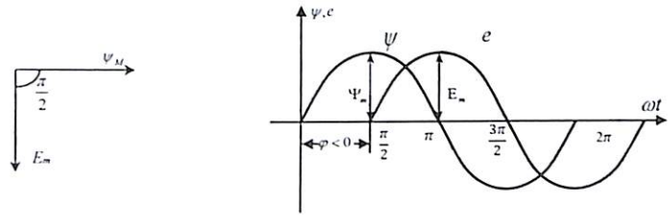
G‘altakning **ilashgan magnit oqimi:** $\psi = \omega\phi = 0{,}5 \sin 314t = \psi_m \sin t$

O‘zinduksiya qonuniga asosan:

$$e = -\frac{d\psi}{dt} = \omega\psi_m \cos\omega t = E_m \sin(\omega t - 90°)$$ yoki: $E_m = \omega\psi_m = 157\ (V)$

EYK effektiv qiymati: $E = \frac{E_m}{\sqrt{2}} = 90\ (V)$

Vektor ifodasi va vaqt bo‘yicha o‘zgaruvchan grafigini chizamiz



2.2-Masala. O‘ramlar soni $W = 20$, yuzasi $S = 100(sm^2)$ bo‘lgan halqa, magnit induksiyasi $B = 2\ (vb/m)$ teng bo‘lgan magnit maydon ichida $n = 6000\ (ayl/min)$ tezlik bilan aylanganda, halqada hosil bo‘ladigan magnit oqim, oniy qiymat, EYK amplitudasi, davri va chastotasi aniqlanib, vektor ifodasi va vaqtga nisbatan o‘zgaruvchan diagrammasi tuzilsin.

Yechish. Halqaning boshlang‘ich holati $\alpha = 0, \alpha = \omega t$ bo‘lib, halqa aylanishi natijasida kesib o‘tuvchi magnit oqimning oniy qiymati:

$$\Phi = BS\cos\alpha = \Phi_m \cos\omega t$$

$$f = \frac{Pn}{60} = \frac{1\cdot 6000}{60} = 100\ Hz$$

Halqada hosil bo‘ladigan ilashgan magnit oqim oniy qiymati:

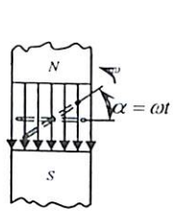
$$\psi = \Phi W = W\Phi_m \cos\omega t = WBS\cos\omega\, t = \psi_m \cos\omega\, t = 20\cdot 2\cdot 100\cdot 10^{-4}\cos 628t = 0{,}4 sin(628t + 90°)$$

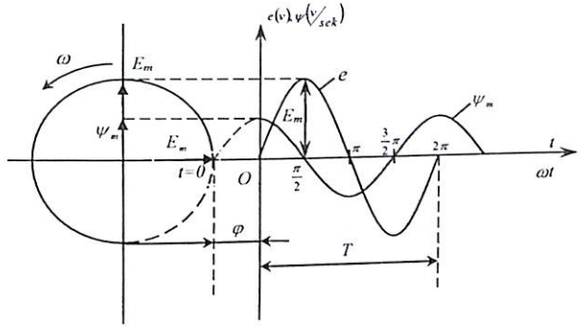
Bunda:

$$\omega = \frac{2\pi\tau}{60} = \frac{2\cdot 3146000}{60} = 628\left(\frac{1}{sek}\right)$$ - burchak chastota

Halqada hosil bo‘ladigan EYK oniy qiymati:

$$e = -\frac{d\psi_m}{dt} = -\frac{d}{dt}(\psi_m \cos\omega t) = \omega\psi_m \sin\omega\, t = E_m \sin\omega t = 251{,}2 \sin 628t$$





Halqa T davrda bir marotaba aylanadi: $\omega T = 2\pi$

Bundan: $T = \frac{2\pi}{\omega} = 0{,}01\ (sek)$

O‘zgaruvchan tok chastotasi: $f = \frac{1}{T} = \frac{1}{0{,}01} = 100(Gs)$

Vektor ifodasi va davriy o’zgaruvchan EYuK grafigi chizmada keltirilgan.

2.3-Masala. O‘ramlar soni ψ bo‘lgan aylanma harakatlanuvchi g‘altakda induksiyalangan EYK to‘g‘ri burchakli impulsli formaga ega bo‘lib, EYK amplitudasi: $E_m = 10\ (V)$ va $f = 50\ (Gs)$ ga teng. EYK E o‘rtacha va effektiv qiymati, amplituda va forma koeffitsienti hamda magnit oqimi qiymatini aniqlang.

Yechish. EYK o‘rta chaqiymati:

$$E_{o'r} = \frac{2}{T}\int_0^{\frac{T}{2}} edt = \frac{2}{T}E_m\ \frac{T}{2} = E_m = 10\ (V)$$

Effektiv qiymat: $\mathrm{E} = \sqrt{\frac{1}{T}\int_0^T e^2 dt} = \sqrt{\frac{1}{T}E_m^2 T} = E_m = 10\ (V)$

Amplituda va forma koeffitsienti: $\mathrm{K_a} = \frac{E_m}{E} = 1$, $\mathrm{K_\phi} = \frac{E}{E_{o'r}} = 1$

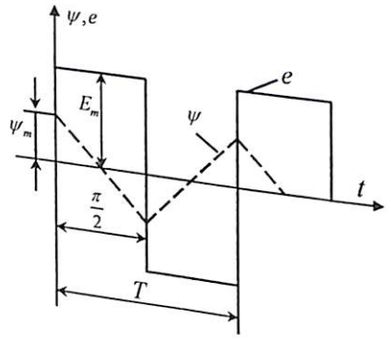
O‘zinduksiya qonuniga asosan: $\psi = -\int edt$

Keltirilgan funksiyada ψ to‘g‘ri burchakli uchburchak shaklida o‘zgaruvchan bo‘lib, $T = 0{,}02\ sek = 20\ m\ sek$ teng, yoki:

$$E_{ur} = \frac{\Delta\psi}{\Delta t}$$

Bundan $\Delta\psi = E_{o'r}\Delta t$ hamda $\Delta\psi = 2\psi_m$, $\Delta t = \frac{T}{2}$ bo‘lganligi uchun g‘altakdagi magnit oqim ψ qiymati:

$$\psi_m = \frac{1}{2}\Delta\psi = \frac{1}{2}E_{o'r}\frac{T}{2} = \frac{1}{2}\cdot 10\cdot\frac{0.02}{2} = 0.05\ vb = 50(mVb)$$



2.4-Masala. Elektr o‘lchov asboblari yordamida aktiv va induktiv qarishilik bo‘lgan elektr zanjirining kuchlanish, tok va chastotasi: $U_R = 20\ V, U_L = 30\ V,\ I = 5\ A, f = 50\ gs$ bo‘lganda, umumiy kuchlanish, parametrlari, quvvat va magnit maydon energiyasi aniqlansin.

Yechish. (2. 14)tenglamaga asosan:

$$U = \sqrt{U^2{}_R + U^2{}_L} = \sqrt{400 + 900} = \sqrt{1300} = 36\ V$$

Umumiy qarshilik: $\mathrm{Z} = \frac{U}{I} = \frac{36}{5} = 7{,}2\ \mathrm{Om}$

Aktiv qarshilik: $\mathrm{R} = \frac{U_R}{I} = \frac{20}{5{,}2} = 4\ \mathrm{Om}.$

Induktiv (reaktiv) qarshilik: $\mathrm{X}_L = \frac{U_L}{I} = \frac{30}{5} = 6\ \mathrm{Om}$

(2. 6) tenglamaga asosan:

$$\cos\varphi = \frac{R}{Z} = \frac{4}{7{,}2} = 0{,}55;\ \sin\varphi = \frac{X}{Z} = \frac{6}{7{,}2} = 0{,}8$$

(2.16, 2.18) tenglamalarga asosan:

Aktiv quvvat: $\mathrm{P} = I^2R = UI\cos\varphi = 25\cdot 4 = 100\ Vt$

Reaktiv quvvat: $Q_L = I^2X_L = UI\sin\varphi = 25\cdot 6 = 150\ VAR$

To‘la quvvat: $S = UI = I^2Z = \sqrt{P^2 + Q^2} = 36\cdot 7{,}2 = 260\ VA$

Induktivlik: $L = \frac{X_L}{\omega} = \frac{6}{314} = 0{,}18GN = 18MGN$

Magnit maydon energiyasi:

$$\mathrm{W}_M = \frac{LI^2}{2} = \frac{25\cdot 18\cdot 10^{-3}}{2} = 225\cdot 10^{-3} = 0.225\cdot DJ$$

2.5-Masala. Sinusoidal o‘zgaruvchan elektr kuchlanish $u = 120\sin 1000t$ bo‘lgan generatorga induktiv qarshilik ulangan bo‘lib, sinusoidal tok o‘tadi: $i = 8\sin(1000t - 53°)$.

O‘zgaruvchan kuchlanish chastotasi ikki martaga kamayganda: induktiv g‘altakning aktiv qarshiligi, induktivligi, tok qiymati va faza burchagi aniqlansin.

Yechish. Masalaning sharti bo‘yicha umumiy qarshilik:

$Z = \frac{U_m}{I_m} = 15\ (\mathrm{Om})$ bo‘lib, faza burchagi $\varphi = \varphi_u - \varphi_i = 53°$

Qarshilik uchburchak ifodaga asosan:

$$R = Z\cos\varphi = 15\cos 53° = 9\ (Om)$$

$$X = Z\sin\varphi = 15\sin 53° = 12\ (Om)$$

Induktivlik: $L = \frac{x_L}{\omega} = \frac{12}{1000} = 0{,}012\ gn = 12\ (mGn)$

Kuchlanish chastotasi ikki martaga kamaytirilgan holda induktiv qarshilik ham ikki martaga kamayadi: $x_L' = 6\ Om$

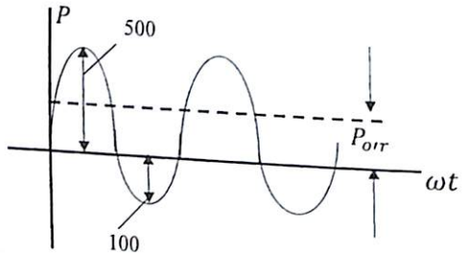
Faza farqi: $\varphi' = arctg\ \frac{x_L'}{R} = \frac{6}{9} = 33°40'$

To'la qarshilik: $Z' = \frac{x_L'}{sin\varphi'} = 10{,}8\ (Om)$

Tok amplitudasi: $I_m' = \frac{U_m}{z'} = 11{,}09\ (A)$

Tokning oniy qiymati: $i = 11{,}09\sin(500t - 33°40')$

2.6-Masala. Oniy quvvat grafigidan passiv ikki qutubli zanjir aktiv quvvati va $\cos\varphi$ burchagini toping.

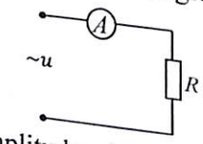


Yechish: Keltirilgan grafikdan $P = P_{o'r} = \frac{500-100}{2} = 200\ BT$

Bunda to'la quvvat: $S = \frac{500+100}{2} = 300\ BA$

Demak quvvat koeffitsenti: $\cos\varphi\ \frac{P}{S} = \frac{200}{300} = 0.67$

2.7.Masala. O'zgaruvchan tok kuchlanishi $u = 283\sin t$ bo'lgan generatorga, aktiv qarshiligi $R = 10(Om)$ reostat ulangan. Reostatdan o'tuvchi tokning effektiv oniy qiymati va o'rtacha quvvat qiymati aniqlanib, vaqt bo'yicha o'zgaruvchan diagrammasi chizilsin.



Yechish. Tokning amplituda qiymati: $I_m = \frac{U_m}{R} = \frac{283}{10} = 28{,}3$ (A);

effektiv qiymati: $I = \frac{I_m}{\sqrt{2}} = 20\ (A)$

Oniy qiymati: $i = I_m\sin\omega t = 28{,}3\sin 314t$

Aktiv quvvatning o'rtacha qiymati:

$$P_{o'r} = \frac{1}{T}\int_0^T Pdt = UI = I^2R = 4000\ VT = 4\ (kVt)$$

Quvvatning oniy qiymati:

$$P = iu = UI + ui\sin(\omega t - 90) = [4 + 4\sin(\omega t - 90)]\ (kVt)$$

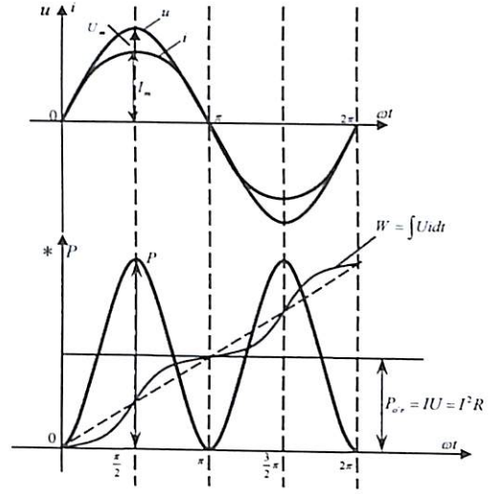
Elektr energiyasining oniy qiymati:

$$W = \int Pdt = uit - \frac{UI}{2\omega}\sin 2\omega t = 4000t - \frac{4000}{2\cdot 314}\sin\omega t = (4000 - 6{,}37\sin 2\omega t)\ (J)$$

Demak Djoul-Lens qonuniga asosan aktiv qarshilik (reostatda)da o'zgaruvchan elektr tok energiyasi issiqlik energiyasi ajralib sarf bo'ladi.

Aktiv quvvat vaqt bo'yicha o'zgaruvchan diagrammasi chizmada keltirilgan.

Bunda tok va kuchlanish orasidagi burchak $\varphi = 0$ bo'lib, I_m va U_m vektor ifodasi ustma-ust tushadi.



2.8-Masala. Tok va kuchlanish oniy qiymatlari $u = 141\sin(314t + 60^0)$ $i = 14.1\sin 314t$ bo'lganda, quydagi qiymatlar topilsin: φ – faza farqi, f – chastota, Z – to'la qarshilik, R – aktiv qarshilik, X – reaktiv qarshilik, $\tilde{S}$ – to'la quvvat, P – aktiv quvvat, Q –reaktiv quvvat.

Yechish: To'la qarshilik: $Z = \frac{U}{I} = \frac{\frac{141}{\sqrt{2}}}{\frac{14.1}{\sqrt{2}}} = 10\ om$

Faza farqi : $\varphi = \varphi_u - \varphi_i = 60^0$

Chastota: $f = \frac{\omega}{2\pi} = \frac{314}{6.28} = 50\ Gs$

Aktiv qarshilik: $R = Z\cos\varphi = 10\cos 60^0 = 10\cdot\frac{1}{2} = 5\ om$

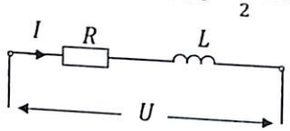
Reaktiv qarshilik: $X = Z\sin\varphi = 10\sin 60^0 = 10\cdot\frac{\sqrt{3}}{2} = 5\sqrt{3}\ om$

To'la quvvat: $\tilde{S} = UI = I^2\cdot Z = 100\cdot 10 = 1000\ Wt = 1\ kWt$

Aktiv quvvat: $P = \tilde{S}\cos\varphi = 1000\cos 60^0 = 1000\cdot\frac{1}{2} = 500\ Wt$

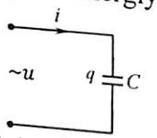
Reaktiv quvvat:

$Q = S\sin\varphi = 1000\sin 60^0 = 1000\cdot\frac{\sqrt{3}}{2} = 500\sqrt{3}\ VAR$



Demak zanjir ekvivalent sxemasi R,L zanjirdan iborat ekan.

2.9-Masala. Sig'imi $C = 41{,}6(mkf)$ bo'lgan kondensator $U_m = 120sin(314\pi + \frac{\pi}{4})$ kuchlanishga ulangan. Sig'imdagi tok i, zaryadi q, quvvat P_c va elektr maydon energiyasi W_e aniqlansin.



Yechish. Sig'im qarshiligini aniqlaymiz:

$$X_c = \frac{1}{\omega C} = \frac{1}{314\cdot 41{,}6\cdot 10^{-6}} = 76{,}6\ Om$$

Tokning amplituda qiymati: $I_m = \frac{U_m}{x_c} = 1{,}57\ (A)$

Tok va kuchlanish orasidagi faza farqi: $\varphi = \varphi_U + \varphi_i = \frac{\pi}{4} + \frac{\pi}{2} = \frac{3}{4}\pi$

Tokning oniy qiymati: $i = 1{,}57\sin(314t + \frac{3}{4}\pi)\ (A)$

Sig'imdagi zaryadning oniy qiymati:

$q = CU_m = 41{,}6\cdot 10^{-6}\cdot 120\sin\left(314t + \frac{\pi}{4}\right) = 5\sin(314t + \frac{\pi}{4})\ (kulon)$

Quvvatning oniy qiymati:

$P_c = U_m I_m[\cos\varphi - \cos(2\omega t + 2\varphi_c - \varphi) = -ui\cos 2\omega t$

Bunda: $\varphi = -\frac{\pi}{2}$ va $\varphi_U = \frac{\pi}{4}$ bo'lganligi uchun:

$$P = \frac{120\cdot 4{,}57}{2}\cos 2\omega t = 93{,}2\cos 2\omega t\ \ (Vt)$$

Sig'imda hosil bo'ladigan elektr maydon energiyasi:

$W_e = \frac{CU_m^2}{2} = \frac{1}{2}\cdot 41.6\cdot 10^{-6}\cdot 120^2 sin^2\left(3{,}14t + \frac{\pi}{4}\right) = 0.15(1 + sin628t)\ (Dj)$

2.10-Masala. Induktivligi $L = 0{,}27\ (Gn)$, aktiv qarshiligi $R = 49\ (Om)$ bo'lgan reaktiv g'altak, sinusoidal o'zgaruvchan tok chastotasi $f = 50(Gs), U = 220\ V$ kuchlanishga ulangan. Tokning effektiv qiymati I, tok va kuchlanish orasidagi burchak φ aniqlanib vektor ifodasi tuzilsin.

Yechish. Om qonuniga asosan:

$$I = \frac{U}{z} = \frac{220}{\sqrt{R^2+(\omega L)^2}} = \frac{220}{\sqrt{49^2+(314\cdot 0{,}27)^2}} = 2{,}24\ A$$

Bunda: $\omega = 2\pi f = 314\cdot 2\cdot 50 = 314\ (rad/sek)$

Burchak fazasi: $\varphi = arctg\frac{x}{R} = \frac{100}{49} = 2 = 60°$

yoki fazadagi farq: $\varphi = \varphi_u - \varphi_i = 0 - 60°$

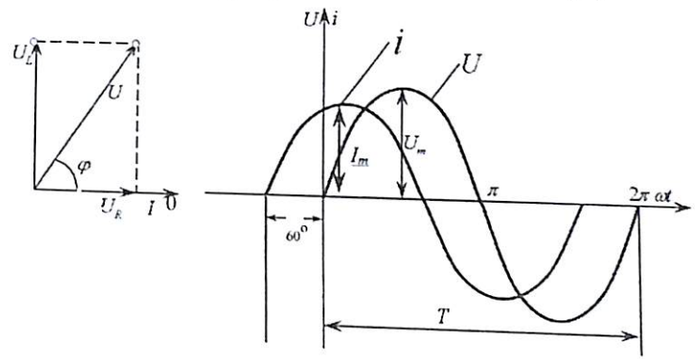
Tokning oniy qiymati: $i = \sqrt{2}\ I = 3{,}16sin(\omega t - 60°)\ (A)$

Kuchlanish oniy qiymati: $u = \sqrt{2}U = 310\sin\omega t\ \ (V)$

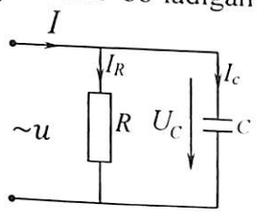
Masshtab tanlab, tok va kuchlanish vektor ifodasini hamda vaqt bo'yicha o'zgaruvchan diagrammasini tuzamiz.

Bunda R va x_L qarshilikdagi kuchlanish:

$$U_R = IR = 2{,}24\cdot 49 = 115(V);$$
$$U_L = I_L\ X_L = 2{,}24\cdot 100 = 224(V)$$



2.11-Masala. Parallel sxemada ulangan elektr zanjir kuchlanishi $U = 150\ (V), I = 5(A), I_R = 3(A)$ va chastotasi $f = 50\ (Gs)$ ga teng. Sig'im parametri C, hamda zanjirda sarf bo'ladigan to'la quvvat aniqlansin.



Yechish. Pifagor teoremasiga asosan tok uchburchak vektor ifodasidan: $I_C^2 = I^2 - I_R^2 = \sqrt{25-9} = 4\ (A)$

Sig'imdagi kuchlanish: $U_C = U = 150\ V$

Sig'im parametri: $C = \frac{I_C}{U_C \omega} = \frac{4}{150 \cdot 314} = 85\ (mkF)$

Elektr zanjir to'la quvvati: $S = UI = 150 \cdot 5 = 750\ (VA)$

Aktiv qarshilik quvvati: $P = UI_R = 150 \cdot 3 = 450\ (Vt)$

Sig'im qarshilik reaktiv quvvati:

$$Q_C = \sqrt{S^2 - P^2} = \sqrt{750^2 - 450^2} = 600\ (Var)$$

2.12-Masala. O'zgaruvchan tok chastotasi $f = 500\ (Gs)$ bo'lgan elektr zanjirda induktivligi $L = 5(MGn)$, tok $I = 10(A)$ bo'lib, $P = 1(KVT)$ quvvat sarflanadi.Umumiy kuchlanish U va quvvat koeffitsienti $\cos\varphi$ aniqlansin.

Yechish. Aktiv quvvat tenglamasidan: $P = I^2 R$

$$R = \frac{P}{I^2} = \frac{1000}{10} = 100\ (Om)$$

G'altak to'la qarshiligi:

$Z_k = \sqrt{R^2 + (\omega L)^2} = \sqrt{100^2 + (6{,}28 \cdot 500 \cdot 5 \cdot 10^{-3})^2} = 18{,}6\ (Om)$

Kuchlanish: $U = IZ_k = 10 \cdot 18{,}6 = 186\ (V)$

Quvvat koeffitsienti: $\cos\varphi = \frac{P}{S} = \frac{1000}{IU} = \frac{1000}{186 \cdot 10} = 0{,}54$

2.13-Masala. Kuchlanish $u = 283 sin 500t$ bo'lgan generatorga parametr $L = 0{,}016\ Gn\ Gn, R = 6\ Om$ bo'lgan induktiv g'altak ulangan bo'lib, shu g'altakdan oqib o'tuvchi tokning oniy qiymati kuchlanishi (U_a, U_p), to'la quvvat aniqlanib, kuchlanish uchburchak vektor ifodasi chizilsin.

Yechish. Induktiv qarshilik: $X_L = \omega L = 500 \cdot 0{,}016 = 8\ Om$

Fazadagi farq: $\varphi = arctg\frac{x}{R} = \frac{8}{6} = 53°,\ \varphi = \varphi_U - \varphi_i = -53°$

To'la qarshilik: $Z = \sqrt{R^2 + x^2} = \sqrt{6^2 + 8^2} = 10\ (Om)$

Tok amplitudasi: $I_m = \frac{U_m}{z} = \frac{283}{10} = 28{,}3\ (A)$

Oniy qiymat: $i_m = 28{,}3 \sin(500t - 53°)$

Aktiv va reaktiv kuchlanish:

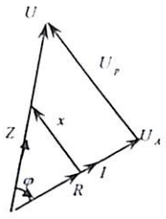
$U_{ma} = U_m \cos\varphi = 170\ (V)\ U_{mp} = U_M \sin\varphi = 226\ (V)$

To'la quvvat: $S = UI = \frac{U_m}{\sqrt{2}} \cdot \frac{I_m}{\sqrt{2}} = 400\ Vt = 4\ (kVt)$

Aktiv quvvat: $P = S\cos\varphi = 4 \cdot 0{,}6 = 2{,}4\ (kVt)$

Reaktiv quvvat: $Q = S \sin\varphi = 4 \cdot 0{,}8 = 3{,}2\ (kVar)$

Vektor ifodasini chizamiz.



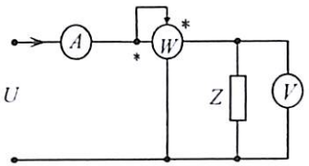
Aktiv qarshilikdagi kuchlanish vektori (U_a) tok vektori bilan ustma-ust tushadi, shu sababli $\varphi_{ua} = -53°$ ga teng.

U_P – kuchlanish esa tok vektoriga nisbatan 90° farq qilib $\varphi_{Up} = 37°$ga teng.

Ya'ni: $U_a = 170 \sin(500t - 53°)\ V$,

$U_p = 226 \sin(500t - 37°)\ V$

2.14-Masala. Berilgan elektr elektr zanjirga ulangan elektr asboblarida: ampermetr toki $I = 20\ A$, voltmetrdagi kuchlanish $U = 100\ V$ va vattmetr quvvati $P = 1200\ Vt$ ga teng. Elektr zanjir induktiv $(\varphi > 0)$ xarakterga ega bo'lgan holat uchun o'xshashlik ekvivalent sxemasi tuzilib, qarshilik parametri aniqlansin hamda uchburchak vektor ifodasi tuzilsin.



Yechish. To'la qarshilik: $Z = \frac{U}{I} = 5\ (Om)$

Aktiv qarshilik: $R = \frac{P}{I^2} = \frac{1200}{20^2} = 3\ (Om)$

Induktiv qarshilik: $x_L = \sqrt{z^2 - R^2} = 4\ (Om)$

Aktiv qarshilik kuchlanishi: $U_R = U_a = IR = 60\ (V)$

Induktivlik reaktiv kuchlanishi: $U_L = U_P = Ix_L = 80\ (V)$

Aktiv o'tkazuvchanlik (2.10) ifodaga asosan: $g = \frac{R}{z^2} = 0{,}12\ (\frac{1}{Om})$

Induktiv o'tkazuvchanlik: $b_L = \frac{x_L}{z^2} = 0{,}16\ (\frac{1}{Om})$

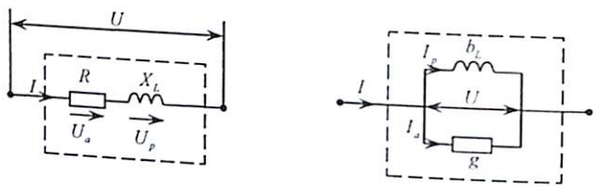
To'la o'tkazuvchanlik:

$y = \frac{1}{z} = \sqrt{g^2 + b_L^2} = 0{,}2\ (\frac{1}{Om})$

Elektr o'lchov asboblari ko'rsatgan qiymatlari bo'yicha:

$g = \frac{P}{U_2} = 0{,}12\ (\frac{1}{Om});\ y = \frac{I}{U} = 0{,}2\ (\frac{1}{Om});\ b_L = \sqrt{y^2 - g^2} = 0{,}16\ (\frac{1}{Om})$

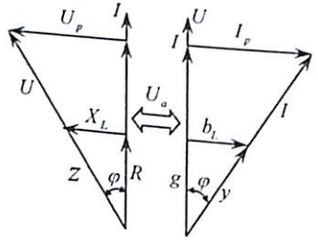
Aniqlangan qiymatlar asosida ekvivalent o‘xshashlik sxemasini chizamiz.



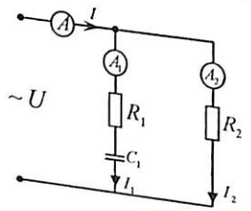
Bundan aktiv qarshilikdagi tok: $I_R = I_a = U_g = 12\ (A)$

Induktivlikdagi reaktiv tok: $I_L = I_P = U_{b_L} = 16\ (A)$

Qarshilik va o‘tkazuvchanlik, tok va kuchlanish ekvivalent (o‘xshashlik) vektor ifodasi quyidagi ko‘rinishda bo‘ladi.



2.15-Masala. Sxemaga ulangan ampermetrning ko‘rsatishi: $I = 25\ A$, $I_1 = 13{,}5\ A$, $I_2 = 15\ (A)$ va $R_2 = 20\ Om, f = 50\ (Gs)$ ga teng bo‘lgan holat uchun zanjir parametr va sarf bo‘ladigan aktiv quvvat (P) hamda quvvat koeffitsienti $(cos\varphi)$ hisoblab topilsin.



Yechish. Parallel ulangan holatda umumiy kuchlanish:

$$U = I_2R_2 = 20 \cdot 15 = 300\ (V)$$

Umumiy tok: $I = \sqrt{I_a^2 + I_p^2}$

Bundan: $I_a = I_2 + I_1 \cos\varphi$, $I_p = I_1 \sin\varphi$,

yoki:

$$I^2 = (I_2^2 + I_1 cos\varphi_1) + I_1^2 sin^2\varphi_1 = I_1^2 + I_2^2 + 2I_1I_2 cos\varphi_1$$

Birinchi tarmoq burchagi: $cos\varphi_1 = \frac{I^2 - I_1^2 - I_2^2}{2I_1I_2} = 0{,}538$

To‘la qarshilik: $z_1 = \frac{U}{I_1} = \frac{300}{13{,}5} = 22{,}2\ (Om)$

Aktiv qarshilik: $R_1 = z_1 cos\varphi_1 = 11{,}9\ (Om)$

Sig‘im qarshiligi: $x_1 = \sqrt{z_1^2 - R_1^2} = 18{,}8(Om)$

Sig‘im parametri: $C_1 = \frac{1}{x_1\omega} = 169 \cdot 10^{-6}\Phi = 169(mk\Phi)$

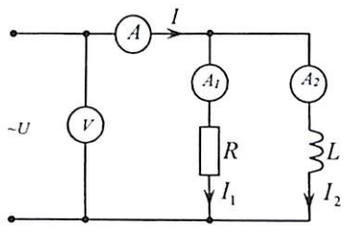
Elektr zanjirning quvvat koeffitsienti:

$$\cos\varphi = \frac{I_a}{I} = \frac{I_2 + I_1 cos\varphi_1}{I} = 0{,}89$$

Zanjirda sarf bo‘ladigan aktiv quvvat:

$$P = UI\cos\varphi = 300 \cdot 25 \cdot 0{,}89 = 6680\ VT = 6{,}68\ (kVt)$$

2.16-Masala. Chizmada keltirilgan sxemaga ulangan elektrodinamik asboblarning ko‘rsatishi: $U = 120\ V, I = 10\ A, I_2 = 6\ A$ bo‘lib, chastotasi $f = 1\ kGs$ bo‘lganda, tok I, aktiv qarshilik R va induktivlik L aniqlansin.



Yechish. O‘zgaruvchan tok burchak chastotasi:

$$\omega = 2\pi f = 6280\ (\frac{1}{sek})$$

Induktiv qarshilik: $x_L = \frac{U}{I_2} = \frac{120}{6} = 20\ (Om)$

Induktivlik: $L = \frac{x_L}{\omega} = 3{,}18\ (mGn)$

Aktiv qarshilikdan o‘tuvchi tok:

$$I_1 = \sqrt{I^2 - I_2^2} = 8\ (A)$$

Qarshiligi: $R = \frac{U}{I_1} = 15\ (Om)$

2.17-Masala. Induktivligi $L = 0{,}18\ (Gn)$, aktiv qarshiligi $R = 30\ Om$ ga teng bo‘lgan induktiv g‘altak, sig‘imi $C = 40\ (mkf)$ bo‘lgan kondensator bilan ketma-ket sxemada biriktirilib, $u_m = 250 \sin 500t\ (V)$ manba kuchlanishiga ulangan. Tok (I_m), faza burchagi (φ), induktivlik va sig‘im kuchlanishi aniqlanib vektor ifodasi tuzilsin.

Yechish. Reaktiv qarshilik ifodasiga asosan:

$x_L = \omega L = 500 \cdot 0.18 = 90\ (Om)$; $x_L = \frac{1}{\omega C} = \frac{10^i}{500 \cdot 40} = 50\ (Om)$

x=$x_L - x_C = 40\ (Om)$

To‘la qarshilik: $z = \sqrt{R^2 + x^2} = 50\ (Om)$

Tok amplitudasi : $I_m = \frac{U_m}{z} = \frac{250}{50} = 5\ (A)$

Tok va kuchlanish orasidagi faza farqi: $\varphi = arctg\frac{x}{R} = 53°8'$

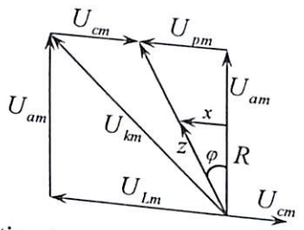
Sig‘imdagi kuchlanish: $U_{cm} = x_c I_m = 5 \cdot 50 = 250\ V$

Induktivlikdagi kuchlanish: $U_{Lm} = x_L I_m = 90 \cdot 5 = 450\ V$

Aktiv qarshilikdagi kuchlanish: $U_{Rm} = RI_m = 30 \cdot 5 = 150V$

G‘altakdagi umumiy kuchlanish: $U_m = \sqrt{U_{Rm}^2 + U_{Lm}^2} = 470\ V$

Aniqlang qiymatlar bo‘yicha mashtab m_i, m_u tanlanib vektor diagrammasini tuzamiz.



2.18-Masala. Induktiv g‘altak parametrlari $R = 3\ Om$, $X_L = 4\ Om$ bo‘lib, $U = 100\ V$ kuchlanishga ulangan. Aktiv, reaktiv, to‘la o‘tkazuvchanlik parametrlari, kuchlanish va tok qiymati aniqlanib, uchburchak vektor ifodalari chizib ko‘rsatilsin.

Yechish. To‘la qarshilikni topamiz:

$$Z = \sqrt{R^2 + X_L^2} = \sqrt{9 + 16} = 5\ Om$$

Om qonuniga asosan tokning haqiqiy qiymati: $I = \frac{U}{z} = \frac{100}{5} = 20\ A.$

Qarshilik uchburchak vektor ifodasidan:

$\cos\varphi = \frac{R}{z} = \frac{3}{5} = 0{,}6$: $\sin\varphi = \frac{X_L}{z} = \frac{4}{5} = 0{,}8$

Shunga asosan: $U_a = \text{U}\cos\varphi = 100 \cdot 0{,}6 = 60\ V$

$U_P = \text{U}\sin\varphi = 100 \cdot 0{,}8 = 80\ V$

Tok qiymatini aniqlaymiz:

$I_a = \text{I}\cos\varphi = 20 \cdot 0{,}6 = 12\ A$; $I_P = \text{I}\sin\varphi = 20 \cdot 0{,}8 = 16\ A$

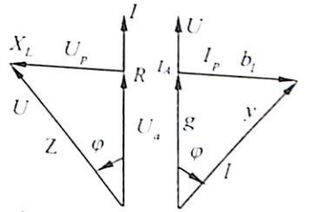
Aniqlangan tok va kuchlanish qiymatidan o‘tkazuvchanlik parametri:

To‘la o‘tkazuvchanlik: $\text{y} = \frac{I}{U} = \frac{20}{100} = 0{,}2\ sim.$

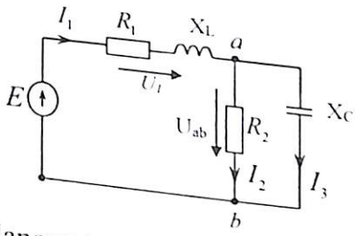
Aktiv o‘tkazuvchanlik: $\text{g} = \text{y}\cos\varphi = 0{,}2 \cdot 0{,}6 = 0{,}12\frac{1}{Om}$

Reaktiv o‘tkazuvchanlik: $b_L = y\sin\varphi = 0{,}2 \cdot 08 = 0{,}16\frac{1}{Om}$

Masshtab tanlash bilan vektor ifodasini tuzamiz.



2.19-Masala. Chizmada keltirilgan sxemada o‘zgaruvchan kuchlanish chastotasi $f = 50\ Gs$ bo‘lgan generatorning aktiv quvvati $P = 31{,}25(kVt)$, zanjir qarshiligi $R_1 = 2\ Om, x_L = 36\ (Om), R_2 = 75\ Om, x_C = 100\ (Om)$ ga teng. Elektr zanjirdagi tok va kuchlanish hisoblansin.



Yechish. Parallel ulangan tarmoq o‘tkazuvchanligi:

$g_{ab} = \frac{1}{R_2} = 1{,}33 \cdot 10^{-2}\ (\frac{1}{Om})$; $b_{ab} = \frac{1}{x_C} = -0.01(\frac{1}{Om})$

Umumiy o‘tkazuvchanlik: $y_{ab} = \sqrt{g_{ab}^2 + b_{ab}^2} = 1{,}67 \cdot 10^{-2}\ (\frac{1}{Om})$

Ikki qutbli elektr zanjirlar ekvivalent o‘xshashlik tenglamasidan (2.11):

$R_{ab} = \frac{g_{ab}}{y_{ab}} = 48\ (Om)$; $x_{ab} = \frac{b_{ab}}{y_{ab}^2} = -\frac{0{,}01}{2{,}78 \cdot 10^{-4}} = 36\ Om$

Zanjirning umumiy aktiv va reaktiv qarshiligi:

$R = R_1 + R_{ab} = 50\ (Om)$; $x = x_L + x_{ab} = 36 - 36 = 0$

To‘la qarshilik: $Z = \sqrt{R^2 + x^2} = 50\ Om$

Birinchi tarmoqdagi tok: $I_1 = \sqrt{\frac{P}{R}} = \sqrt{\frac{31250}{50}} = 25\ (A)$

Umumiy kuchlanish $U = I_1 z = 1250\ (B)$ bo‘lib, faza burchagi $\varphi = 0$.

Birinchi tarmoq kuchlanishi: $U_{1a} = R_1 I_1 = 25 \cdot 2 = 50\ (V)$,

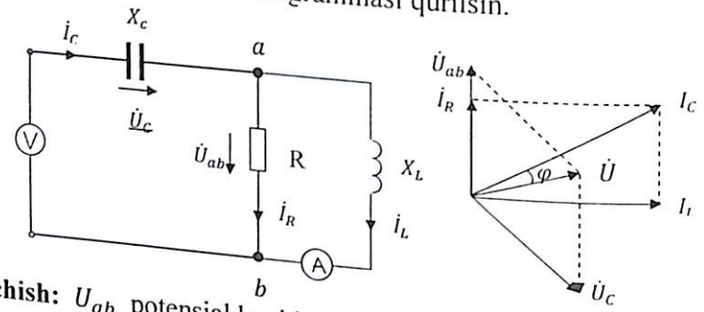
$U_{1p} = x_1 I_1 = 25 \cdot 36 = 900\ (V)$ $U_1 = \sqrt{U_{a1}^2 + U_{p1}^2} = 900\ (V)$

Parallel ulangan tarmoqdagi kuchlanish:

$$U_{ab} = \frac{I_1}{y_{ab}} = \frac{25}{1{,}67 \cdot 10^{-2}} = 1500\ (V)$$

Tarmoqdagi tok: $I_2 = \frac{U_{ab}}{R_2} = 20\ (A)$ $I_3 = \frac{U_{ab}}{x_c} = 15\ (A)$

2.20-Masala. Zanjir parametrlari: $X_C = 20\ om$, $X_L = 30\ om$, $R = 40\ om$ ampermetr $I_L = 4\ A$ ni ko’rsatsa, tarmoq toklari I va voltmetr kuchlanishi U topilib, vektor diagrammasi qurilsin.



Yechish: U_{ab} potensial kuchlanishni topamiz:

$$U_{ab} = I \cdot X_L = 4 \cdot 30 = 120$$

Om qonuniga asosan: $I_R = \frac{U_{ab}}{R} = \frac{120}{40} = 3\ A$

Krixgofning 1-qonunig asosan:

$$I_C = \sqrt{I_R^2 + I_L^2} = \sqrt{3^2 + 4^2} = 5\ A$$

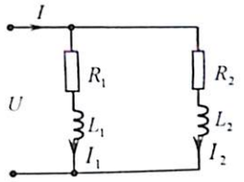
Sig’imdagi kuchlanish: $U_C = I_C \cdot X_C = 5 \cdot 20 = 100\ V$

Unda voltmetrda kuchlanish:

$$U = \sqrt{U_{ab}^2 + U_C^2} = \sqrt{120^2 + 100^2} \approx 155\ V$$

Tok va kuchlanishlar qiymatlari bo’yicha masshtab ($m_I = \frac{A}{sm}$, $m_U = \frac{V}{sm}$) tanlash bilan vektor diagrammasini tuzamiz:

2.21-Masala. Kuchlanish $U = 120\ V$ chastotasi $f = 50\ Gs$ bo‘lgan elektr zanjir parametri: $R_1 = 4Om, L_1 = 0{,}6\ MGn, R_2 = 6\ Om, L_2 = 25{,}5\ MGn$ bo‘lgan ikkita induktiv g’altak parallel ulangan. Tarmoqdagi tok, zanjirning quvvat koeffitsienti va iste’molchilarda sarf bo‘ladigan aktiv quvvat aniqlansin.



Yechish. Birinchi g‘altak induktiv qarshiligi:

$$x_{L_1} = 2\pi f L_1 = 2 \cdot 3{,}14 \cdot 50 \cdot 0{,}6 \cdot 10^{-3} = 3\ Om$$

Birinchi g‘altak to‘la qarshiligi: $Z_1 = \sqrt{R_1^2 + x_{L_1}^2} = \sqrt{4^2 + 3^2} = 5\ Om$

Birinchi tarmoqdagi tok: $I_1 = \frac{U}{Z} = \frac{120}{5} = 24\ A$

Birinchi g‘altak quvvat koeffitsienti: $\cos\varphi_1 = \frac{R_1}{Z} = \frac{4}{5} = 0{,}8$

(burchak $\varphi_1 = 36°50'$ bo‘lganda $\sin\varphi_1 = 0{,}6$)

Bunda birinchi tarmoqdagi tok aktiv tashkil etuvchisi:

$$I_{a_1} = I_1 \cos\varphi_1 = 24 \cdot 0{,}8 = 19{,}2\ A$$

Reaktiv tashkil etuvchisi: $I_{P_1} = I_1 \sin\varphi_1 = 24 \cdot 0{,}6 = 14{,}4\ A$

Ikkinchi g‘altak induktiv qarshiligi:

$$x_{L_2} = 2\pi f L_2 = 2 \cdot 3{,}14 \cdot 50 \cdot 2{,}5 \cdot 10^{-3} = 10\ Om$$

Ikkinchi tarmoqdagi to’la qarshilik:

$$Z_2 = \sqrt{R_2^2 + x_{L_2^2}} = \sqrt{36^2 + 100^2} = \sqrt{136} = 12$$

Ikkinchi tarmoqdagi tok: $I_2 = \frac{U}{Z_2} = \frac{120}{12} = 10\ A$

Ikkinchi g‘altak quvvat koeffitsienti: $\cos\varphi_2 = \frac{R_2}{Z_2} = \frac{6}{10} = 0{,}6$

(burchak$\varphi_2 = 52°10'$ bo‘lganda $\sin\varphi_2 = 0{,}8$)

Ikkinchi tarmoqdagi tok aktiv tashkil etuvchisi:

$$I_{a_2} = I_2 \cos\varphi_2 = 12 \cdot 0{,}6 = 7{,}2\ A$$

Reaktiv tashkil etuvchisi: $I_{P_2} = I_2 \sin\varphi_2 = 12 \cdot 0{,}8 = 9{,}6\ A$

Umumiy tok aktiv tashkil etuvchisi qismi:

$$I_a = I_{a_1} + I_{a_2} = 19{,}2 + 7{,}2 = 26{,}4\ A$$

Reaktiv tashkil etuvchisi:

$$I_P = I_{P_1} + I_{P_2} = 14{,}4 + 9{,}6 = 26\ A$$

Umumiy tok qiymati: $I = \sqrt{I_a^2 + I_p^2} = 36\ A$

Zanjirdagi quvvat koeffitsienti: $\cos\varphi = \frac{I_a}{I} = \frac{26,4}{36} = 0,733$

Birinchi g‘altakda sarf bo‘ladigan aktiv quvvat:

$$P_1 = UI_1 \cos\varphi_1 = 120 \cdot 24 \cdot 0,8 = 2304\ Vt$$

Ikkinchi g‘altakda sarf bo‘ladigan aktiv quvvat:

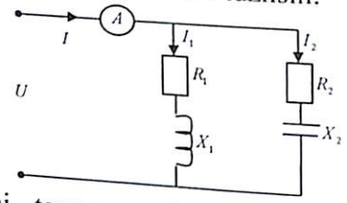
$$P_2 = UI_2 \cos\varphi_2 = 120 \cdot 12 \cdot 0,8 = 864\ Vt$$

Iste’molchilarda sarf bo‘ladigan aktiv quvvat:

$$P = P_1 + P_2 = 2304 + 864 = 3168\ Vt$$

$$Q = Q_1 + Q_2 = UI_1 sin\varphi_1 + UI_2 sin\varphi_2 = 120 \cdot 14.4 + 120 \cdot 9.6 = 2880(VAr)$$

2.22-Masala. Parallel sxemada ulangan zanjirga kiruvchi tok $I = 2\ A$ bo‘lib, parametri $R_1 = 3\ Om,\ X_1 = 4\ Om,\ R_2 = 6\ Om,\ X_2 = 8\ Om$ ga teng. Umumiy kuchlanish U, tarmoqdagi tok I_1, I_2, aktiv, reaktiv va to‘la quvvat qiymatlari aniqlanib vektor ifodasi tuzilsin:



Yechish. Birinchi tarmoq to‘la qarshiligi: $Z_1 = \sqrt{R_1^2 + X_1^2} = \sqrt{3^2 + 4^2} = 5\ Om$. Ekvivalent parametr tenglamasidan (2.10) aktiv o‘tkazuvchanlik: $g_1 = \frac{R_1}{Z_1^2} = \frac{3}{25} = 0,12\ \frac{1}{Om}$

Reaktiv o‘tkazuvchanlik: $b_1 = \frac{X_1}{Z_1^2} = \frac{4}{24} = 0,16\ \frac{1}{Om}$

Ikkinchi tarmoq to‘la qarshilik:

$$Z_2 = \sqrt{R_2^2 + X_2^2} = \sqrt{36 + 64} = 10\ Om$$

yoki: $g_2 = \frac{R_2}{Z_2} = \frac{6}{10^2} = 0,06\ (\frac{1}{Om})$ $b_c = b_2 = \frac{X_2}{Z_2} = -\frac{8}{10^2} = -0,08\ \frac{1}{Om}$

Zanjir to‘la aktiv o‘tkazuvchanligi:

$$g = g_1 + g_2 = 0,12 + 0,06 = 0,18\ \frac{1}{Om}$$

To‘la reaktiv o‘tkazuvchanlik:

$$b = b_1 + b_2 = 0,16 - 0,08 = 0,08\ \frac{1}{Om}$$

Umumiy o‘tkazuvchanlik:

$$y = \sqrt{g^2 + b^2} = \sqrt{(0,18)^2 + (0,18)^2} = 0,197\ \frac{1}{Om}$$

Om qonuniga asosan zanjirdagi kuchlanish: $U = \frac{I}{y} = \frac{2}{0,197} \approx 10\ V$

Tarmoqdagi tok: $I_1 = \frac{U}{Z_1} = \frac{10}{5} = 2\ A$ $I_2 = \frac{U}{Z_2} = \frac{10}{10} = 1\ A$

Faza burchagini topamiz: $\varphi = arctg\frac{b}{g} = arctg\frac{0,08}{0,18} = 24°$

$$\varphi_1 = arctg\frac{X_1}{Z_1} = 53°\ \varphi_2 = arctg\frac{X_2}{Z_2} = -53°$$

Quvvat ifodasidan: $P = U^2 g = 100 \cdot 0,18 = 18\ Vt$

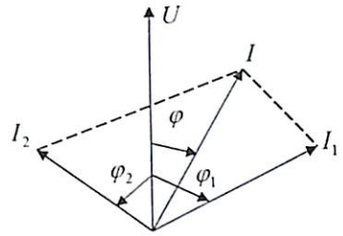
$Q = U^2 b = 100 \cdot 0,08 = 8\ var$; $S = U^2 y = 100 \cdot 0,197 = 19,7\ VA$

Quvvat koeffitsienti ifodasida: $cos\varphi = \frac{P}{S} = \frac{P}{UI} = \frac{210}{855} = 0,25$

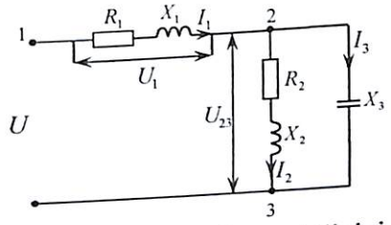
Quvvat siljish koeffitsienti ifodasidan: $P^2 + Q^2 = S^2 - T^2$

bundan:

$$T = \sqrt{S^2 - (P^2 + Q^2)} = \sqrt{855^2 - (210^2 + 8^2)} = 828.7$$



2.23-Masala. Qarshiligi aralash sxemada ulangan elektr zanjirda sarf bo‘ladigan aktiv quvvat $P = 1,2\ (kVt)$ bo‘lib, parametr qiymati: $R_1 = 2\ (Om), x_1 = 26\ (Om), R_2 = 10\ (Om), x_2 = 10, x_3 = -10\ (Om)$ ga teng. Zanjirdagi umumiy kuchlanish U tarmoqdagi tok I_1, I_2, I_3, reaktiv quvvati (Q) aniqlanib vektor diagrammasi tuzilsin.



Yechish. Zanjirning aktiv va reaktiv qarshiligini, qarshilik ekvivalent parametr o‘xshashlik tenglamasiga asosan (2. 10) aniqlaymiz:

$$g_2 = \frac{R_2}{R_2^2 + x_2^2} = \frac{10}{20} = 0,05\ \frac{1}{OM};$$

$$b_2 = \frac{x_2}{R_2^2 + x_2^2} = \frac{10}{20} = 0,05\ \frac{1}{OM};$$

Uchinchi tarmoq o‘tkazuvchanligi: $g_3 = 0, b_3 = \frac{1}{x_3} = -0,1\ \frac{1}{Om}$

Tarmoq parallel ulangan qismi uchun: $g_{23} = g_2 + g_3 = 0{,}05\ \frac{1}{Om}$

$$b_{23} = b_2 + b_3 = 0.05 - 0.1 = -0.05\ \frac{1}{Om}$$

Umumiy o'tkazuvchanlik: $y_{23} = \sqrt{g_{23}^2 + b_{23}^2} = \sqrt{0{,}005}\ \frac{1}{Om}$

O'xshashlik ekvivalent parametrlar tenglamasiga asosan (2.11) aktiv qarshilik: $R_{23} = \frac{g_{23}}{y_{23}^2} = \frac{0{,}05}{0{,}005} = 10\ Om$

Reaktiv qarshilik: $x_{23} = \frac{b_{23}}{y_{23}^2} = \frac{0{,}05}{0{,}005} = -10\ Om$

To'la qarshilik: $z_{23} = \sqrt{R_{23}^2 + x_{23}^2} = 14{,}1\ Om$

Zanjirning umumiy aktiv qarshiligi: $R = R_1 + R_{23} = 12\ Om$

Umumiy reaktiv qarshiligi: $x = x_1 + x_{23} = 16\ Om$

Aktiv quvvat tenglamasiga asosan: $P = I^2 R\ (Vt)$

yoki $I = \sqrt{\frac{P}{R}} = \sqrt{\frac{1200}{12}} = 10\ A$

Burchak fazasi: $\varphi = arctg\frac{x}{R} = \frac{16}{12} = 1{,}33 = 53°10'$

Umumiy kuchlanish: $U = \frac{P}{Icos\varphi} = \frac{1200}{10 \cdot 0{,}6} = 200\ V$

To'la quvvat: $S = UI = 200 \cdot 10 = 2000\ VA = 2\ KVA$

To'la qarshilik: $z = \frac{S}{I^2} = \frac{2000}{100} = 20\ Om$

Burchak: $\sin\varphi = \frac{x}{z} = \frac{16}{20} = 0{,}8$

Reaktiv quvvat: $Q = S\sin\varphi = 2 \cdot 0{,}8 = 1600\ VAR = 1{,}6\ KVAR$

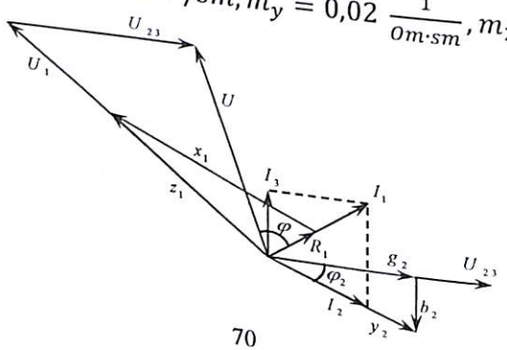
Tarmoqdagi kuchlanishlari:

$U_1 = Z_1 I_1 = 26{,}2 \cdot 10 = 262\ V, U_{23} = Z_{23} I_1 = 14{,}1 \cdot 10 = 141\ V$

Tarmoqdagi tok: $I_2 = \frac{U_{23}}{Z_{23}} = \frac{141}{14{,}1} = 10\ A,\ I_3 = \frac{U_{23}}{Z_3} = \frac{141}{10} = 14{,}1\ A$

Vektor diagramma chizish uchun tok va kuchlanish masshtablari tanlanadi:

$(m_1 = 5\ A/sm, m_u = 25\ V/sm, m_y = 0{,}02\ \frac{1}{Om \cdot sm}, m_2 = 5\ \frac{Om}{sm})$



2.3. Mustaqil yechish uchun masalalar

2.1-Masala. Qutblar soni $P = 3$ bo'lgan sinxron generatorning magnit maydonida $n = 1000\ ayl/min$ tezlik bilan aylanganda hosil bo'ladigan EYK chastotasi aniqlansin.

Javob: $f = 50\ Gs$.

2.2-Masala. O'zgaruvchan tok generatorining yakor aylanish tezligi $n = 500\ ayl/min$ bo'lib, $f = 50\ Gs$ chastotali EYK hosil qilganda qutblar soni nechta bo'ladi?

Javob: $P = 6$

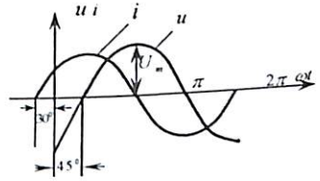
2.3-Masala. O'zgaruvchan EYK amplituda qiymati $E_m = 120\ V$ chastotasi $f = 100\ Gs$ bo'lganda, $t = 0{,}0075\ sek$ vaqtda EYK oniy qiymati aniqlansin.

Javob: $e = 120\sin 270°;\ e = E_m = -120\ V$

2.4-Masala. Magnit maydonida o'ramlar soni $W = 40$ ga teng bo'lgan g'altak aylanganda hosil bo'ladigan magnit oqimi $\Phi = 0{,}02\sin 314t$ bo'lib, g'altakda induksiyalanadigan EYK oniy qiymati aniqlansin.

Javob: $e = 250\sin(314t - 90°)$

2.5-Masala. Rasmda keltirilgan sinusoidal funksiya uchun analitik ifoda yozilib, tok va kuchlanish orasidagi burchak φ aniqlansin.



2.6-Masala. Aktiv qarshiligi $R = 44$ Om zanjir $U = 155{,}2\sin 1256t$ kuchlanishga ulangan. Kuchlanish haqiqiy qiymati U, tok I, chastota f, davr T, aktiv quvvat P va sarf bo'ladigan elektr energiya W topilsin.

Javobi: $U = 110\ V, I = 2{,}5\ A, f = 200\ Hz, T = 0.0005\ s, P = 275\ Vt, W = 1{,}375\ J$

2.7-Masala. Kuchlanish va tok oniy qiymatlari $u = 170\ \sin(\omega t + 45°)$ $i = 10\sin(\omega t - 45°)$ bo'lganda, ular orasidagi burchak φ topilib, $t = 0$ bo'lganda oniy qiymati aniqlansin.

Javob: $U_m = 120\ V, I_m = 7A, \varphi = 90^\circ$

2.8-Masala. Aktiv qarshilikga ega bo'lgan sinusoidal o'zgaruvchan elektr zanjirga $U = 141\sin\omega t$ kuchlanish ulanganda, $i = 7{,}95\sin(\omega t - 45°)$tok o'tadi. Elektr quvvat $P_{o'r}$ – o'rtacha qiymati va R qarshiligi aniqlansin.

Javob: $P_{o'r} = 750VT \quad R = 70(Om)$

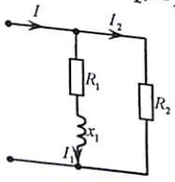
2.9-Masala. O'zgaruvchan tok chastotasi $f = 160\ Gs, U = 220\ V$ kuchlanishga ulangan bo'lib g'altakdan $I = 4\ A$ tok o'tadi. G'altak induktivligi aniqlansin.

Javob: $L = 30\ MGn$

2.10-Masala. Aktiv qarshiligi $R = 44\ om$ bo'lgan zanjir u= 155,2 sin1256 t kuchlanishga ulangan. Kuchlanish va tok haqiqiy, o'rtacha qiymati chastotasi, davri, aktiv quvvat va elektr energiya qiymatlarini toping.

Javob: $U = 110\ V;\ U_{o'rt} = \frac{2}{\pi}\cdot 155{,}2;\ I = 2{,}5\ A;\ f = 200\ Gs;$
$T = 0{,}0005\ sek;\ P = 275\ Wt;\quad W = 1{,}375\ Joul.$

2.11-Masala. Tarmoqdagi tok $I = 16\ A,\ I_1 = 8{,}93A, I_2 = 10\ A$ va qarshilik $R_2 = 2\ Om$ bo'lganda P_1 aktiv quvvat, $\cos\varphi_1$ quvvat koeffitsienti va R_1, X_1 qarshilik parametrlari aniqlansin.

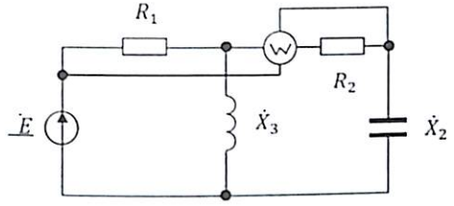


Javob: $P_1 = 810\ Vt,\ \cos\varphi_1 = 0{,}446,$
$R_1 = 10\ Om,\ X_1 = 6.8\ Om, U = 200\ V$

2.12-Masala. Parametri $R = 6\ Om,\ L = 25\ MGn$ bo'lgan g'altak chastotasi $f = 50\ Gs$ bo'lgan $U = 120\ V$ sinusoidal o'zgaruvchan kuchlanishga ulangan. Quvvat koeffitsienti va aktiv, reaktiv quvvat aniqlansin.

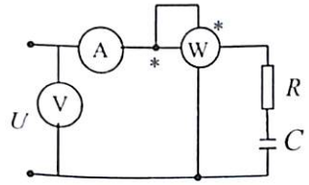
Javob: $\cos\varphi = 0{,}6, P = 864\ Vt,\ Q_L = 1152\ VAR$

2.13-Masala. Zanjir parametrlari: $R_1 = 10\ om,\quad R_2 = 20\ om,\quad X_2 = 20\ om,\quad X_3 = 40\ om,\quad \dot{E} = 120\sin\omega t$ ulangan bo'lsa, vattmetr quvvati qancha bo'ladi?



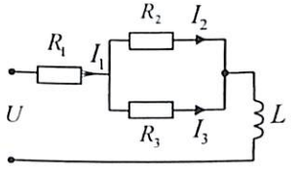
Javob: $P = 289\ Wt$

2.14-Masala. Elektr o'lchov asboblari ko'rsatishi: $U = 200\ B, I = 2A, P = 240\ Vt$ bo'lib, chastotasi $f = 50\ Gs$ ga teng. Aktiv va sig'im qarshilik parametri aniqlansin.



Javob: $R = 60\ Om, C = 40\ mkF$

2.15-Masala. Sinusoidal o'zgaruvchan elektr zanjir parametri: $R_1 = 4\ Om, R_2 = 10\ Om, R_3 = 15\ Om$ va induktivligi $L = 95\ MGn$ bo'lib, R_2 qarshilikdan chastotasi $f = 50\ Gs$ bo'lgan $I = 2A$ tok o'tadi. Umumiy kuchlanish U qiymati, burchak koeffitsienti $\cos\varphi$ va aktiv quvvat P aniqlansin.

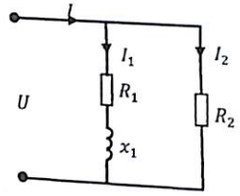


Javob: $U = 100\ V,$
$\varphi = 36°50^1, P = 160Vt$

2.16-Masala. Induktiv g'altak parametrlari R=X_L=20 Om bo'lib $u = 100\sqrt{2}\sin(10^3 t + 15^0)\ V$ ulangan. t=0 vaqtda tokning oniy i va I_m –maksimal qiymati topilsin.

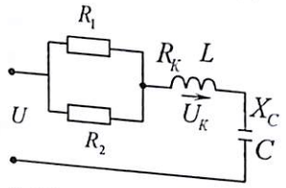
Javob: $i = 5\sin(10^3 t + 15^0)$ yoki t=0 da $I_m = 5\sin 15^0 = 1{,}29\ A$

2.17-Masala. Elektr zanjir tarmoq toklari $I = 16\ A, I_1 = 8{,}93\ A, I_2 = 10\ A$ bo'lib aktiv qarshiligi $R_2 = 2\ Om$ bo'lganda, aktiv quvvat $P_1, \cos\varphi, R_1, x_1$ aktiv va reaktiv qarshiliklar qiymatlari aniqlansin.



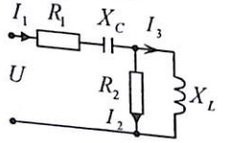
Javob: $P_1 = 810\ vt, \cos\varphi = 0{,}446,$
$R_1 = 10\ Om, x_1 = 6{,}8\ Om$

2.18-Masala. Sinusoidal o'zgaruvchan elektr zanjirning qarshiligi: $R_1 = R_2 = 100\ Om, R_K = 30\ Om, X_C = 100\ Om, X_L = 40\ Om$ bo'lib, g'altakdagi kuchlanish $U_K = 100V$ chastotasi $f = 50\ Gs$ ga teng. Zanjirdan o'tuvchi tokning haqiqiy qiymati I, umumiy kuchlanishi U, sig'im va induktivlik parametri L, C, aktiv quvvat P hamda elektr W_E va magnit W_L maydon energiyalari aniqlansin.



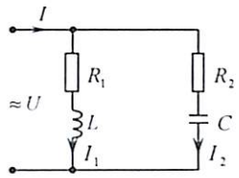
Javob: $U = 200\ V, I = 2\ A,$
$L = 0{,}127\ MGn\ \ C = 32\ mkF,$
$P = 320\ Vt, W_E = 1{,}24\ Dj,$
$W_L = 0{,}5\ Dj$

2.19-Masala. Qarshilik parametri: $R_1 = 12Om,\ R_2 = 10\ Om, X_C = 24\ Om,\ X_L = 20Om$ bo'lgan elektr zanjir $f = 50Gs$ bo'lgan $U = 220\ V$ sinusoidal kuchlanishga ulangan. Tarmoqdagi tok I_1, I_2, I_3 haqiqiy qiymati aniqlansin.



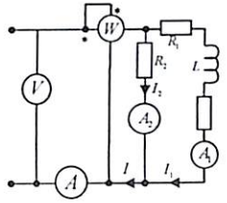
Javob: $I_1 = 7\ A, I_2 = 4{,}4\ A,$
$I_3 = 5{,}25\ A$

2.20-Masala. Parametri $R_1 = 160\ Om, L = 0{,}04\ MGn$ bo'lgan induktiv g'altak aktiv qarshiligi $R_2 = 30\ Om$, sig'imi $C = 50\ mkF$ bo'lib parallel sxemada ulangan. O'zgaruvchan tok kuchlanishi $U = 110\ V$, chastotasi $f = 50\ Gs$ bo'lganda umumiy o'tkazuvchanlik, tarmoqdagi tok va o'tkazuvchanligi aniqlansin.



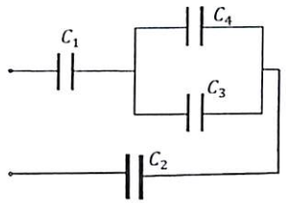
Javob: $y_1 = 0{,}036\ \frac{1}{Om}, y_2 = 0{,}0316\ \frac{1}{Om},$
$y = 0{,}036\ \frac{1}{Om},\ I = 3{,}96\ A,$
$I_1 = 1{,}1\ A, \qquad I_2 = 3{,}5\ A$

2.21-Masala. Parallel zanjir parametri: $R_1 = 100\ Om,\ R_2 = 200\ Om,\ L = 0{,}276\ gn, f = 100\ gs$ bo'lib, $I_1 = 1\ A$ ga teng. Elektr o'lchov asboblari ko'rsatish qiymati topilsin.



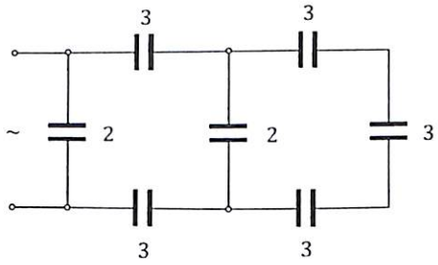
Javob: $U = 200\ V,$
$I = 1{,}73\ A,\ P = 300\ Vt.$

2.22-Masala. Kondensatorli $C_1 = C_2 = C_3 = C_4 = 10$ mkf C_4 teng zanjir $U = 100\ V$ kuchlanishga ulangan. Umumiy sig'imi C_{um}, zaryad q va elektr maydon energiyasi W_e topilsin.



Javob: $Cum = 4$ mkf
$q = 4 \cdot 10^{-4}\ kulon$
$W_e = 2 \cdot 10^{-2} DJ$

2.23-Masala. Zanjir ekvivalent sig'im qarshiligi topilsin, agar chastota $f = 10^3\ Gs$ bo'lsa.



Javob: $X_{c\,um} = 53{,}1\ om$

Nazorat savollari

1. Sinusoidal o‘zgaruvchan tok xususiyati nimadan iborat?
2. Sinusoidal o‘zgaruvchan tok qanday hosil qilinadi, manbai nima?
3. Sinusoidal o‘zgaruvchan tok bilan o‘zgarmas tokning farqi nimada?
4. Sinxron generatorning tuzilishi va ishlash prinsipini bilasizmi?
5. O‘tkazgich magnit maydonda harakatlanganda unda hosil bo‘ladigan EYK nimaga teng?
6. Elektr mashina va apparatlarida magnit o‘zak (ferromagnetik) qanday maqsad uchun xizmat qiladi?
7. Magnit doimiyligi deganda nimani tushunasiz?
8. Induktivlik nima va qanday birlikda o‘lchanadi?
9. O‘zinduksiya qonuniga asosan induktivlikda hosil bo‘lgan EYK yo‘nalishi qanday aniqlanadi va haqiqiy qiymati nimaga teng?
10. Sinusoidal o‘zgaruvchan tok qanday qiymatda ifodalanadi?
11. Sinusoidal o‘zgaruvchan tok chastotasi, davri va oniy qiymat ifodalarini yozing.
12. Sinusoidal o‘zgaruvchan tok vektor ifodasiga ta’rif bering. Elektr zanjir uchun vektor diagramma qanday tuziladi?
13. Sinusoidal o‘zgaruvchan tok va kuchlanish boshlang‘ich fazasi va faza farqi qanday aniqlanadi?
14. Aktiv induktivlik va sig‘im qarshilik parametri uchun Om qonuni ifodasini yozing.
15. Ketma-ket va parallel sxemada ulangan R, L, C zanjir uchun Om qonuni tenglamasini yozing.
16. Ikki qutbli zanjir uchun ekvivalent o‘xshashlik tenglamasini yozing.
17. Ketma-ket ulangan aktiv va induktiv qarshiligi bo‘lgan elektr zanjir uchun vektor ifodasini tuzib, to‘la qarshilik ifodasini yozing.
18. Aktiv va sig‘im qarshiligi bo‘lgan elektr zanjir uchun vektor ifoda tuzib, to‘la qarshilik tenglamasi yozilsin.
19. Ketma-ket biriktirilgan R, L, C zanjirida $X_L > X_S, X_L < X_S, X_L = X_S$ bo‘lgan holat uchun vektor ifoda tuzib, qaysi xarakterga ega ekanligini tushuntiring.
20. Aktiv, reaktiv va to‘la quvvat tenglamasini yozing.
21. Aktiv va reaktiv elementlarda elektr energiyasi qayerda va qanday sarflanadi?

22. Quvvat koeffitsienti $cos\varphi$ nima va qanday amaliy ahamiyatga ega?
23. O‘zgarmas tokga nisbatan induktiv va sig‘im qarshiligi nimaga teng?
24. Nima uchun sig‘imdan o‘zgaruvchan tok o‘tadi, o‘zgarmas tok esa o‘tmaydi?
25. Ketma-ket sxemada ulangan R, L elektr zanjir qarshiligidagi kuchlanish: $U_r = 60V, U_L = 80V$ ga teng bo‘lganda umumiy (U) kuchlanish nimaga teng?
26. Parallel sxemada ulangan R, C elektr zanjirda o‘tuvchi tok $I_r = 3A, I_c = 4A$ bo‘lganda, umumiy tok (I) qanchaga teng?
27. R, L, C ketma-ket ulangan zanjirning to‘la qarshiligi $Z = 100Om, R = 80\ Om, X_C = 40\ Om$ bo‘lsa, g‘altakning induktiv qarshiligi X_L necha Om ga teng?
28. Agar $C = 20\ mkf$ bo‘lgan sig‘im parametri $U = 220(\sin 314t - 60)V$ kuchlanishga ulanganda tokning oniy qiymati (i) ni aniqlang.
29. Kuchlanish $U = 100\ V$, tok kuchi $I = 5A$ va faza burchagi $\varphi = 60°$ bo‘lgan zanjirning aktiv quvvati necha $vatt$ bo‘ladi?
30. Kuch qarshilik va quvvat uchburchak vektor ifodasiga asosan $\cos\varphi$, $\sin\varphi$, $tg\ \varphi$ tenglama tuzing.
31. Qarshilik va quvvatlar uchburchak vektor ifodasidan, aktiv va reaktiv tashkil etuvchi vektor qanday ma’noni bildiradi?
32. Sinusoidal elektr zanjir kuchlanishi $u = 141\sin(314 + 80^{\circ})$ va tok $i = 14{,}1\sin(314 + 20^{\circ})$ bo‘lganda, aktiv quvvat necha $vatt$ ga teng. (Javob: $P = 500Vt$).
33. Sinusoidal elektr zanjirda kuchlanish $u = 28{,}2\sin(628 + 80^{0})$ va tok $i = 2{,}82\sin(628 + 50^{0})$ bo‘lganda, reak-tiv quvvat qancha bo‘ladi? (Javob: $Q = 20\ VAR$).
34. Elektr zanjir to‘la quvvati $S = 1000$ bo‘lib $\cos\varphi = 0{,}8$ bo‘lganda aktiv quvvat qiymatini toping.
35. Elektr zanjir kuchlanishi $U = 220\ V$, tok $I = 10\ A$, aktiv quvvat $P = 1{,}1$ kvt ga teng bo‘lganda $\cos\varphi$ nimaga teng?
36. Tok amplitudasi $I_m = 4\ A$ fazasi $\varphi_i = 30^{0}$ bo’lsa $t = 0$, $t = 60^{0}$ ga oniy, effektiv va o’rtacha qiymatlari nimaga teng?
37. Ketma-ket ulangan R, L, C zanjirning to‘la qarshiligi $Z = 100\ Om$, aktiv qarshiligi $R = 30\ Om$ va sig‘im qarshiligi $X_C = 40\ Om$ bo‘lsa, induktiv qarshilik necha Om bo‘ladi?

38. Ketma-ket ulangan R, L, C zanjirdagi kuchlanish $U_R = 30V, U_L = 40V, U_C = 40V$ bo'lganda umumiy kuchlanish (U) qancha bo'ladi?

39. Induktiv g'altakning to'la qarshiligi $Z = 10\,Om$, aktiv qarshilik qismidagi kuchlanish $U_R = 30\,V$, induktivlikda $U_L = 40\,V$ bo'lganda, umumiy kuchlanish U va tok I nimaga teng?

40. Parallel sxemada ulangan R, C zanjirdagi tok $I_R = 4A$, $I_c = 3A$ bo'lib, $U = 100\,V$ kuchlanishga ulangan. To'la o'tkazuvchanlik (y) va to'la quvvat (S) qiymati qancha bo'ladi?

41. Tok va kuchlanish oniy qiymati: $u = 282\sin(\omega t + 60^\circ)$; $i = 141\sin(\omega t + 30^\circ)$ bo'lganda, faza burchagi φ, to'la, aktiv va reaktiv quvvat qancha bo'ladi?

42. Quvvat koeffitsienti $cos = 0{,}85$ bo'lgan elektrodvigatel $U = 120V$ kuchlanishga ulangan bo'lib, $I = 2A$ tok sarflaydi. To'la, aktiv va reaktiv quvvat qiymatini aniqlang.

43. Induktiv g'altak aktiv qarshiligi $R = 15\,Om$ bo'lib, ampermetr – 5A va voltmetr – 220 V ni ko'rsatadi. Zanjirning to'la, aktiv, reaktiv quvvati, induktiv qarshiligi, qarshiliklardagi kuchlanish va burchak $\cos\varphi$ nimaga teng?

44. Induktivligi $L = 0.003$ Gn bo'lgan g'altakga $U = 120\sqrt{2}\sin 314t$ kuchlanishga ulangan. X_L qarshiligi va tokning oniy qiymati i topilsin.

45. Ampermetrdagi $I_m = 4\,A$, fazasi $\varphi_i = 30°$ bo'lgan sinusoidal tokning $t = 0$; $\varphi_i = 60°$ da oniy qiymati qanchaga teng.

46. Ketma-ket yoki parallel sxemada ulangan R, L, C zanjirlarda $\varphi = 0$ bo'lganda qanday holat yuzaga keladi, va reaktiv qarshilik qanday munosabatda bo'ladi.

46. Agar $\varphi > 0$ yoki $\varphi < 0$ bo'lganda zanjir qaysi xarakterga ega bo'ladi?

47. Agar $\varphi = 0$ reaktiv qarshiliklar qanday munosabatda bo'ladi va qanday hodisa yuzaga keladi?

48. Agar $EYUK\ e_1 = 120\sin(\omega t + 45^0)$, $e_2 = 120\sin(\omega t - 15^0)$, bo'lsa φ burchak qancha bo'ladi va $\omega t = 0$; $\omega t = 30^0$ $e_1, e_2 - oniy$ qiymatlarini ham toping?

3. SINUSOIDAL O'ZGARUVCHAN ELEKTR ZANJIRNI KOMPLEKS (SIMVOLIK) USULDA HISOBLASH

3.1. Asosiy nazariy tushunchalar

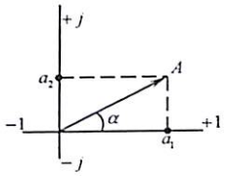
1. Kompleks son.

Kompleks son **Eyler** formulasiga asosan $e^{\pm i\varphi} = \cos\varphi \pm j\,\sin\varphi$ ifodalanadi, kompleks tekislikda vektor ko'rinishda tasavvur qilish mumkin bo'lib, kompleks son uch xil ko'rinishda ifodalanadi.

$\dot{A} = a_1 + ja_2$ – algebraik

$\dot{A} = a(\cos\alpha + j\sin\alpha)$ - trigonometrik

$\dot{A} = ae^{j\alpha}$ – ko'rsatkichli



Bunda:

$a_1 = a\cos\alpha = Re\dot{A}$ – haqiqiy son qismi.

$a_2 = a\sin\alpha = Jm\dot{A}$ – mavhum son qismi.

A – kompleks son moduli:

$|A| = \sqrt{a_1^2 + a_2^2}$ α– kompleks son argumenti: $\alpha = arctg\frac{a_2}{a_1}$

Shuningdek: $e^{\pm\pi}/_2 = \pm j$; $\frac{1}{j} = -j$; $j^2 = -1$; $j = \sqrt{-1}$ $j^3 = j\ va\ j^4 = 1$

Kompleks sonlarni qo'shish yoki ayirish amalini bajarishda algebraik ko'rinishda, ko'paytirish va bo'lish amalini bajarishda esa ko'rsatkichli ifodasidan foydalaniladi.

Sinusoidal o'zgaruvchan tok, kuchlanishlar va EYK funksiyasini kompleks ko'rinishdagi ifodasi:

$i = I_m\sin(\omega t + \varphi i) \doteqdot I_m e^{j\omega t} \cdot I_m e^{j\varphi i} = \dot{I}_m e^{j\omega t}$

$u = U_m\sin(\omega t + \varphi u) \doteqdot U_m e^{j\omega t} \cdot U_m e^{j\varphi u} = \dot{U}_m e^{j\omega t}$

$e = E_m\sin(\omega t + \varphi e) \doteqdot E_m e^{j\omega t} \cdot Imee^{j\varphi e} = \dot{E}_m e^{j\omega t}$

Bunda: $\dot{I}_m, \dot{U}_m, \dot{E}_m$ – sinusoidal o'zgaruvchan tok, kuchlanish, va EYK kompleks amplitudasi.

Elektr zanjirni kompleks usulda hisoblash jarayonida faqatgina vaqt funksiyasi tarzida emas, balki uning hosilasi yoki integral tarzida ham uchrashi mumkin.

$\frac{di}{dt} = \omega I_m\sin\left(\omega t + \psi_i + \frac{\pi}{2}\right) \doteqdot \omega I_m e^{j\left(\omega t + \varphi i + \frac{\pi}{2}\right)} = j\omega\dot{I}_m e^{j\varphi i} \cdot e^{j\omega t} = j\omega\dot{I}_m e^{j\omega t}$

$\int idt = \frac{I_m}{\omega}\sin\left(\omega t + \varphi_1 - \frac{\pi}{2}\right) \doteqdot \frac{\dot{I}_m}{\omega} e^{j\left(\omega t + \varphi i - \frac{\pi}{2}\right)} = \frac{\dot{I}_m}{j\omega} e^{j\varphi i} \cdot e^{j\omega t} =$

$= \frac{\dot{I}_m}{j\omega} e^{j\omega t}$

Demak, kompleks shaklda berilgan har qanday sinusoidal funksiya tasviri $\dot{I}me^{j\omega t}$ bo'lsa, bu funksiyadan hosila olish $\ll j\omega \gg$ ko'paytirish yoki integrallash esa $\ll j\omega \gg$ ga bo'lish bilan barobar ekan.

2. Sinusoidal o'zgaruvchan elektr zanjirni kompleks usulda hisoblash.

Om qonunining kompleks ifodasi: $\dot{I} = \frac{\dot{U}}{\underline{Z}} = \underline{Y}\dot{U}$ (A)

To'la qarshilik: $\underline{Z} = R + jx = \underline{Z}e^{j\varphi}$ (Om)

To'la o'tkazuvchanlik: $\underline{Y} = \frac{1}{\underline{Z}} = g - jb = Ye^{-j\varphi}$

To'la quvvat kompleks ifodasi:

$\tilde{S} = \dot{U}I^* = \dot{U}e^{j\varphi i} \cdot Ie^{j\varphi i} = \dot{U}\dot{I}cos\varphi + j\dot{U}\dot{I}sin\varphi = P + jQ$ (VA)

I^* – kompleks tokning burchak fazasini teskari ishorasi bilan olingan qiymati.

Murakkab sinusoidal o'zgaruvchan elektr zanjirni hisoblashda, Om va Kirxgof qonuni bilan bir qatorda Kirxgof qonunini tatbiq etish konturli tok usuli, tugun kuchlanishlar, ustma-ustlik (superpozitsiya) usuli, mutanosiblik prinsipi, ekvivalent generator usullaridan foydalaniladi.

Iste'molchilar ketma-ket ulangan oddiy elektr zanjirlarda tok umumiy bo'lib Om qonuniga asosan.

$\dot{I} = \frac{\dot{U}}{\underline{Z}}$; bunda $\underline{z} = \underline{z}_1 + \underline{z}_2 + \ldots\ldots\ldots \underline{Z}_n = \sum_{b=1}^{n=1} \underline{Z}_n$

Iste'molchilar parallel ulangan elektr zanjirda kuchlanish umumiy bo'lib $\dot{I} = \dot{U}\underline{y}$ bunda $\underline{y} = \underline{y}_1 + \underline{y}_2 + \ldots\ldots\ldots \underline{y}_n = \sum_{b=1}^{n=v} \underline{y}_n$

Aralash sxemada ulangan elektr zanjir uchun kompleks qarshiligi $\underline{Z}_{12} = \frac{\underline{Z}_1 \cdot \underline{Z}_2}{\underline{Z}_1 + \underline{Z}_2}$ bo'lib, tarmoqdagi tok: $\dot{I}_1 = \frac{\underline{Z}_2}{\underline{Z}_1 + \underline{Z}_2}\dot{I}$; $\dot{I}_1 = \frac{\underline{Z}_1}{\underline{Z}_1 + \underline{Z}_2}\dot{I}$.

$\dot{I}$ – umumiy tokning kompleks qiymati. Kirxgof qonunining kompleks ifodasi.

1-qonun; $\sum_{k=1}^{n} \dot{I}_k = 0$

2-qonun; $\sum_{k=1}^{n} \dot{E}_k = \sum_{k=1}^{n} \dot{Z}_k \dot{I}_k$

3. Murakkab sinusoidal o'zgaruvchan elektr zanjirni kompleks usulda hisoblash.

a) Kirxgof qonunini tatbiq qilish.

Murakkab elektr zanjirni Kirxgof qonuniga asosan hisoblashda berilgan zanjir uchun elektr muvozanat tenglamasi tuziladi. Tuzilgan tenglama soni tarmoqdagi tok soniga teng bo'lishi kerak. Agar zanjirning tarmoqlar soni R, tugunlar soni q ga teng bo'lsa, u holda Kirxgof 1-qonuni $(p - q + 1)$ tenglamasi tuziladi. Tenglamalar sistemasini yechish bilan $\dot{I}_1, \dot{I}_2, \ldots\ldots\ldots + \dot{I}_p$ tarmoqdagi tok aniqlanadi.

b) konturli tok usuli.

Konturli tok usuli Kirxgof 2-qonuniga asoslangan bo'lib, berilgan zanjirning kontur uchun tuzilgan tenglamalar sistemasini yechish bilan konturdagi tok va tarmoqdagi tok aniqlanadi.

Umumiy holda konturdagi tok tenglamalar soni $(p - q + 1)$ ga teng bo'ladi.

q – zanjirdagi tugunlar soni

p – tarmoqlar soni

Agar zanjir n ta kontur toklariga ega bo'lsa, uning tenglamasi quyidagicha tuziladi:

$$\left.\begin{aligned} \dot{I}_{k1}\underline{Z}_{11} + \dot{I}_{k2}\underline{Z}_{12} + \ldots\ldots\ldots\ldots + \dot{I}_{kn}\underline{Z}_{1n} = \dot{E}_{11} \\ \dot{I}_{k1}\underline{Z}_{12} + \dot{I}_{k2}\underline{Z}_{22} + \ldots\ldots\ldots\ldots + \dot{I}_{kn}\underline{Z}_{2n} = E_{12} \\ \dot{I}_{k1}\underline{Z}_{n1} + \dot{I}_{k2}\underline{Z}_{n2} + \ldots\ldots\ldots\ldots + \dot{I}_{k1}\underline{Z}_{nn} = \dot{E}_{nn} \end{aligned}\right\}$$

Bunda: $\underline{Z}_{nn}$ – n – konturning xususiy garshiligi $\underline{Z}_{qs}$ – q va S – yon konturning o'zaro qarshiligi.

Agar yondosh konturdagi tokning $\dot{I}_{kq}$ va $\dot{I}_{ks}$ yo'nalishi mos bo'lsa, tarmoqning qarshiligi tenglamalar sistemasiga (+) ishora, qarama-qarshi bo'lsa, (−) ishora kiritiladi. $\dot{E}_{nn}$ – n – konturning xususiy EYK

d) tugun potensiallar usuli.

Tugunlararo kuchlanishlar usulidan foydalanish asosan ko'p elementlardan tarkib topgan tarmoqlangan murakkab elektr zanjirni hisoblashda ancha qulay bo'lib, ixtiyoriy elektr zanjiridagi $q = (n + 1)$ tugundan bittasini nisbiy kuchlanish (potensiali) nolga teng deb olinadi $\varphi_n = 0$. Qolgan barcha tugun potensial tenglamasi shunga nisbatan tuziladi.

$$\left.\begin{aligned} \underline{y}_{11}\dot{U}_{10} + \underline{y}_{12}\dot{U}_{20} + \ldots\ldots\ldots\ldots \underline{y}_{1k}\dot{U}_{ko} = \dot{I}_{11} \\ \underline{y}_{21}\dot{U}_{10} + \underline{y}_{22}\dot{U}_{20} + \ldots\ldots\ldots\ldots \underline{y}_{2k}\dot{U}_{ko} = \dot{I}_{22} \\ \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \\ \underline{y}_{n1}\dot{U}_{10} + \underline{y}_{k2}\dot{U}_{20} + \ldots\ldots\ldots\ldots \underline{y}_{nn}\dot{U}_{ko} = \dot{I}_{nn} \end{aligned}\right\}$$

Bunda:

$$\left.\begin{aligned} \underline{y}_{nn} &= \sum_{\substack{p=1 \\ p\neq n}}^{n} \underline{y}_{pn} \\ \dot{I}_{nn} &= \sum_{\substack{p=1 \\ p\neq n}}^{n} \underline{y}_{pn}\dot{E}_{pn} \end{aligned}\right\}$$

Tenglamalar sistemasini yechish bilan tugun kompleks kuchlanishi:

$\dot{U}_{10}, \dot{U}_{20}, \dot{U}_{n0}$ $\quad (\varphi_1 - \varphi_0;\ \varphi_2 - \varphi_0;\ \varphi_3 - \varphi_{0\ldots\ldots})$

va tugunlar orasidagi kompleks kuchlanishlar aniqlanadi.

$$\dot{U}_{nm} = \dot{U}_{no} - \dot{U}_{m0}$$

Tarmoqdagi tok esa butun zanjir uchun Om qonuniga asosan

$$\dot{I}_{nn} = \underline{y}_{nn}(\dot{E}_{nm} + \dot{U}_{nm})$$

Agar elektr zanjiri faqat ikkita tugundan iborat bo‘lsa $(q = 2)$ tenglama

$$\underline{y}_{nn} \cdot \dot{U}_{10} = \dot{I}_{11}; \qquad \dot{U}_{10} = \frac{\dot{I}_{11}}{\underline{y}_{nn}}$$

Ya’ni, tugunlararo kuchlanish tenglamasiga asosan ikkita tugun o‘rtasidagi kuchlanish aniqlanib, Om qonuniga asosan tarmoqlardagi tok topiladi.

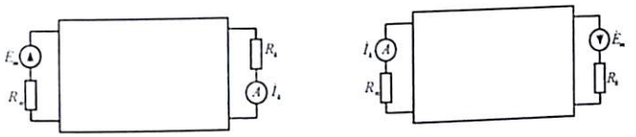
$$\dot{U}_{ab} = \frac{\underline{y}_1\dot{E}_1 + \underline{y}_2\dot{E}_2 + \underline{y}_3\dot{E}_3 + \ldots\ldots\ldots + \underline{y}_n\dot{E}_n}{\underline{y}_1 + \underline{y}_2 + \underline{y}_3 + \ldots\ldots\ldots \underline{y}_n} = \frac{\sum_{p=1}^{n} \underline{y}_n\dot{E}_n}{\sum_{p=1}^{n} \underline{y}_n}$$

e) ustma-ustlik (superpozitsiya) usuli.

Parametrlari chiziqli bo‘lgan elektr zanjirning biror K tarmog‘idan o‘tuvchi tok shu zanjirni tashkil etuvchi EYK hosil qiladigan tokning yig‘indisidan iborat bo‘ladi. Shu sababli chiziqli murakkab elektr zanjirni hisoblashda, har bir EYK ta’sirida zanjir tarmoqlaridan o‘tuvchi tok alohida aniqlanadi (qolgan EYK nolga teng deb olinib, zanjirning ichki qarshiligi saqlanadi). Natijada har bir EYK ta’sirida tarmoqdan o‘tuvchi tokning algebraik yig‘indisi umumiy tok qiymatiga teng bo‘ladi:

$$\dot{I} = \dot{I}' + \dot{I}'' + \ldots\ldots\ldots + \dot{I}_K''$$

Ustma-ustlik usuli yordamida faqatgina zanjirdagi tok va kuchlanish aniqlanib, quvvatni hisoblashda tavsiya etilmaydi.



f) mutanosiblik prinsipi.

Bu prinsip chiziqli elektr zanjir uchun Maksvell tomonidan taklif etilgan bo‘lib, har qanday murakkab elektr zanjirning (K) tartibida joylashgan $\dot{E}_K = \dot{E}$ EYK manba (boshqa manbalar bo‘lmagan holda), shu zanjirning ixtiyoriy p tarmog‘ida $\dot{I}_n = \dot{I}$ tok hosil qilgan bo‘lsa, shu EYK manbaning o‘zi n tarmoqqa ko‘chirilgan holda $\dot{E}_K = \dot{E}$ (K) tarmoqdagi tokni hosil qiladi.

Masalan: Konturli tok usuliga asosan k tarmoq zanjirining q konturiga, n tarmog‘i S konturiga kirgan deb faraz qilamiz. Bu holda konturda kontur toklari $\dot{I}_k = \dot{I}_q$ va $\dot{I} = \dot{I}_3$ bo‘ladi va EYK qaysi tarmoqqa ulanganidan qat’i nazar, ularning qiymati $\dot{I}_k = \dot{I}_q = \dot{E}\frac{\Delta_{qs}}{\Delta}$ va $\dot{I}_n = \dot{I}_s = \dot{E}\frac{\Delta_{qs}}{\Delta}$ ga teng bo‘ladi.

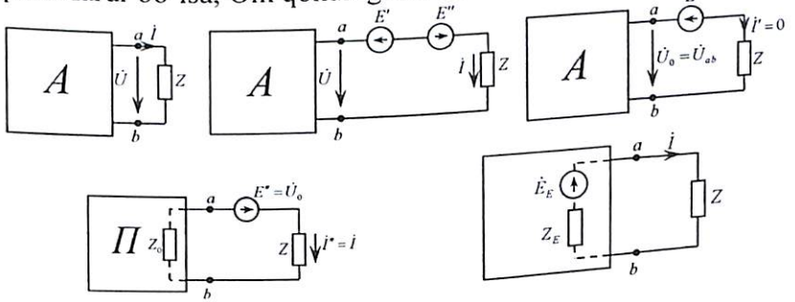
Demak: $\dot{I}_k = \dot{I}_n = \dot{I}$, chunki $\Delta_{qs} = \Delta_{sq}$ bo‘lib, $\frac{\dot{E}_k}{\dot{I}_n} = \frac{\dot{E}_n}{\dot{I}_k} = \frac{\dot{E}}{\dot{I}} = Z - qs$

konturlararo qarshilik $Z - qs$ ga teng bo‘lib, ushbu usulning mutanosibligini tasdiqlaydi.

g) ekvivalent generator usuli.

Bu usul murakkab elektr zanjirining biror qismidagi tarmoq tokini aniqlashda qulay bo‘lib, amalda qisqa tutashtiruv yoki uzilish (salt holat) tajribalari o‘tkaziladi. Elektr energiyasi bo‘lgan ikki qutbli elektr zanjir ekvivalent manba va parametr bilan almashtiriladi. Bunda zanjir manba kuchlanish salt holat kuchlanishiga teng bo‘ladi. $\dot{E} = \dot{U}_0 = \dot{U}_{ab}$ ichki qarshilik esa ekvivalent qarshilikga teng $Z_0 = Z_E$

Ikki qutbli aktiv zanjirning biror (K) tarmoqdagi R qarshilik tokni aniqlash zarur bo‘lsa, Om qonuniga asosan.

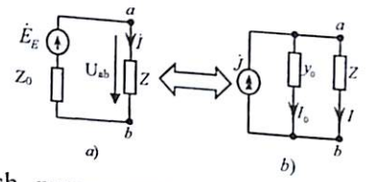


4. EYK manbaini tok manbaiga almashtirish.

Amalda EYK va tok manbaini almashtirishga imkon beruvchi, noldan farq qiladigan ichki parametrlar $R \neq 0$ va $g \neq 0$ mavjud; ularni o'zaro almashtirish mumkin. (a) manba kuchlanish tenglamasi:

$$\dot{U}_{ab} = \dot{E} - \underline{Z}_0 \dot{I}$$

Ba'zi hollarda manba kuchlanishi parallel sxema bilan almashtirilib tok manbai ko'rinishida ham ifodalanadi (b) .



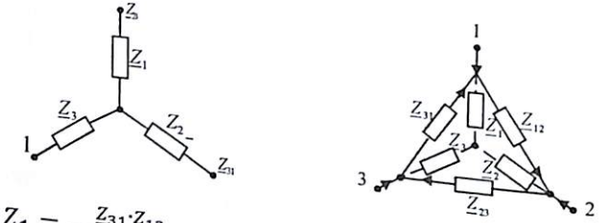
Bunda kuchlanish muvozanat tenglamasi manba qarshiligi Z_0 ga bo'linsa

$$\frac{\dot{U}_{ab}}{Z_0} = \frac{\dot{E}}{\underline{Z}_0} - \dot{I};$$

$\dot{J} = \frac{\dot{E}}{\underline{Z}_0}$; $\underline{Y}_0 = \frac{1}{\underline{Z}_0}$ teng ekanligidan $\dot{I}_0 = \dot{J} - \dot{I}$

Yulduzcha va uchburchak tarzida ulangan tarmoqlarni o'zaro almashtirish (ekvivalent parametrlar)

a) uchburchak shaklida ulangan qarshiliklarni yulduzcha shaklida almashtirish tenglamalari



$$\underline{Z}_1 = \frac{\underline{Z}_{31} \cdot \underline{Z}_{12}}{\underline{Z}_{12}+\underline{Z}_{31}+\underline{Z}_{23}}; \quad \underline{Z}_2 = \frac{\underline{Z}_{12} \cdot \underline{Z}_{23}}{\underline{Z}_{12}+\underline{Z}_{23}+\underline{Z}_{31}}; \quad \underline{Z}_3 = \frac{\underline{Z}_{23} \cdot \underline{Z}_{31}}{\underline{Z}_{12}+\underline{Z}_{23}+\underline{Z}_{31}};$$

b) yulduzcha shaklidan uchburchak shakliga almashtirish tenglamalari:

$$\underline{Z}_{12} = \underline{Z}_1 + \underline{Z}_2 + \frac{\underline{Z}_1 \cdot \underline{Z}_2}{\underline{Z}_3}; \quad \underline{Z}_{23} = \underline{Z}_2 + \underline{Z}_3 + \frac{\underline{Z}_2 \cdot \underline{Z}_3}{\underline{Z}_1};$$

$$\underline{Z}_{31} = \underline{Z}_3 + \underline{Z}_1 + \frac{\underline{Z}_1 \cdot \underline{Z}_3}{\underline{Z}_2};$$

3.2. Masalalar yechish va uslubiy ko'rsatmalar

3.1-Masala. Berilgan kuchlanish va tok $u = 100 \sin\left(\omega t + \frac{\pi}{6}\right)$ (V). $i = 5 \sin\left(\omega t + {}^{\pi}/_{6}\right)$ funksiyalarining kompleks ifodasi, kompleks to'la qarshilik , $\underline{Z}$ to'la o'tkazuvchanlik $\underline{Y}$ va to'la quvvat $\tilde{S}$ aniqlansin.

Yechish:

$u = 100 \sin(\omega t + 30°) \div 100e^{j30°}$ $i = 5 \sin(\omega t - 30°) \div 5e^{-j30°}$

Kompleks to'la qarshilik:

$$Z = \frac{\dot{U}_m}{\dot{I}_m} = \frac{100e^{j30°}}{5e^{-j30°}} = 20e^{j60°} = 10 + j17{,}3 \quad (Om)$$

Kompleks to'la o'tkazuvchanlik: $\underline{Y} = \frac{1}{\underline{Z}} = 0{,}1 + j0{,}06$ $\left(\frac{1}{Om}\right)$

Kompleks to'la quvvat: $\underline{\tilde{S}} = \dot{U}I^* = \dot{U} \cdot \dot{I}e^{j(\varphi_U - \varphi_I)} = 500e^{j60°} = 500 \cos 30° + j500 \sin 60° = 250 + j430$ (VA)

Bundan aktiv quvvat: $P = 250\,Vt$; Reaktiv quvvat: $Q = 430\,(VAR)$.

3.2-Masala. Qarshiligi $R = 3\,Om, X = \pm 4\,Om$ bo'lgan elektr zanjir kuchlanishi $U = 100\,V$. Tok va to'la quvvat kompleks qiymati hisoblab topilsin.

Yechish. To'la qarshilik kompleks ifodasi:

$$\underline{Z} = R \pm jx = 3 \pm j4 = 5e^{\pm j53°}$$

Tok: $\dot{I} = \frac{\dot{U}}{\underline{Z}} = \frac{100e^{j0}}{5e^{\pm j53°}} = 20e^{\pm j53°} = 12 \pm j16$

To'la quvvat kompleks ifodasi:

$\tilde{S} = \dot{U}I^* = 100 \cdot 205e^{\pm j53°} = 2000 \cos 53° \pm j2000 \sin 53° = 1200 \pm j1600$ (BA)

3.3-Masala. Kuchlanish $\dot{U} = (80 + j60)$ tok $\dot{I} = (24 - j7)$ kompleks ifodalari uchun aktiv va reaktiv qarshilik qiymati aniqlanib, tok va kuchlanish vektor ifodasi chizilsin.

Yechish. Tok va kuchlanish ko'rsatkichli ifodasi aniqlanadi

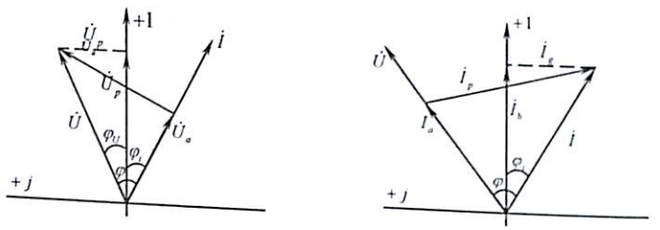
$\dot{U} = (80 + j60) = 100e^{j36°50'}$ (V) $\dot{I} = (24 - j7) = 25e^{j16°15'}$ (A)

Kompleks to'la qarshilik: $\underline{Z} = \frac{\dot{U}}{\dot{I}} = 4e^{j53°} = (2{,}4 \pm j3{,}2)\,(Om)$

Bundan aktiv qarshilik $R = 2{,}4\,Om$; reaktiv qarshilik $X = 3{,}2\,Om$.

Kuchlanish va tok orasidagi fazadagi farq: $\varphi = \varphi_u - \varphi_I = 53°$

Kompleks tekislikda tok va kuchlanishlar vektor ifodasini tuzamiz.

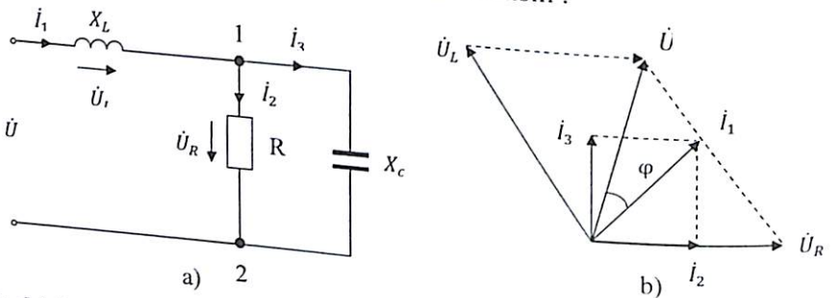


Vektor diagrammadan:

$\dot{U}_a = U\cos\varphi$ $\qquad \dot{I}_a = I\cos\varphi$

$\dot{U}_p = U\sin\varphi;\ U = \sqrt{U_a^2 + U_p^2}$ $\qquad \dot{I}_p = I\sin\varphi;\qquad I = \sqrt{I_a^2 + I_p^2}.$

3.4-Masala. Zanjir qarshiliklari $x_L = x_c = \mathrm{R} = 10\ \Omega$ teng bo'lib, u=100sin ωt sinusoidal kuchlanishga ulangan. Kompleks tok va to'la quvvat qiymatlari aniqlanib, vektor ifodasi tuzilsin .



a) 2 b)

Yechish: Kuchlanish kompleks ifodasi: u = 100sin ωt $\div$ $\dot{U}$=100 $e^{j\varphi}$

Tarmoq toklari: $\dot{I}_1 = \frac{\dot{U}}{jX_L + \frac{-RjX_c}{R-jX_c}} = \frac{100(R-jX_c)}{RjX_L - X_LX_C - RjX_C} = \frac{1000-j1000}{j100-100-j100} = -10$

$+\mathrm{j}10 = 10 - \mathrm{j}10 = \frac{10e^{-j45^0}}{\sqrt{2}}$ $\qquad \dot{I}_3 = \dot{I}_1 \frac{R}{R-jX_c} = \frac{100e^{-j45^0}}{10-j10} = 10$

Kirxgofning I qonuniga asosan: I^*

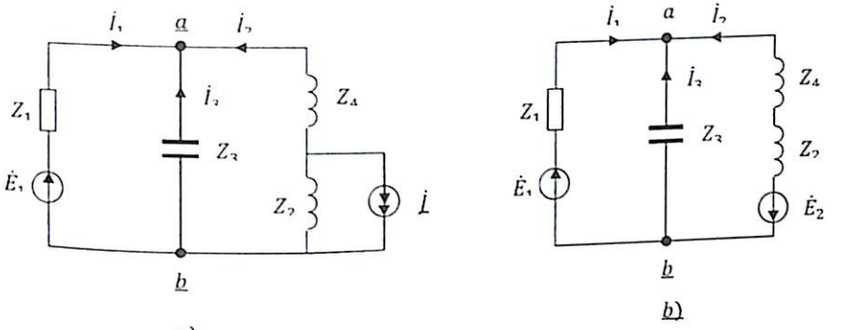
$\dot{I}_2 = \dot{I}_1 \frac{X_C}{R-jX_C} = \frac{10e^{-j45^0} * 10e^{-j90^0}}{10-j10} = \frac{100e^{-j135^0}}{10e^{-j45^0}} = 10\ e^{-j90^0} = -\mathrm{j}10$

To'la quvvat: $\tilde{S} = \dot{U}I^* = 1000e^{j45^0} = 1000 + \mathrm{j}1000 = \mathrm{P} + \mathrm{jQ}$

Demak, aktiv quvvat P =1000 Wt reaktiv quvvat Q =1000 VAR

Vektor ifodasi b) rasmda chizilgan.

3.5-Masala. Zanjir parametrlari: $Z_1 = 10\ om,\ Z_2 = 5\ om,\ Z_3 = 10\ om,\ Z_4 = 5\ om,\ \dot{E}_1 = 15\ mV,\ \dot{J} = 5\ mA$ bo'lib, tok $\dot{J}$, $\dot{E}_1$ – $EYUK$ ga nisbatan $\varphi = 90^0$ orqada qoladi. Tarmoq toklari topilsin.



a) b)

Yechish: Tok manbai $\dot{J}$ ni EYUK manbai E_2 bilan almashtiramiz. Masalaning shartiga asosan; $\dot{J} = -j5\ mA$, demak $\dot{E}_2 = -Z_2\dot{J} = -j25\ mV$ bo'lib, ekvivalent sxemasi b)- rasm.

Ikki tugun potensiallar usuliga asosan:

$$\dot{U}_{ab} = \frac{\sum \dot{E}_n Y_n}{\sum Y_n} = \frac{\dot{E}_1Y_1 - \dot{E}_2Y_2}{Y_1 + Y_2 + Y_3} = \frac{15 \cdot 0{,}1 - j25 \cdot (-j0{,}2)}{0{,}1 - j0{,}2 + j0{,}1} = 15 + j25$$

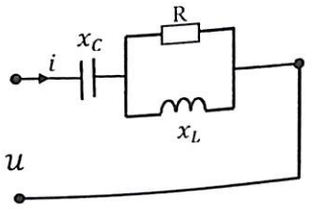
bunda $y_1 = \frac{1}{Z_1} = \frac{1}{10}\ (sim),\ y_2 = y_4 = \frac{1}{j10}\ (sim),\ y_3 = \frac{1}{-j10}\ (sim)$

Tarmoq toklari: $\dot{I}_1 = (\dot{E}_1 - \dot{U}_{ab}) \cdot y_1 = -j2{,}5\ mA$

$\dot{I}_2 = (-\dot{E}_2 - \dot{U}_{ab}) \cdot y_2 = (-2{,}5 + j4)\ mA$

$\dot{I}_3 = (-\dot{U}_{ab}) \cdot y_3 = (2{,}5 - j1{,}5)\ mA$

3.6-Masala. Elektr zanjir parametrlari: $R = x_L = x_C = 10\ Om$ bo'lib $u = 282\ \sin(314t + 60°)$ kuchlanishga ulnganda. Kompleks umumiy qarshiligi $\underline{Z}$, tokning oniy qimati i, to'la quvvati $\tilde{S}$ xisoblab topilsin.



Yechish: Zanjir to'la kompleks qarshiligi:

$$\underline{Z} = -jx_C + \frac{R \cdot jx_L}{R \cdot jx_C} = -j10 + \frac{j100}{10 + j10} = -j10 + 10 + j10 = 10\ Om$$

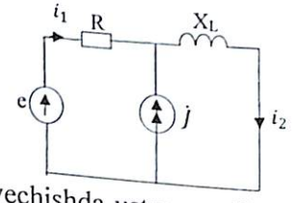
Kompleks tok: $\dot{I} = \frac{\dot{U}}{Z} = \frac{282e^{j60^\circ}}{10} = 28.2e^{j60^\circ} = 14.1 + j31.4 \quad (A)$

Tokning oniy qiymati: $i = 28.2\ \sin(314t + 60^\circ)$

Kompleks quvvat: $\tilde{S} = \dot{U} \cdot I^* = Ue^{j60} \cdot Ie^{-j60^\circ} = 282 \cdot 28.2 = 7952.4\ BA$

Demak: $\tilde{S} = P + jQ = P = 7952.4$ Vt aktiv quvvatga teng bo'lar ekan.

3.7-Masala. Zanjir parametrlari R=X_L=10 Om bo`lib, e=$100\sqrt{2}\sin\omega t\ V$, va $j = 10\sqrt{2}\sin(\omega t + 90^\circ)A$ ulangan bo`lganda i_1 va i_2 toklarning oniy qiymatlari topilsin.



Yechish: Masalani yechishda ustma-ustlik usulidan foydalanamiz; İ'- tokni topish uchun e=0 desak j-tok manbaini uzatamiz :

$$\dot{I}_1' = \dot{I}_2' = \frac{E}{R + jX} = \frac{100\ e^{j0}}{10 + j10} = 5\sqrt{2}e^{-j45^0}$$

j-tok manbai ta`siridagi toklar:

$$\dot{I}_1'' = -j\frac{jX}{R + jX} = -10e^{j90^0} \cdot \frac{10e^{j90^0}}{10 + j10} = 5\sqrt{2}e^{-j45^0}$$

$$\dot{I}_2'' = j\frac{jX}{R + jX} = 10e^{j90^0} \cdot \frac{10}{10 + j10} = 5e^{j45^0}$$

Haqiqiy tok qiymatlari:

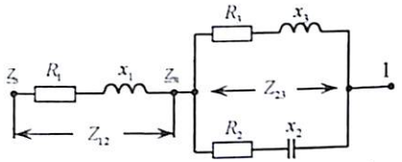
$$\dot{I}_1 = \dot{I}_1' + \dot{I}_1'' = 5\sqrt{2}e^{-j45^0} + 5\sqrt{2}e^{-j45^0} = 10\sqrt{2}\ e^{-j45^0}$$

$$\dot{I}_2 = \dot{I}_2' + \dot{I}_2'' = 5\sqrt{2}e^{-j45^0} + 5\sqrt{2}e^{j45^0} = 10\sqrt{2}\ e^{j0}$$

Toklarning oniy qiymatlari:

$i_1 = 10\sqrt{2}\sin(\omega t - 45^\circ)$; $\quad i_2 = 10\sqrt{2}\sin\omega t$.

3.8-Masala. Elektr zanjir parametri: $R_1 = 30\ Om, X_1 = 20\ Om, R_2 = 50Om,\ X_2 = -100\ Om, R_3 = 100\ Om, X_3 = 50\ Om$ ga teng bo`lganda, ekvivalent to'la, aktiv, reaktiv qarshilik qiymati topilsin.



Yechish. Zanjirning parallel ulanlgan qismi uchun kompleks to'la qarshilik:

$$\underline{Z}_{23} = \frac{(R_3 + jx_3)(R_2 + jx_2)}{R_3 + jx_3 + R_2 - jx_2} = \frac{112e^{j26^\circ 30} \cdot 112e^{-j63^\circ}}{150 - j50} = \frac{12250e^{-j37^\circ}}{150e^{-j18^\circ 26'}}$$

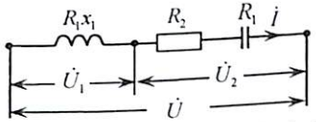
$$= 79{,}5e^{j18^\circ 26'} = 75{,}2 - j25{,}3$$

Endi umumiy kompleks ekvivalent qarshilikni topish uchun to'la kompleks qarshilikni qo'shamiz:

$$\underline{Z} = R_1 + jx_1 + \underline{Z}_{23} = 30 + j20 + 75{,}2 - j25{,}3 = 105{,}5 - j5.3$$

Bundan aktiv qarshilik $R = 105{,}5\ Om$, reaktiv qarshilik $X_C = -5{,}3\ Om$ ga teng bo'lib, sig'im parametriga mos keladi.

3.9-Masala. Qarshiligi $R_1 = 10\ Om, X_1 = 50\ Om$ bo'lgan induktiv g'altak, aktiv qarshiligi $R_2 = 10m$ va sig'im qarshiligi $X_2 = -30\ Om$ bilan ketma-ket sxemaga biriktirilib va $U = 127\ V$ kuchlanishga ulangan. Zanjirdan o'tuvchi tok, g'altakdagi kuchlanish va sig'im kuch-lanishlari aniqlansin.



Yechish. Qarshilikning kompleks ifodasini yozamiz:

$\underline{Z}_1 = 10 + j50 = 51e^{j78^\circ 40'}$ $\quad \underline{Z}_2 = 1 - j30 = 30e^{-j88^\circ}$ (Om)

Umumiy kompleks qarshilik: $\underline{Z} = \underline{Z}_1 + \underline{Z}_2 = 11 + j20 = 22{,}8e^{j61^\circ}$

Kompleks tok: $\dot{I} = \frac{\dot{U}}{\underline{Z}} = \frac{127}{22{,}8e^{j61^\circ}} = 5{,}56e^{-j61^\circ}$

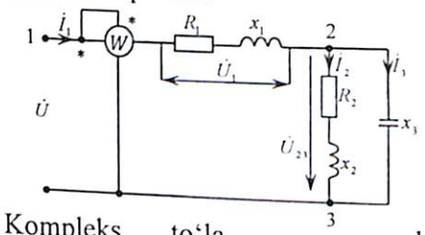
G'altakdagi kuchlanish: $\dot{U}_1 = \underline{Z}_2\dot{I} = 284e^{j17^\circ 30'}$ yoki $\varphi_1 = -17^\circ 30'$

Sxemadagi kuchlanish:

$\dot{U}_2 = \underline{Z}_2\dot{I} = 30e^{-j88^\circ} \cdot 5{,}56e^{-j61^\circ} = 167e^{-j149^\circ}$; $\varphi_2 = -149^\circ$

Kuchlanishlar orasida fazadagi farq: $\varphi = \varphi_1 - \varphi_2 166^\circ 30'$

3.10-Masala. 2.23-masala shartiga asosan kompleks usuldan foydalanib tarmoq toklari aniqlansin.



Yechish. Kompleks to'la qarshilik:

Bunda: $\underline{Z}_1 = (2 + j26)\ Om$ $\underline{Z}_2 = (10 + j10)\ Om$ $\underline{Z}_3 = -j26\ Om$

Zanjirning qarshiliklari parallel ulangan qismi uchun:

$$\underline{Z}_{23} = \frac{\underline{Z}_2\underline{Z}_3}{\underline{Z}_2 + \underline{Z}_3} = (10 - j10)\ (Om)$$

Zanjirning umumiy kompleks qarshiligi

$$\underline{Z} = \underline{Z}_1 + \underline{Z}_{23} = (2 + j26) + (10 - j10) = (12 + j16)\ Om$$

Aktiv quvvat ifodasidan $P = {I_2}^2 R$, zanjiriga kiruvchi tok:

$$I_1 = \sqrt{\frac{P}{R_1}} = \sqrt{\frac{1200}{12}} = 10\ A,$$ ya'ni $I_1 = 10\ A$ teng va haqiqiy qiymatga ega. Zanjirdagi umumiy kuchlanish:

$$\dot{U} = I_1\underline{Z} = (12 + j16) \cdot 10 = (120 + j160)\ V$$

Bundan: $U = \sqrt{120^2 + 160^2} = 200\ V$

Parametrlari ketma-ket ulangan qismdagi kuchlanish:

$$\dot{U}_1 = \underline{Z}_1\dot{I}_1 = (2 + j26) \cdot 10 = (20 + j260$$

yoki: $U_1 = \sqrt{20^2 + 260^2} = 261\ V$

Parallel sxemada ulangan qismdagi kuchlanish:

$$\dot{U}_{23} = \dot{I}\underline{Z}_{23}(10 + j10) \cdot 10 = (100 + j100)V$$

yoki: $U_{23} = \sqrt{100^2 + 100^2} = 100\sqrt{2}$ V

Tarmoqdagi tok: $\dot{I}_2 = \frac{\dot{U}_{23}}{\underline{Z}_1} = \frac{100e^{-j45°}}{10e^{j45}} = 10e^{-j90°} = (-j10)\ A$

yoki: $I_2 = 10\ A$

$$\dot{I}_3 = \frac{\dot{U}_{23}}{\underline{Z}_3} = \frac{100e^{-j45°}}{10e^{j90}} = 100e^{-j45°} = (10 + j10)\ A$$

yoki: $I_3 = \sqrt{10^2 + 10^2} = 14{,}1\ A$

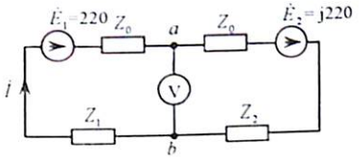
To'la quvvat $\tilde{S} = \dot{U}I^* e^{j\varphi i} = 12000 + \text{j}1600$ Ba

Masalaning yechimini tekshiramiz:

$$\dot{I}_1 = \dot{I}_2 + \dot{I}_3 = -j10 + 10 + j10 = 10\ A$$

3.11-Masala. Kompleks qarshiliklari:

$\underline{Z}_0 = (3 + j4)$; $\underline{Z}_1 = (44 + j74)$ $\underline{Z}_2 = -j80$ bo'lgan elektr zanjir ketma-ket sxemada ikkita generatorga ulangan bo'lib, tok qiymati va voltmetr kuchlanishi aniqlansin.



Yechish. Zanjirdagi tok: $\dot{I} = \frac{\dot{E}_1 + \dot{E}_2}{2\underline{R}_0 + \underline{Z}_1 + \underline{Z}_2} = \frac{220 + j220}{(6+j8)+(44+j74)+(-j80)} = \frac{220e^{j45}}{50+j2} \approx\approx 4{,}4e^{j45} = (4{,}4 + j4{,}4)$

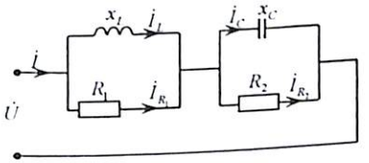
yoki: $I = \sqrt{4{,}4^2 + 4{,}4^2} \approx 6\ A$

Voltmetrdagi kuchlanish: ikki tugun potensiallar tenglamasidan:

$$\dot{U}_{ab} = \frac{\dot{E}_1 + \dot{E}_2(\underline{Z}_0 + \underline{Z}_1)}{2\underline{Z}_0 + \underline{Z}_1 + \underline{Z}_2} = \frac{220 + j220[(3+j4)+(4+j74)]}{(6+j8)+(44+j74)+(-j80)} = 335 - j547$$

Bundan: $U_{ab} = \sqrt{335^2 - 547^2} = 642\ V$

3.12-Masala. Elektr zanjir qarshiliklari: $R_1 = R_2 = 25Om, X_L = 33{,}3\ Om, X_C = -33{,}3Om$ bo'lib, $U = 320V$ kuchlanishga ulangan. To'la qarshilik Z, burchak $\cos\varphi$ va toklari aniqlansin.



Yechish: Parallel ulangan birinchi kontur to'la qarshiligi:

$$\underline{Z}_1 = \frac{33{,}3e^{j90°} \cdot 25}{25 + j33{,}3} = \frac{830e^{j90°}}{41{,}5e^{j53°}} = 20e^{j37°} = 16 + j12\ Om$$

Ikkinchi kontur to'la qarshiligi:

$$\underline{Z}_1 = \frac{33{,}3e^{j90°} \cdot 25}{25 - j33{,}3} = \frac{830e^{-j90°}}{41{,}5e^{-j53°}} = 20e^{-j37°} = 16 - j12\ Om$$

To'la kompleks qarshiligi: $\underline{Z} = \underline{Z}_1 + \underline{Z}_2 = 16 + j12 + 16 - j12 = 32\ Om$

Umumiy tok: $\dot{I} = \frac{\dot{U}}{\underline{Z}} = \frac{320}{32} = 10\ A$

To'la quvvat: $\tilde{S} = \dot{U}I^* = 320 \cdot 10 = 3200\ VA$

Aktiv quvvat: $P = RI_2{}^2 = 32 \cdot 102 = 3200\,Vt$

Zanjirning quvvat koeffitsienti: $\cos\varphi = \frac{P}{S} = 1$ bo‘lib, aktiv qarshilik xarakteriga ega.

Birinchi va ikkinchi kontur kuchlanishlar:

$$\dot{U}_1 = \dot{I}\underline{Z}_1 = 10 \cdot 20e^{j37^\circ} = 200e^{j37^\circ}(\text{V})$$
$$\dot{U}_2 = \dot{I}\underline{Z}_2 = 10 \cdot 20e^{-j37^\circ} = 200e^{-j37^\circ}(\text{V})$$

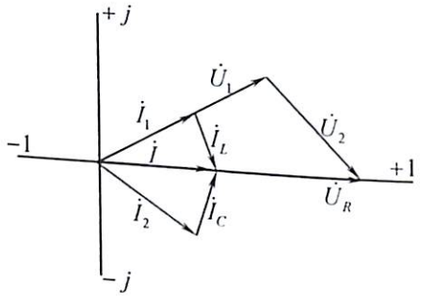
Tokni aniqlaymiz:

$\dot{I}_1 = \frac{\dot{U}_1}{R_1} = \frac{200e^{-j37^\circ}}{25} = 8e^{j37^\circ}\text{A}$ $\quad \dot{I}_L = \frac{\dot{U}_L}{X_L} = \frac{200e^{j37^\circ}}{33{,}3e^{j90^\circ}} = 6e^{-j53^\circ}\text{A}$

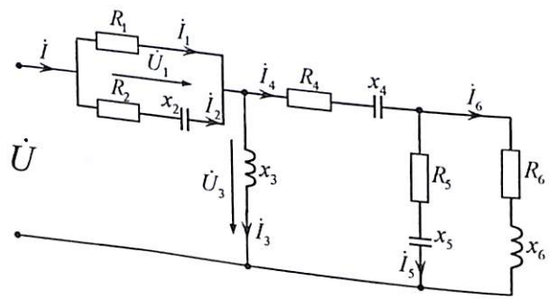
Ikkinchi konturdagi tokni aniqlaymiz:

$\dot{I}_2 = \frac{\dot{U}_2}{R_2} = \frac{200e^{-j37^\circ}}{25} = 8e^{-j37^\circ}\text{A}$ $\quad \dot{I}_C = \frac{\dot{U}_C}{X_C} = \frac{200e^{-j37^\circ}}{33{,}3e^{-j90^\circ}} = 6e^{j53^\circ}\text{A}$

Kompleks tekislikda tok va kuchlanish vektor ifodasi:



3.13-Masala. Berilgan elektr zanjir parametri: $R_1 = 50\,Om, X_2 = -25\,Om, R_2 = 25\,Om, X_3 = 10\,Om, R_4 = 2{,}5\,Om, X_4 = -5Om, R_5 = 1\,Om, X_5 = -2\,Om, R_6 = 1\,Om, X_6 = 2\,Om$ bo‘lib, U=100 V kuchlanishga ulangan.Tarmoqdan o‘tuvchi $\dot{I}_1, \dot{I}_3$ va $\dot{I}_4$ kompleks tok qiymatlari aniqlansin.



Yechish. Tarmoq kompleks qarshiligi aniqlanadi:

$\underline{Z}_6 = R_6 + jX_6 = 1 + j2 = e^{j63^\circ}$ $\quad \underline{Z}_5 = R_5 - jX_5 = 1 - j2 = e^{-j63^\circ}$

Parallel ulangan tarmoq kompleks qarshiligi:

$$\underline{Z}_{56} = \frac{\underline{Z}_6 \cdot \underline{Z}_5}{\underline{Z}_6 + \underline{Z}_5} = 2{,}5\,Om$$

To‘rtinchi tarmoq kompleks qarshiligi:

$\underline{Z}_4 = R_4 - jX_4 + \underline{Z}_{56} = 2{,}5 - j5 + 2{,}5 = 5 - j5 = 7{,}1e^{-j45^\circ}Om$

Uchinchi tarmoq kompleks qarshiligi:

$$\underline{Z}_3 = \frac{\underline{Z}_4 \cdot \underline{Z}_3}{\underline{Z}_4 + jX_4} = \frac{71e^{-j45^\circ} \cdot 10e^{j90^\circ}}{5 - j5 + j10} = 10\,Om$$

Parallel ulangan birinchi kontur kompleks qarshiligi:

$$\underline{Z}_{12} = \frac{R_1(R_2 - jX_2)}{R_1 + R_2 - jX_2} = 20{,}6 - j10{,}3 = 23e^{-j26^\circ30'}\,Om$$

Zanjirning kompleks to‘la qarshiligi:

$\underline{Z} = \underline{Z}_{12} + \underline{Z}_3 = 20{,}6 + j10{,}3 + 10 = 30{,}6 - j10{,}3 = 32{,}4e^{-j12^\circ}\,Om$

Zanjirga kiruvchi tok qiymati:

$$\dot{I} = \frac{\dot{U}}{\underline{Z}} = \frac{100}{32{,}4e^{-j12^\circ}} = 3{,}1e^{j18^\circ} = 3 + j\,A$$

Tarmoqdagi kuchlanish:

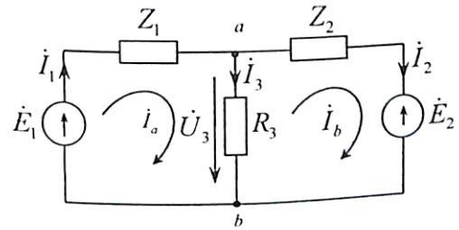
$\dot{U}_{R1} = \dot{I}R_{12} = 3{,}1e^{j18^\circ} \cdot 23e^{-j26^\circ30'} = 71{,}5e^{-j8^\circ30'} = 70{,}5 - j10{,}5\,V$

$\dot{U}_{X1} = \dot{U} - \dot{U}_{R1} = 100 - 70{,}5 + j10{,}5 = 29{,}5 + j10{,}5 = 31{,}5e^{j19^\circ30'}\,V$

Tarmoqdagi tok :

$$\dot{I} = \frac{\dot{U}_{X3}}{jX_3} = \frac{31{,}5e^{j19^\circ30'}}{10e^{j90^\circ}} = 3{,}15e^{-j70^\circ30'} = -j3 + 1\,A$$
$$\dot{I}_4 = \dot{I}_1 + \dot{I}_3 = 3 + j - 1 + j3 = 2 + j4\,A$$

3.14-Masala. Ikki konturli elektr zanjirga ichki qarshiliklari $Z_1 = Z_2 = 1 + j2\,Om$; EYK $E_1 = 120\,V, E_2 = 115\,V$ ga teng. Ikkita generator o‘rtasidagi qarshiligi $R_3 = 10\,Om$ bo‘lgan iste’molchi ulangan. Tarmoqdagi tok va kuchlanishlari har xil usullar yordamida hisoblansin.



Yechish.

1. Konturli tok usuli.

Berilgan zanjir ikkita konturdan iborat bo'lib, tarmoq va konturdagi tok yo'nalishini shartli ravishda belgilab olamiz. EYK yo'nalishini hisobga olgan holda $\dot{I}_a, \dot{I}_b$ konturlar uchun ikkita tenglama tuzamiz.

$$\dot{I}_a(\underline{Z}_1+\underline{Z}_3)-\dot{I}_b\underline{Z}_3=\dot{E}_1 \quad \dot{I}_b(\underline{Z}_2+\underline{Z}_3)-\dot{I}_a\underline{Z}_3=\dot{E}_1$$

Tenglamalar sistemasini yechish bilan konturdagi tok aniqlanadi:

$$\left.\begin{aligned}\dot{I}_a(11+j2)-\dot{I}_b 10=120\\ \dot{I}_b(11+j2)-\dot{I}_a 10=-115\end{aligned}\right\}^{10}_{(11+j2)}$$

$$\dot{I}_b(11+j2)(11+j2)-100\dot{I}=1200-115(11+j2)$$

Bundan: $\dot{I}_b(-5{,}04-j0{,}47)\ A$

Birinchi tenglamadan: $\dot{I}_a=\frac{120+\dot{I}_b 10}{11+j2}$

Birinchi generatordagi tok konturdagi tok qiymatiga teng:

$\dot{I}_1=\dot{I}_2=(6{,}05-j1{,}53)A$ yoki $I_1=\sqrt{(6{,}05)^2+(-1{,}53)^2}=6{,}24\ A$

Ikkinchi generatordagi tok:

$\dot{I}_2=\dot{I}_b=(-5{,}04-j0{,}47)A$ yoki $\dot{I}_2=\sqrt{(-5{,}04)^2+(-0{,}47)^2}=5{,}28\ A$

Iste'molchidagi tok:

$\dot{I}_3=\dot{I}_a-\dot{I}_b=\dot{I}_1-\dot{I}_2=(6{,}05-j1{,}53)-(-5{,}04-j0{,}47)=(11{,}09+j1{,}06)$

yoki $\dot{I}_3=\sqrt{(11{,}09)^2+(1{,}06)^2}=11{,}14\ A$

Iste'molchidagi va generatordagi kuchlanish:

$$\dot{U}_3=\dot{I}_3R_3=(11{,}09-j1{,}06)\cdot 10=(110{,}9-j10{,}6)\ V$$

$$U_3\sqrt{(11{,}09)^2+(1{,}06)^2}=11{,}14\ V$$

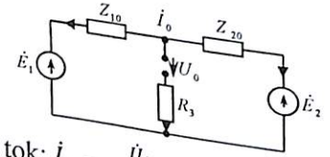
2. Ekvivalent generator usuli.

Zanjirning iste'molchi ulangan tarmog'i uzilgan bo'lsa.

Bunda:

$$\dot{U}_0=\dot{E}_1-\dot{I}_0\underline{Z}_1=\dot{E}_1\frac{(\dot{E}_1-\dot{E}_2)}{\underline{Z}_1+\underline{Z}_2}\underline{Z}_1=120-\frac{120-115}{2(1+j2)}(1+j2)=117{,}5\ V$$

Uzilgan holatda zanjirning ichki qarshiligi $(\dot{E}_1=0,\ \ \dot{E}_2=0)$ ya'ni, ekvivalent generator qarshiligi: $Z_e=\frac{Z_1Z_2}{\underline{Z}_1+\underline{Z}_2}=(0.5+j1)\ Om.$



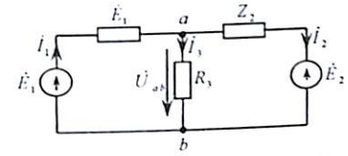
Iste'molchidagi tok: $\dot{I}_3=\frac{\dot{U}_0}{R_3+Z_e}=\frac{117{,}5}{10+(0{,}5+j1)}=(11{,}09-j1{,}06)A$

$$\dot{I}_3=\sqrt{(11{,}09)^2+(j1{,}06)^2}=11{,}14\ V$$

Iste'molchidagi kuchlanish: $\dot{U}_3=\dot{I}_3R_3=(11{,}09-j1{,}06)\ V;$

yoki: $U_3=\sqrt{(11{,}09)^2-(j1{,}06)^2}=111{,}44\ V$

3. Tugun kuchlanishlar usuli.



Zanjirning a va b tugun potensiallaridagi kuchlanish:

$$\dot{U}_{ab}=\frac{\dot{E}_1\underline{Y}_1+\dot{E}_2\underline{Y}_2}{\underline{Y}_1+\underline{Y}_2+\underline{Y}_3}=\frac{5}{2{,}1+j0{,}2}=(2{,}36-j0{,}225)\ \ V$$

$$U_{ab}=\sqrt{(2{,}36)^2-(0{,}225)^2}=2{,}37\ V$$

Birinchi $\dot{E}_1$ generatordagi tok:

$$\dot{I}_1=\frac{\dot{E}_1-\dot{U}_{ab}}{\underline{Z}_1}=\frac{120-(2{,}36+j0{,}225)}{1+j2}=(23{,}6-j47)$$

yoki: $I_1=\sqrt{(23{,}6)^2-(-47)^2}=52{,}6\ A$

Ikkinchi E2 generatordan o'tuvchi tok:

$\dot{I}_2=\frac{-\dot{E}_2-\dot{U}_{ab}}{\underline{Z}_2}=(23{,}41-j47)$ yoki $I_2=\sqrt{(23{,}6)^2-(-47)^2}=52{,}5\ A$

Iste'molchidagi tok: $\dot{I}_3=\frac{\dot{U}_{ab}}{\underline{Z}_3}=\frac{2{,}36-j0{,}225}{10}=(0{,}24-j0{,}023)\ A$

Bundan: $I_3\approx 0{,}24\ A$

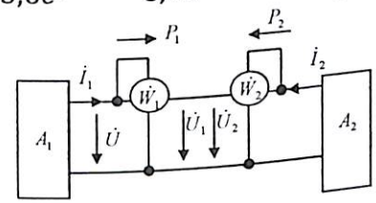
3.15-Masala. Elektr zanjir kuchlanishdagi va tok: $\dot{U}=100+j\,200\ V$, tok $\dot{I}=8+j2{,}5\ A$ bo'lganda, vattmetr ko'rsatishi aniqlansin.

Yechish. Birinchi vattmetr ko'rsatishi P_1 aniqlanadi:

$\underline{U}=100+j200=223{,}6e^{(j63{,}4^\circ)}\quad \dot{I}=8+j2{,}5=8{,}4e^{j17^\circ}$ (A)

yoki $\dot{I}=8{,}4e^{-j17^\circ}\ A$

$P_2=R_e[\dot{U}\cdot\dot{I}]=223{,}6e^{j63{,}4^\circ}\cdot 8{,}4e^{-j17^\circ}=R_e[1874e^{j46^\circ}]=130\ VT$



Ikkinchi vattmetr ko‘rsatishini P_2 aniqlanadi.

$\dot{U} = 100 + j200 = 223{,}6e^{(j63{,}4°)}$ $\quad \dot{I} = -\left[8{,}4e^{j17°}\right] = 8{,}38e^{j163°}\ A$

$P_2 = R_e\left[\dot{U}\cdot\dot{I}\right] = R_e\left[223{,}6e^{j63{,}4°}\cdot 8\cdot 38e^{j163°}\right] = R_e\left[1873e^{j226°}\right] = -130\ VT$

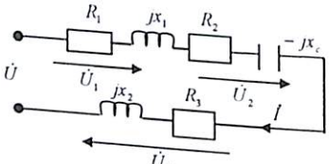
Bunda minus ishora birinchi vattmetr elektr energiyasiga nisbatan ikkinchi vattmetr energiyasiga qarama-qarshi ekanligini ifodalaydi.

Agarda vattmetr, ampermetr va voltmetr ko‘rsatish qiymati ma’lum bo‘lsa, ikki qutbli passiv parametrni hisoblab topish mumkin bo‘ladi.

Ya’ni: $Z = \frac{U}{I}$; $\quad R = UI\cos\varphi$; $\quad$ yoki $\cos\varphi = \frac{P}{UI}$; $\quad R = Z\cos\varphi$; $X = \sqrt{Z^2 - R^2}$

Eslatma: Ikki qutbli zanjir parametrini aniqlashda vattmetr o‘rniga fazo metrdan ham foydalanish mumkin.

3.16-Masala. Ketma-ket ulangan elektr zanjirdan $\dot{I} = 5A$ tok o‘tadi. Tokga nisbatan ayrim qismlardagi kuchlanishlar: $\dot{U}_1, \dot{U}_2, \dot{U}_3$ va $\cos\varphi_1 = 0{,}707$, $\cos\varphi_2 = 0.8$, $\cos\varphi_3 = 0{,}6$ burchakka farq qilib, aktiv qarshlikdagi quvvat qiymati $P_1 = 250\ VT$, $P_2 = 200\ VT$, $P_3 = 300\ VT$ bo‘lganda, zanjir parametri va kuchlanish qiymati aniqlanib, vektor ifodasi tuzilsin.



Yechish. Aktiv qarshilik qiymatini aniqlashda quvvatlar ifodasiga asosan: $P_1 = R_1I^2$; $P_2 = R_2I^2$; $P_3 = R_3I^2$

Bundan:

$R_1 = \frac{P_1}{I^2} = \frac{250}{25} = 10\ Om$; $R_2 = \frac{P_2}{I^2} = \frac{200}{25} = 8\ Om$; $R_1 = \frac{P_3}{I^2} = \frac{300}{25} = 12\ Om$;

Reaktiv qarshilik qiymatini aniqlashda quyidagi ifodadan foydalanamiz: $tg\varphi_1 = \frac{x_1}{R_1}$; $tg\varphi_2 = \frac{x_2}{R_2}$; $tg\varphi_3 = \frac{x_3}{R_3}$

Bundan: $x_1 = 10\ Om$; $x_2 = 6\ Om$; $x_3 = 16\ Om$.

Kuchlanish kompleks ifodasi esa:

$\dot{U}_1 = (R_1 + jx_{L_1})\dot{I} = (10 + j10)5 = 150 + j50$ V

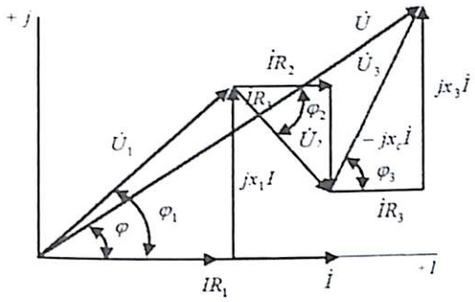
$\dot{U}_2 = (R_2 - jx_c)\dot{I} = (8 - j6)5 = 40 - j30$ V

$\dot{U}_3 = (R_3 + jx_{L_2})\dot{I} = (12 + j16)5 = 60 + j80$ V

Umumiy kuchlanish:

$\dot{U} = \dot{U}_1 + \dot{U}_2 + \dot{U}_3 = 250 + j100 = 180\ e^{j33°45'}$

Masshtab tanlash bilan kompleks tekislikda vektor ifodasini tuzamiz.

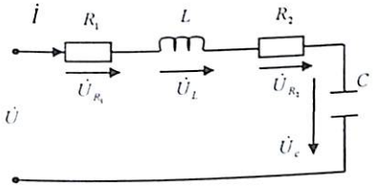


3.17-Masala. Ketma-ket ulangan zanjir parametri: $R_1 = 5\ Om$, $R_2 = 18\ Om$, $L = 50\cdot 10^{-3}\ gn$, C= $30\cdot 10^{-4}$ bo‘lib, $u = 75\sin(80t + 15^0)$ sinusoidal o‘zgaruvchan kuchlanishga ulangan. To‘la qarshilik, tok va kuchlanish haqiqiy qiymati va sarf bo‘ladigan quvvat balans tenglamasi va vektor ifodasi tuzilsin.

Yechish. Reaktiv qarshilik qiymatini topamiz:

$$X_L = \omega L = 2\pi fL = 2\cdot 3{,}14\cdot 80\cdot 50\cdot 10^{-3} = 25\ Om$$

$$X_c = \frac{1}{2\pi fC} = \frac{1}{502\cdot 30\cdot 10^{-6}} = 66\ Om$$



Kompleks qarshilik:

$Z = R_1 + jx_L + R_2 - jx_c = 5 + j25 + 18 - j66 = 23 - j41 = 47e^{-j60°}$

Tokning haqiqiy qiymat kompleks ifodasi: $\dot{I} = \frac{52{,}9e^{j15°}}{47e^{-j60}} = 1{,}2e^{+j75°}$

Faza farqi: $\varphi = \varphi_u - \varphi_i = 15° - 75° = -60°$

Quvvat balans tenglamasiga asosan:

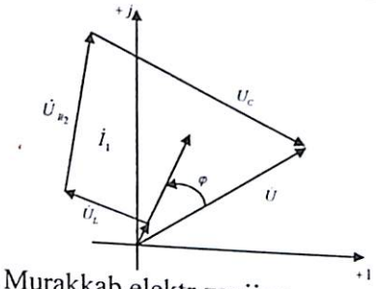
$\tilde{S} = \dot{U}I^* = 52{,}9e^{j15°}\cdot 1{,}2e^{-j75} = 65e^{-j60°} = \dot{I}^2\underline{Z} = 1{,}2^2(23 - j41)$

$= 32 - j57 = 65e^{-j60°}(VA)$

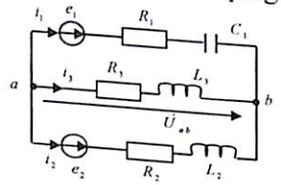
Vektor ifodasini tuzish uchun qarshilikdagi kompleks kuchlanish qiymatini topamiz:

$$\bar{U} = \bar{U}_{R_1} + \bar{U}_{L_1} + \bar{U}_{R_2} + \bar{U}_c = \overline{IR} + \bar{I}_j X_L + \bar{I}R_2 - j\bar{I}X_c =$$
$$= 1{,}2 \cdot e^{j75} \cdot (5 + j2{,}5 + 18 - j66) =$$
$$= 6e^{j75} + 30e^{j165^\circ} + 22e^{j75} + 78e^{-j15^\circ}$$

Tok va kuchlanish masshtabini tanlash bilan kompleks tekislikda moduli va faza burchaklari bo'yicha vektorni yo'naltirgan holda chizamiz.



3.18-Masala. Murakkab elektr zanjir parametri: $e_1 = 212\sin(\omega t + 30°)\ V$, $e_2 = 212\sin\omega t\ (V)$, $R_1 = 8\ Om$, $R_2 = 10\ Om, R_3 = 7\ Om$, $L_2 = 32mGn, C_1 = 212\ mkF$, chastota $f = 50\ Hz$ bo'lganda tarmoqdagi tok aniqlansin.



Yechish. EYK kompleks ifodasini yozamiz:

$\dot{E}_1 = \frac{212}{\sqrt{2}}e^{j30°} = 150e^{j30°} = (130° + j75)$; $\dot{E}_2 = \frac{212}{\sqrt{2}} = 150\ V$

Tarmoqdagi kompleks qarshilik:

$Z_1 = R_1 - \frac{1}{j\omega c} = 8 - \frac{10^6}{j(314\cdot 212)} = 8 - j15 \approx 17e^{-j62°}\ Om.$

$Z_2 = R_2 + j\omega L2 = 10 + j314 \cdot 32 \cdot 10^{-3} = 10 + j10 = 10\sqrt{2}e^{j45°}$ Om.

$Z_3 = R_3 + j\omega L_3 = 7 + j314 \cdot 32 \cdot 10^{-3} \approx 7 + j10 = 12{,}2\sqrt{2}e^{j55°}$ Om.

Ikki tugun orasidagi potensiallar usuliga asosan:

$$\dot{U}_{ab} = \frac{\dot{E}_1 y_1 + \dot{E}_2 y_2}{y_1 + y_2 + y_3} = \frac{\dot{E}_1\left(\frac{1}{Z_1}\right) + \dot{E}_2\left(\frac{1}{Z_2}\right)}{\frac{1}{Z_1} + \frac{1}{Z_2} + \frac{1}{Z_3}} = \frac{\frac{150e^{j30°}}{17e^{-j62}} + \frac{150}{14{,}1e^{j45°}}}{\frac{1}{17e^{-j62}} + \frac{1}{14{,}1e^{j45°}} + \frac{1}{12{,}2e^{j55}}} =$$

$53{,}7e^{36°} \approx 43{,}4 + j31{,}6\ V.$

Tarmoqdagi tok:

$$\dot{I}_1 = \frac{\dot{E}_1 - \dot{U}_{ab}}{Z_1} = \frac{130 + j75 - 43{,}4 - j31{,}6}{17e^{-j62^\circ}} = \frac{97e^{j26^\circ}}{17e^{-j62^\circ}} = 5{,}7e^{j88^\circ}$$

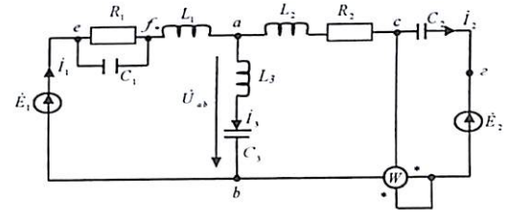
$$\dot{I}_2 = \frac{\dot{E}_2 - \dot{U}_{ab}}{Z_2} = \frac{150 - 43{,}4 - j31{,}6}{14{,}1e^{j45^\circ}} \approx \frac{111e^{-j16{,}5}}{14{,}1e^{j45^\circ}} = 7{,}9e^{j61{,}5^\circ}$$

$$\dot{I}_3 = \frac{-\dot{U}_{ab}}{Z_3} = \frac{-53{,}7e^{j36^\circ}}{12{,}2e^{j55^\circ}} = -4{,}4e^{j19^\circ}$$

$\tilde{S} = \tilde{S}_1 + \tilde{S}_2 = \dot{E}_1 \cdot I^*_1 + \dot{E}_2 \cdot I^*_2 = 150e^{j30^\circ} \cdot 5.7e^{-j88^\circ} + 150 \cdot 7.9e^{-j61.5} = 855e^{-j58^\circ} + 1195e^{-j61.5^\circ} = 855(\cos 58^\circ - j\sin 58^\circ) + 1995(\cos 61.5^\circ - j\sin 61.5^\circ) = (427 - j\sqrt{3}\cdot 427) + (600 - j\sqrt{3}\cdot 600) = (1027 - j\sqrt{3}\cdot 2\cdot 1027)\ VA$

Demak $P = 1027\ Vt\ Q = \sqrt{3}\cdot 2054\ VAP$

3.19-Masala. Murakkab elektr zanjir parametri: $\dot{E}_2 = 200e^{j45^\circ}$ V; $\dot{E}_2 = 240e^{j0^\circ}V; R_1 = 12\ Om; L_1 = 2\cdot 10^{-3}\ gn; C_1 = 20\cdot 10^{-6}f; R_2 = 14\ Om;\ L_2 = 8\cdot 10^{-3}gn;\quad C_2 = 100\cdot 10^{-6}f;\quad R_3 = 4\ Om;\ L_3 = 5\cdot 10^{-3}gn; C_3 = 50\cdot 10^{-6}f;\quad f = 500\ gs$ ga teng.



Tarmoqlardagi tok, vattmetr ko'rsatish qiymati aniqlanib, quvvat muvozanat tenglamasi tuzilsin.

Yechish. Ikki tugunlararo potensiallar usuliga asosan:

$$\dot{U}_{ab} = \frac{\dot{E}_1 y_1 + \dot{E}_2 y_2}{y_1 + y_2 + y_3} \qquad (1)$$

Bu yerda: $y_1 = \frac{1}{Z_1} = \frac{1}{7{,}67e^{j40°}} = 0{,}13e^{-j4°} = 0{,}13 - j0{,}009\ \frac{1}{Om}$

yoki: $Z_1 = Z_1^1 + j\omega L = \frac{R_1 \cdot jx_c}{R_1 + jx_c} + j\omega L = (7{,}67 - j5{,}75) + j6{,}28 = 7{,}67e^{j40}om$

$$y_2 = \frac{1}{Z_2} = \frac{1}{26e^{j57°20'}} = 0{,}0385e^{-j57°20'} = 0{,}0208 - j0{,}0324\ \frac{1}{Om}$$

$$y_3 = \frac{1}{Z_3} = \frac{1}{8{,}63e^{j90°}} = 0{,}107e^{-j90°}\ \frac{1}{Om}$$

Aniqlangan qiymatlarni (1) tenglamaga qo'yamiz:

$$\dot{U}_{ab} = \frac{200e^{j45^\circ}:0{,}13e^{-j4^\circ} - 240 \cdot 0{,}0385e^{-j57^\circ 20^1}}{(0{,}13 - j0{,}009) + (0{,}0208 - j0{,}0324) + (-j0{,}107)} =$$

$$= \frac{26e^{j41^\circ} - 9{,}25e^{-j57^\circ 20^1}}{0{,}151 - j0{,}157} = \frac{(20 + j17) - (5 - j7{,}8)}{0{,}218e^{-j45^\circ}} =$$

$$= \frac{29e^{j58^\circ 40^1}}{0{,}218e^{-j46^\circ}} = 133e^{j104^\circ 50^1} = -34 + j127{,}5\ V.$$

Om qonuniga asosan tarmoqdagi tokni aniqlaymiz:

$$\dot{I}_1 = (\dot{E}_1 - \dot{U}_{ab})y_1 = \left(200e^{j45^\circ} - 133e^{j104^\circ 50'}\right)0{,}13e^{-j4^\circ} =$$

$(175 + j13{,}5) \cdot 0{,}13e^{-j4^\circ} = 175e^{j4^\circ 20'} \cdot 0{,}13e^{-j4^\circ} = 22{,}7\ A.$

$$\dot{I}_2 = (\dot{E}_1 + \dot{U}_{ab})y_2 = (240 + 133e^{j104^\circ 50^1}) \cdot 0{,}0385e^{-j57^\circ 20^1} = (206 +$$

$j127{,}5) \cdot 0{,}0385e^{-j57^\circ 20'} = 242e^{j31^\circ 75'} \cdot 0{,}0385e^{-j57^\circ 20'} = 9{,}3e^{-j25^\circ 35'} =$
$8{,}35 - j4\ A.$

$$\dot{I}_3 = \dot{U}_{ab}y_3 = 133e^{j104^\circ \cdot 50'} \cdot 0{,}107e^{j90^\circ} = 125e^{j14^\circ 50^1}$$
$$= 12{,}1 + j3{,}2\ A.$$

Masalaning yechimini tekshiramiz:

$\dot{I}_1 = \dot{I}_2 + \dot{I}_3 = (-8{,}35 + j4) + (-12{,}1 - j3{,}2) = -20{,}45 + j0{,}8 \approx 21\ A.$

Sig'imdan o'tuvchi tokni topamiz:

$$I_{c_1} = \frac{U_{cf}}{jx_{c_1}} = \frac{I_1 Z_1^1}{jx_{c_1}} = \frac{22{,}7 \cdot 9{,}6e^{-j36^\circ}}{16e^{-j90^\circ}} = 13{,}6e^{j52^\circ 10^1} = 8{,}15 + j10{,}9\ A.$$

Quvvat muvozanat tenglamasiga asosan: $\tilde{S}_{gen} = \tilde{S}_{ist}$

Manbadagi to'la quvvat:

$\tilde{S}_{gen} = \dot{E}_1 I^*{}_1 + \dot{E}_2 I^*{}_1 = 200e^{j45^\circ} - 240 \cdot e^{j25^\circ 35'} = 4450e^{j45^\circ} -$
$2240e^{j25^\circ 35'} = (3200 + j3200) - (2002 - j965) = 5202 + j2235$

Aktiv quvvat: $P = 5202\ VT$. Reaktiv quvvat: $Q = 2235\ VAR$.

Iste'molchilarda sarf bo'ladigan to'la quvvat:

$\tilde{S}_{ist} = (I_{R1}^2)R_1 - j(I_{C_1}^2)X_{C1} + j(I_1^2)X_{L1} + j(I_3^2)(X_{L3} - X_{C3}) +$
$j(I_2^2)X_{L2} + I_2^2 R_2 - j(I_2^2)X_{C2} = 330 \cdot 12 - j185 \cdot 16 + j515 \cdot 6.28 +$
$j156 \cdot 9.4 + j86 \cdot 25 + 86 \cdot 14 - j86 \cdot 3.2 = 3960 - j2960 +$
$j3200 + j1460 + j2150 + 1260 - j276 = 5160 + j2600$

Vattmetr ko'rsatish qiymatini aniqlaymiz:

$\tilde{S} = \dot{E}_{bc} \cdot I^*{}_2 = 260e^{j174^\circ} \cdot 9.3e^{j25^\circ 35'} = 2400e^{j148^\circ 25'} = 2040 + j1250\ VA$

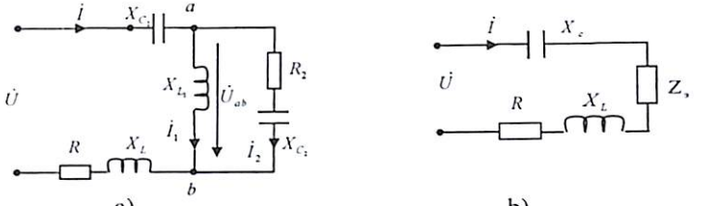
Bundan: $\dot{U}_{bc} = \varphi_b - \varphi_c = 0 - 260e^{j174}$

$P = 2040\ VT,$

yoki $P = U\dot{I}\cos\varphi = 260 \cdot 9{,}3\cos 148^\circ 2 = 2040\ VT.$

3.20-Masala. Elektr zanjir qarshilik parametri:

$x_{C_1} = 10\ Om,\ x_{L_1} = 5\ Om,\ x_L = 4\ Om,\ R = 4\ Om,\ R_2 = 8\ Om,\ x_{C_2} = 6\ Om$ bo'lib, $u = 11{,}45 \cdot \sqrt{2}\sin(\omega t - 102°)V$ kuchlanishga ulangan. Tarmoqdagi tok $\dot{I}$, $\dot{I}_1$, $\dot{I}_2$ toklar kompleks qiymati va to'la quvvat topilsin.



a) b)

Yechish. Zanjirning parallel sxemada ulangan qismini ekvivalent to'la qarshilik bilan almashtiramiz (b)

$$Z_e = \frac{jx_{L_1}(R_2 - jx_{c_2})}{jx_{L_1} + (R_2 + jx_{c_2})} = \frac{j5(8-j6)}{j5+8-j6} = \frac{j40+30}{8-j1} = \frac{50e^{j53^C}}{8e^{-j70}} = 6{,}2e^{j6^\circ} =$$

$3{,}08 + j5{,}4\ Om.$

Keltirilgan (b) ekvivalent sxemadan:

$$Z_{um} = -\mathrm{jx_c} + Z_e + jx_L + R = -j10 + 3{,}08 + j5{,}4 + j4 + 4$$
$$= 7{,}08 - j0{,}6 = = 7{,}1e^{-j4{,}8^\circ}\ Om$$

Zanjirga kiruvchi tok: $\dot{I} = \frac{\dot{U}}{Z_{um}} = \frac{11{,}45e^{-j102^\circ}}{7{,}1 \cdot e^{-4{,}8^\circ}} = 1{,}62e^{-j97{,}3^\circ}$

Zanjirning tarmoqlangan qismlaridagi tok:

$$\dot{I}_1 = \frac{\dot{U}_{ab}}{Z_1} = \dot{I} \cdot \frac{R_2 + jx_{c_2}}{jx_{L_1} + R_2 - jx_{s_2}} = \frac{1{,}62e^{-j97^\circ} \cdot (8-j6)}{j5+8-j6} = -1{,}2 - j1{,}6\ A$$

$$\dot{I}_2 = \frac{\dot{U}_{ab}}{Z_2} = \dot{I}\frac{jx_4}{jx_{L_1} + R_2 - jx_{c_2}} = \frac{1{,}62e^{-j97^0} \cdot 5e^{j90^\circ}}{j5+8-j6} = 1\ A$$

To'la quvvatni topamiz: $\tilde{S} = \dot{U} \cdot I^* = 11{,}45e^{j102^\circ} \cdot 1{,}62e^{j97^\circ} =$
$18{,}4e^{j200^\circ} = 18{,}4(\cos 200^\circ + j\sin 200^\circ)\ VA$

3.3. Mustaqil yechish uchun masalalar

3.1-Masala. Tok va kuchlanishning kompleks ifodasi:

$\dot{U} = 100\ (V)$ $\quad \dot{I} = (16 + j12)\ A$

$\dot{U} = 60 + j80\ (V)$ $\quad \dot{I} = 20\ A$

$\dot{U} = 60 + j80\ (V)$ $\quad \dot{I} = j20\ A$

$\dot{U} = 100e^{j\frac{\pi}{3}}$ (V) $\quad \dot{I} = 20e^{j\frac{\pi}{3}}$ A

bo'lgan qiymatlar uchun kompleks to'la qarshilik, aktiv va reaktiv tashkil etuvchi qarshiliklar aniqlansin.

3.2-Masala. Tok va kuchlanishning haqiqiy (effektiv) kompleks ifodasi $\dot{I} = (5 + j5)$ va $\dot{U} = (20 + j20)$ bo'lganda, tok va kuchlanish oniy qiymat ifodasi va to'la qarshiligi aniqlansin.

Javob: $\underline{Z} = 4 + j4\ Om$

3.3-Masala. Tok va kuchlanish kompleks ifodasi:

$\dot{U} = 100e^{j\frac{\pi}{3}}$ (V) $\quad \dot{I} = 10e^{j\frac{\pi}{6}}$ (A)

$\dot{U} = 10^5 e^{-j\frac{\pi}{3}}$ (V) $\quad \dot{I} = 50e^{j\frac{\pi}{6}}$ (A)

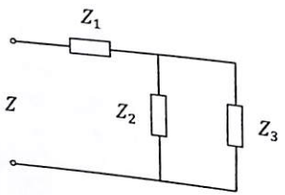
bo'lganda aktiv quvvat, to'la qarshilik va to'la o'tkazuvchanlik kompleks ifodasi aniqlansin.

Javob: 1) $P = 1\ kVt$, 2) $P = 0$

3.4-Masala. Induktiv g'altak $\dot{U} = 100\ (V)$ kuchlanishga ulangan bo'lib, qarshiligi $R = 3\ Om, X = \pm 4\ Om$. Tok va to'la quvvat kompleks ifodasi aniqlansin.

Javob: $\tilde{S} = \dot{U}\dot{I} = (1200 \pm j1600)\ VA$

3.5-Masala. Elektr zanjir parametrlari: $Z_1 = 10 + j10$, $Z_2 = 2 + j3$, $Z_3 = 5 - j8$, bo'lsa, to'la, aktiv va reaktiv qarshiliklari qancha bo'ladi?



Javob:

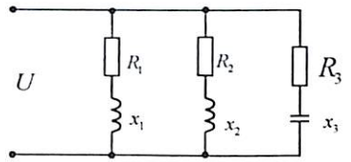
$Z = 13{,}34 + j12{,}18 = 18\ e^{j42^0 20'}$,

$R = 13{,}34\ om$ $\quad X = 12{,}18\ om$

3.6-Masala. Qarshilik parametri $R = 20\ Om, X_L = 10\ Om$. Induktiv g'altak chastotasi $f = 50\ Gs$ bo'lgan $U = 100\sin(\omega t + 45°)\ (V)$ kuchlanish ulangan. Chastota ikki martagacha ko'paygan holat uchun kompleks to'la qarshiligi, tok va to'la quvvat aniqlansin.

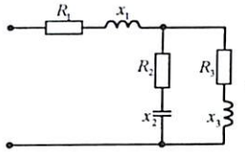
Javob: $\dot{I} = 2.5\ A, \tilde{S} = 177\ VA$

3.7-Masala. Parallel sxemada ulangan uchta iste'molchi parametrlari: $R_1 = 5\ Om, X_1 = 2\ Om, R_2 = 2{,}5\ Om, X_2 = 5\ Om, R_3 = 1{,}25 Om, X_3 = -2{,}5 Om$ ga teng. Ekvivalent kompleks o'tkazuvchanlik parametri va umumiy zanjir uchun burchak $\cos\varphi$ aniqlansin.



Javob: $\underline{y} = 0{,}425\ (\frac{1}{Om})$;
$\cos\varphi = 0{,}995$

3.8-Masala. Elektr zanjir parametri: $R_1 = 3\ Om, X_1 = 2\ Om, R_2 = 5\ Om, X_2 = 10\ Om, R_3 = 10\ Om, X_3 = 5\ Om$ zanjirning ekvivalent aktiv va reaktiv qarshilik qiymati aniqlansin.



Javob: $R = 105{,}5\ (Om), X = -0{,}53\ (Om)$.

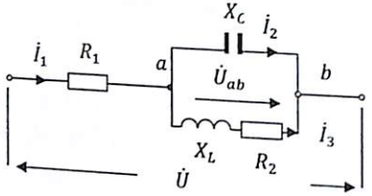
3.9-Masala. Elektr zanjirdagi tok $I = 10\ A$ ulangan. Kuchlanish $U = 130\ V$. Iste'mol qiladigan aktiv quvvati $P = 500\ Vt$ bo'lib $\varphi > 0$ va $\varphi < 0$ bo'lgan holatlarda to'la qarshilik va o'tkazuvchanlik kompleks ifodasini yozing.

Javob: $Z = (5 \pm j12) Om$; $\quad Y = (2{,}96 \pm j7{,}1)10^{-2}\ \frac{1}{Om}$

3.10-Masala. Kuchlanish va tok oniy qiymati $u = 141\sin(\omega t + 90^\circ)$, $i = 14{,}1\sin(\omega t + 30^\circ)$ bo'lganda, to'la qarshilik Z va aktiv, reaktiv va to'la quvvat qiymati topilsin.

Javob: $Z = 5 + j5\sqrt{3}\ om$, $\quad \tilde{S} = 500 + j500\sqrt{3}\ VA$.

3.11-Masala. Zanjir parametrlari: $\dot{U}_{ab} = 40\ V$ $R_1 = 40\ om$ $R_2 = 10\ om$ $C = 5\ mkf$ $L = 2\ mGn$ $\omega = 10^4\ rad/sek$ bo'lganda, toklari umumiy kuchlanish va to'la quvvat qiymatlari topilsin.



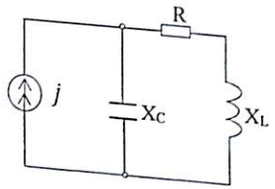
Javob: $\dot{I}_1 = 4 \cdot e^{j20^\circ}$,
$\dot{U} = 193 + j52$,
$\tilde{S} = 800 \cdot e^{-j5^\circ}$

3.12-Masala. Kompleks sonlar soddalashtirilib, ko'rsatkichli va algebraik ifodalari yozilsin.

$$\frac{(4{,}36 - j \cdot 5{,}02)(-j \cdot 4{,}37) + 7{,}3e^{-j205}}{54e^{j180^\circ} + j0{,}437(j5{,}5)\left(e^{j90^\circ} + 5{,}07 - j2{,}5\right)}$$

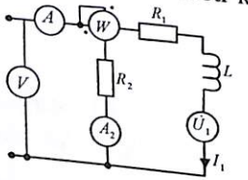
Javob: $1{,}71e^{j6{,}8^\circ} = 1{,}7 + j0{,}2.$

3.13-Masala. Sxemada tok $j = 5\sqrt{2}\sin(314t + 90^0)$ bo`lib, qarshilik parametrlari: $R=X_c=10$ Om, $X_L=20$ Om bo`lganda induktivlikdagi kuchlanishi qancha bo`ladi.



Javob: $U_L = 50\sqrt{2}e^{j45^0}$

3.14-Masala. Keltirilgan sxemada tok $I_1 = 1\ A$ va parametri $R_1 = 100\ Om, L = 0{,}276\ gn, R_2 = 200\ Om, f = 100\ gs$ bo'lganda, voltmetr, ampermetr, va vattmetr ko'rsatish qiymati aniqlansin.

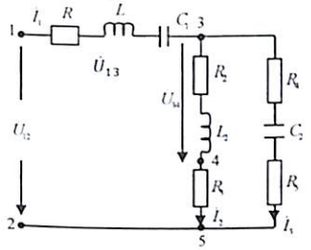


Javob:
$U = 200\ V, I = 1{,}73\ A, P = 300\ VT.$

3.15-Masala. 2-20, 2-21, 2-22, kompleks usulda yeching

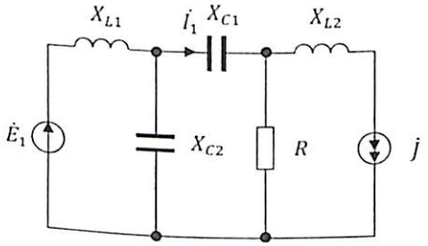
3.16-Masala. Murakkab elektr zanjir parametri:
$R_1 = 10\ Om,\ X_{L_1} = 7\ Om, X_{C_1} = 25\ Om, R_2 = 5\ Om,\ X_{L_2} = 20\ Om,$
$R_3 = 12\ Om,\ R_4 = 15\ Om,\ R_5 = 9\ Om.$

bo'lib, $\varphi_3 - \varphi_4$ potensial kuchlanish $\dot{U}_{34} = 60\ V$ ga teng kompleks qarshilik, kirishdagi kuchlanish U_{12}, tarmoqdagi tok va kompleks quvvat qiymat aniqlansin.



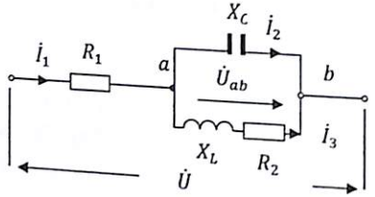
Javob: $Z = 36{,}6e^{-j18^\circ}$;
$\dot{I}_1 = 2{,}9e^{-j75^\circ}$; $\dot{I}_2 = 1{,}8e^{j30^\circ}$;
$\dot{I}_3 = 3e^{j40^\circ}$; $\dot{U}_{12} = 109{,}8e^{j60^\circ}$;
$\tilde{S} = 329e^{-j18^\circ} = 311 - j105\ VA.$

3.17-Masala. Zanjir parametrlari: $X_{L1} = 5\ om,\ X_{L2} = 10\ om,$ $X_{C1} = 10\ om,\ X_{C2} = 10\ om,\ R = 10\ om,\ \dot{E}_1 = 100\sin\omega t\ J = 20\sin(\omega t + 90^0)$ teng. Ekvivalent generator usuliga asosan $\dot{I}_1$ –tok qiymati aniqlansin.



Javob: $\dot{I}_1 = 20\sqrt{2}\ e^{-j45}$

3.11-Masala. Zanjir parametrlari: $\dot{U}_{ab} = 40\ V$ $R_1 = 40\ om$ $R_2 = 10\ om$ $C = 5\ mkf$ $L = 2\ mGn$ $\omega = 10^4\ rad/sek$ bo'lganda, toklari umumiy kuchlanish va to'la quvvat qiymatlari topilsin.



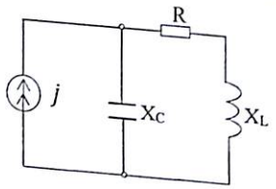
Javob: $\dot{I}_1 = 4 \cdot e^{j20^\circ}$, $\dot{U} = 193 + j52$, $\tilde{S} = 800 \cdot e^{-j5^\circ}$

3.12-Masala. Kompleks sonlar soddalashtirilib, ko'rsatkichli va algebraik ifodalari yozilsin.

$$\frac{(4{,}36 - j \cdot 5{,}02)(-j \cdot 4{,}37) + 7{,}3e^{-j205}}{54e^{j180^\circ} + j0{,}437(j5{,}5)\left(e^{j90^\circ} + 5{,}07 - j2{,}5\right)}$$

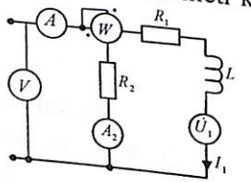
Javob: $1{,}71e^{j6{,}8^\circ} = 1{,}7 + j0{,}2.$

3.13-Masala. Sxemada tok $j = 5\sqrt{2}\sin(314t + 90^0)$ bo`lib, qarshilik parametrlari: $R=X_c=10$ Om, $X_L=20$ Om bo`lganda induktivlikdagi kuchlanishi qancha bo`ladi.



Javob: $U_L = 50\sqrt{2}e^{j45^0}$

3.14-Masala. Keltirilgan sxemada tok $I_1 = 1\ A$ va parametri $R_1 = 100\ Om, L = 0{,}276\ gn, R_2 = 200\ Om, f = 100\ gs$ bo'lganda, voltmetr, ampermetr, va vattmetr ko'rsatish qiymati aniqlansin.



Javob:
$U = 200\ V, I = 1{,}73\ A, P = 300\ VT.$

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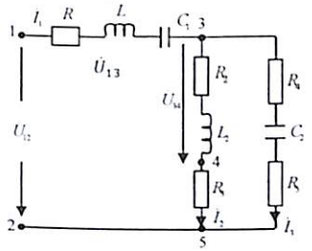
bo`lib, $\varphi_3 - \varphi_4$ potensial kuchlanish $\dot{U}_{34} = 60\ V$ ga teng kompleks qarshilik, kirishdagi kuchlanish U_{12}, tarmoqdagi tok va kompleks quvvat qiymat aniqlansin.



Javob: $Z = 36{,}6e^{-j18^\circ}$;
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$\dot{I}_3 = 3e^{j40^\circ}$; $\dot{U}_{12} = 109{,}8e^{j60^\circ}$;
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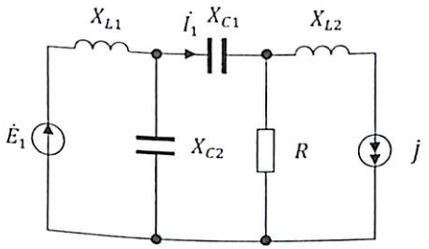
3.17-Masala. Zanjir parametrlari: $X_{L1} = 5\ om,\ X_{L2} = 10\ om,$ $X_{C1} = 10\ om,\ X_{C2} = 10\ om,\ R = 10\ om,\ \dot{E}_1 = 100\sin\omega t\ J = 20\sin(\omega t + 90^0)$ teng. Ekvivalent generator usuliga asosan $\dot{I}_1$ –tok qiymati aniqlansin.



Javob: $\dot{I}_1 = 20\sqrt{2}\ e^{-j45}$

Nazorat savollari

1. Kompleks son matematik ifodasini yozing. Eyler formulasiga izoh bering.
2. Kompleks sonlar bilan qo‘shish, ayirish, ko‘paytirish va bo‘lish amallari bajarilganda qanday ko‘rinishda yoziladi?
3. Sinusoidal o‘zgaruvchan elektr zanjirni kompleks (simvolik) usulda hisoblashda qanday afzalliklar bor?
4. Nima uchun kompleks ifoda $\pm j$ yoki $e^{\pm j\varphi}$ ga burilish burchagi deyiladi?
5. Sinusoidal o‘zgaruvchan (tok, kuchlanish, EYK) funksiyalarni kompleks son ko‘rinishda ifodalanishini isbotlang.
6. Sinusoidal o‘zgaruvchan tok, kuchlanish va EYKlar kompleks ifodasini yozing.
7. Kompleks sonlarni differensiallash va integrallash qanday bajariladi?
8. Om va Kirxgof qonuni kompleks usulda qanday ifodalanadi?
9. Aktiv, reaktiv va to‘la qarshilik kompleks ifodasini yozing.
10. Aktiv, reaktiv va to‘la o‘tkazuvchanlik kompleks ifodasini yozing.
11. Aktiv, reaktiv va to‘la quvvat tenglamalarining kompleks ifodasini yozing.
12. $U = 220\sin(\omega t + 45), i = 10\sqrt{2}\sin(\omega t + 90)$ tok va kuchlanish funksiyalari kompleks usulda qanday ifodalanadi?
13. Kuchlanish $\dot{U} = 100e^{j120}\,V$, tok $\dot{I} = j10\,A$ bo‘lganda, kompleks to‘la qarshilik va to‘la o‘tkazuvchanlik qiymatini aniqlang.
14. To‘la qarshilik $\underline{Z}_1 = 5 + j11\,Om$, $\underline{Z}_2 = 4 - j2\,Om$ ga teng ketma-ket ulangan elektr zanjir sxemasini tuzing, umumiy va to‘la qarshilikni aniqlang.
15. Kompleks ifodalari $\dot{U} = 60e^{j90}, \dot{I} = 5e^{j30}$ bo‘lganda kompleks to‘la quvvat ifodasi va aktiv, reaktiv quvvat qiymati qanday aniqlanadi?
16. Parallel sxemada biriktirilgan iste’molchilar kompleks qarshiligi $\underline{Z}_1 = 10e^{j60}Om$, $\underline{Z}_2 = 5^{-j30}\,Om$ bo‘lganda, kompleks ekvivalent qarshilik qanchaga teng?
17. $\dot{U} = -220 + j220\,V, \dot{I} = 15 - j5\,A$ kompleks ifodalarining oniy sinusoidal o‘zgaruvchan qiymatini yozing.

18. $\dot{I} = -5e^{j90}\,A, \dot{U} = j\,141\,e^{j90}\,V$ bo‘lgan kompleks ifodalarning oniy qiymat tenglamasini tuzing.
19. Kompleks qarshilik $Z = 8 + j6\,Om$ bo‘lganda, aktiv va reaktiv o‘tkazuvchanlik qiymati nimaga teng?
20. Kompleks o‘tkazuvchanlik: $y = 1{,}41 + j1{,}73\frac{1}{Om}$ bo‘lganda, aktiv va reaktiv qarshilikni aniqlang.
21. Agar $\dot{U} = 60 + j8$ va $\dot{I} = 20\,A$ bo’lsa, R, X, Z qarshiliklari qancha bo’ladi?
22. Agar $U = 80 + j60$ va $I = 3 + j4$ bo’lsa aktiv P, reaktiv Q va to’la $\tilde{S}$ quvvatlar qanchaga teng?
23. Kompleks tok $\dot{I} = 6 + j8$ bo’lsa, oniy, effektiv, o’rtacha qiymatlari va φ-burchak qanchaga teng?

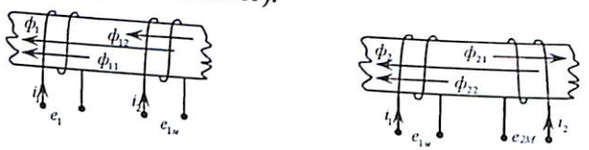
4. O‘ZARO INDUKTIV BOG‘LANGAN O‘ZGARUVCHAN ELEKTR ZANJIRLAR

4.1. Asosiy nazariy tushunchalar

Elektromagnit induksiya qonuniga asosan induktiv g‘altakda, tok i, magnit oqimi ϕ, yoki induktiv parametr L o‘zgaruvchan bo‘lsa, o‘zinduksiya EYK hosil bo‘ladi.

$$e_L = -\frac{d\psi}{dt} = -W\frac{d\phi}{dt} = -L\frac{di}{dt}$$

Agarda ikkita induktiv elementlarning biridan o‘tuvchi tok ikkinchi induktivlikda EYK hosil qilsa, bunday elektr zanjir **o’zaro induktiv bog‘langan** deyiladi (transformator).



Bunda induktivlikda hosil bo‘lgan magnit oqim:

$$\begin{cases}\Phi_1 = \Phi_{11} + \Phi_{12}\\ \Phi_2 = \Phi_{22} + \Phi_{21}\end{cases} \text{ yoki } \begin{cases}\Phi_{1umumiy} = \Phi_1 \pm \Phi_{21}\\ \Phi_{2umumiy} = \Phi_2 \pm \Phi_{12}\end{cases}$$

Chulg‘amlarga ilashgan magnit oqim:

$$\Psi_1 = W_1(\Phi_1 \pm \Phi_{21}) = \Psi_1 \pm \Psi_{21}$$
$$\Psi_2 = W_2(\Phi_2 \pm \Phi_{12}) = \Psi_2 \pm \Psi_{12}$$

Induktivlikda hosil bo‘lgan o‘zaro induksiyada aylanuvchi E.Y.K.

$$e_1 = \frac{d\Psi_1}{dt} = -\frac{d(\Psi_1 \pm \Psi_{21})}{dt} = -\frac{d\Psi_1}{dt} \pm \frac{d\Psi_{21}}{dt} = -L_1\frac{di_1}{dt} \pm M_{21}\frac{di_2}{dt}$$
$$= l_{1L} + l_{2L}$$

$$e_2 = \frac{d\Psi_2}{dt} = -\frac{d(\Psi_2 \pm \Psi_{12})}{dt} = -\frac{d\Psi_2}{dt} \pm \frac{d\Psi_{12}}{dt} = -L_2\frac{di_2}{dt} \pm M_{12}\frac{di_1}{dt}$$
$$= e_{1L} + e_{2M}$$

$M = M_{12} = M_{21}$ o‘zaro **induktivlik koeffitsienti** deyiladi va Gn da o‘lchanadi.

M – koeffitsient induktiv g‘altakning o‘ramlar soniga, o‘zaro joylashishiga va magnit tavsifiga ham bog‘liq bo‘ladi.

O’zaro induktiv bog’langan zanjir ulanish sxemalari.

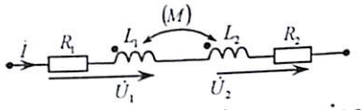
1. Ketma-ket sxemada ulangan induktiv g‘altak.

Bu holda kompleks to‘la qarshilik:

$\underline{Z} = \underline{Z}_1 + \underline{Z}_2 \pm 2\underline{Z}_M = (R_1 + j\omega L_1) + (R_2 + j\omega L_2) \mp 2\omega M$

yoki $\underline{Z}_M = \mp 2\omega M$ – o‘zaro induksiya kompleks qarshiligi.

Plus ishora ikkita induktivlik **ketma-ket**, **minus** ishora esa **qarama-qarshi** ulanishga mos bo‘ladi.



Ekvivalent induktivlik o‘zaro ulanish sxemasiga asosan:

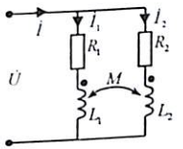
$L_{mos} = L_1 + L_2 + 2M$ $\qquad L_{qarama-qarshi} = L_1 + L_2 - 2M$

Induktivlikdagi kuchlanish:

$\dot{U}_1 = \dot{I}_1(\underline{Z}_1 \pm j\omega M)$ $\qquad \dot{U}_2 = \dot{I}_2(\underline{Z}_2 \pm j\omega M)$

2. Parallel sxemada ulanish.

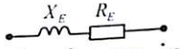
Parallel sxemada biriktirilgan induktiv bog‘langan elektr zanjirni hisoblashda Kirxgof 2-qonuniga asosan har bir tarmoq uchun tuzilgan kompleks tenglamalar sistemasini yechish bilan tarmoqdagi tok aniqlanadi.



Tarmoq ekvivalent qarshiligi:

$$\underline{Z}_{1Э} = \frac{\underline{Z}_1\underline{Z}_2 - \underline{Z}_M^2}{\underline{Z}_2 - \underline{Z}_M} \qquad \underline{Z}_{2Э} = \frac{\underline{Z}_1\underline{Z}_2 - \underline{Z}_M^2}{\underline{Z}_1 - \underline{Z}_M}$$

Tenglamaga asosan ekvivalent sxemasini tuzamiz.



Demak parallel sxemada ulangan induktiv g‘altak elektr zanjirni ekvivalent sxema yoki qarshilik parametri orqali induktiv bog‘lanmagan aktiv qarshilik R_E va X_E induktiv qarshilik ko‘rinishda ifodalanishi mumkin.

$\underline{Z}_E = R_E + jx_E$ Agar $R_1 = R_2 = 0$ bo‘lsa:

$$L_{1E} = \frac{L_1L_2 - M^2}{L_2 \mp M}, \qquad L_{2E} = \frac{L_1L_2 - M^2}{L_1 \mp M}$$

Zanjirning umumiy qarshiligi: $\underline{Z}_E = \frac{Z_1Z_2 - \underline{Z}_M^2}{Z_1\underline{Z}_2 \mp 2\underline{Z}_M}$

3. Induktiv bog‘langan zanjirni hisoblashda bog‘lanish koeffitsienti K orqali ham ifodalanadi. $K = \frac{M}{\sqrt{L_1 L_2}} \leq 1$

Induktiv bog‘langan g‘altak **mos** ravishda yoki **qarama-qarshi** biriktirilgan bo‘lsa:

$L_{mos} = L - M > 0$; $L_{qq} = L - M < 0$ yoki $M = \frac{L_M - L_{qq}}{4}$

Induktivlik (L) va o‘zaro induktivlik (M) muvozanat tenglamasi.

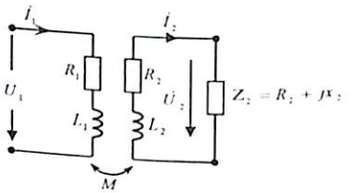
$M^2 \leq L_1 L_2$ yoki $2M^2 \leq L_1 + L_2$

4. O‘zaksiz transformator (havo transformatori).

Sxemada berilgan o‘zaksiz transformator zanjirini hisoblashda konturli tok usuli yoki ekvivalent sxemasi bilan bajariladi. Agarda transformatorning birlamchi chulg‘amidagi tokni aniqlash zarur bo‘lsa, murakkab induktiv bog‘langan elektr zanjir ekvivalent sxemasidan foydalangan holda ikkilamchi chulg‘am kompleks qarshiligi o‘rniga birlamchi chulg‘amga kiruvchi aktiv R_0 va reaktiv x_0 qarshiliklar bilan almashtiriladi:

$$R_0 = \frac{Z_M^2}{R_2^2 + x_2^2} R_{22}$$

$$x_0 = \frac{Z_M^2}{R_2^2 + x_2^2} x_{22}$$



Bunda R_{22} va x_{22} transformatorning ikkilamchi chulg‘am aktiv va reaktiv qarshiligi.

Iste’molchi qarshiligi inobatga olinganda:

$R_2' = R_2 + R_H$, $x_2' = x_2 + x_H$

Doimo $R' \geq 0$ bo‘lib, sarf bo‘ladigan quvvatni ifodalaydi.

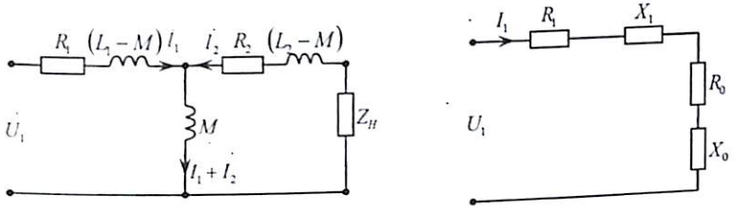
Agar transformator ikkilamchi chulg‘amiga induktiv qarshilik ulangan bo‘lsa, bunda $x_{2_L} > 0$, $x_0 < 0$ bo‘lib, transformator magnit oqimi **susayadi.**

Agarda sig‘im qarshiligi ulangan bo‘lsa, $x_{2_C} > 0$, $x_0 < 0$ bo‘lib, transformatorning magnit oqimi **kuchayadi.**

Transformator ekvivolent tenglamasi:

$$\begin{cases} \dot{U}_1 = R_1 \dot{I}_1 + j\omega(L_1 - M)\dot{I}_1 + j\omega M(\dot{I}_1 + \dot{I}_2) \\ 0 = R_2 \dot{I}_2 + j\omega(L_2 - M)\dot{I}_2 + j\omega M(\dot{I}_1 + \dot{I}_2) + Z_2 \dot{I}_2 \end{cases}$$

Shunga asosan transformatorning ekvivalent sxemasini chizamiz.



5. Bir nechta induktiv bog‘langan murakkab elektr zanjirni hisoblash, Kirxgof qonuni, konturli tok usuli, ustma-ustlik usuli va ekvivalent generator usulidan foydalaniladi.

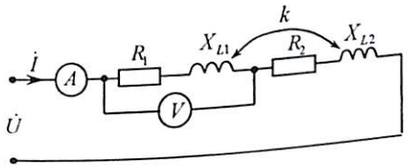
O‘zaro induktiv bog‘langan elektr zanjirlar Kirxgof 2-qonuniga asosan tenglama tuzilganda qo‘shimcha: $\dot{U}_M = \pm j\omega M_{nk} \cdot \dot{I}_k$ ifoda paydo bo‘lib n g‘altak $\dot{I}_k$ tok o‘tganda hosil bo‘ladigan kuchlanishni ifodalaydi. Bunda plus (+) yoki minus (-) ishora induktiv g‘altakning ulanish sxemasi bilan bog‘liq bo‘ladi.

Induktiv bog‘langan elektr zanjirni konturli tok usulidan foydalanib hisoblashda, n konturdagi $\pm j\omega M_{nk} \cdot \dot{I}_k$ ifoda ishorasini aniqlashda, n va k konturlar boglovchi g‘altakdagi kontur toklari $\dot{I}_n$ va $\dot{I}_k$ **bir xil** yo‘nalishda bo‘lsa **plus, qarama-qarshi** yo‘nalishda bo‘lsa **minus ishora** bilan olinadi. (Sxemada nuqta bilan belgilangan ishoralar tokning kirishiga mos keladi hamda plus ishorasi bilan hisobga olinadi.)

4.2. Masalalar yechish va uslubiy ko‘rsatmalar

4.1-Masala. Ketma-ket ulangan ikkita induktiv g‘altak parametri $R_1 = 6\ Om$, $R_2 = 4\ Om$, $x_{L_1} = 8\ Om$, $x_{L_2} = 1\ Om$ bo‘lib, $U = 300V$ kuchlanishga ulangan.

Bog‘lanish koeffitsienti $K = 0{,}565$ bo‘lgan ikkita g‘altakning o‘zaro mos va qarama-qarshi ulangan sxemasi uchun elektr o‘lchov asboblarning ko‘rsatish qiymati aniqlansin.



Yechish.

a) ketma-ket (mos) ulanish.

O‘zaro induktiv qarshilik:

$$x_1 = \omega M = k\sqrt{\omega L_1 \cdot \omega L_2} = 0{,}565\sqrt{8 \cdot 1} = 1{,}6\ Om$$

Kompleks tok: $\dot{I} = \frac{\dot{U}}{R + j\omega L_{mos}} = \frac{\dot{U}}{\underline{Z}}$

Bunda:

$$X_{mos} = \omega L_1 + \omega L_2 + 2\omega M = 8 + 1 + 2 \cdot 1{,}6 = 12{,}2\ Om;$$

$$R = R_1 + R_2 = 6 + 4 = 10\ Om$$

Kompleks kuchlanish: $\dot{U} = U = 300V$

yoki: $\dot{I} = \frac{\dot{U}}{R + j\omega L_{mos}} = \frac{300}{10 + j12{,}2} = 12{,}05 - j14{,}7A$

Ampermetr ko‘rsatgan tokning haqiqiy qiymati:

$$I = \sqrt{12{,}05^2 + 14{,}7^2} = 19A$$

Birinchi g‘altakdagi kompleks kuchlanish:

$\dot{U}_1 = \dot{I}_1(R_1 + j\omega L_1 + j\omega M) = (12{,}05 - j14{,}7) \cdot (6 + j8 + j1{,}6) = (213{,}3 + j27{,}5)V$

Voltmetrdagi kuchlanish: $U_1 = \sqrt{213^2 + 27{,}5^2} = 216V$

Ikkinchi g‘altakdagi kompleks kuchlanish:

$\dot{U}_2 = \dot{I}(R_2 + j\omega L_2 + j\omega M_2) = (12{,}05 - j14{,}7) \cdot (4 + j1 + j1{,}6) = (86{,}4 - j27{,}4)\ (V)$

Masalaning yechimi tekshiramiz:

$\dot{U} = \dot{U}_1 + \dot{U}_2 = 213{,}3 + j27{,}48 + 86{,}4 - j27{,}4 = 299{,}7 + j0{,}06 \approx 300V$ yoki $U = \sqrt{(299{,}7)^2 + (0{,}06)^2} = 300V$

b) qarama-qarshi ulanish.

Kompleks tok: $\dot{I} = \frac{\dot{U}}{R + j\omega L_{qq}}$

Bunda: $L_{qarama-qarshi} = L_1 + L_2 - 2M$

Yoki:

$X_{L_{qq}} = \omega L_{qq} = \omega L_1 + \omega L_2 - 2\omega M = 8 + 1 - 2 \cdot 1.6 = 5.8\ Om$

Tok: $\dot{I} = \frac{300}{10 + j5{,}8} = (22{,}5 - j13)\ A$

Ampermetr ko‘rsatgan qiymat: $I = \sqrt{(22{,}5)^2 + (-13)^2} = 26A$

Birinchi g‘altakdagi kuchlanish kompleks ifodasi

$\dot{U}_1 = (R_1 + j\omega L_1 - j\omega M) = (22{,}5 - j14) \cdot (6 + j8 - j1{,}6) = (218 - j65{,}6)$

Voltmetrdagi kuchlanish:

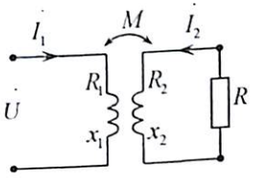
$$U_1 = \sqrt{(218)^2 + (65{,}6)^2} = 226V$$

Ikkinchi voltmetrdagi kompleks kuchlanish:

$\dot{U}_2 = \dot{I}(R_2 + j\omega L_2 - j\omega M) = (82.2 - j65.5)$ V yoki $U_2 = 100\ V$

O‘zaro induktiv qarshilik absolut qiymati $x_M = \omega M > x_{L_2} = \omega L_2$ bo‘lib, reaktiv qarshiligi minus ishoraga teng hamda kompleks sig‘im qarshiligiga mos ekanligini ifodalaydi.

4.2-Masala. O‘zaksiz transformator-ning (havo transformatori) ikkilamchi chulg‘ami iste’molchi qarshiligi $R = 10\ Om;\ x_M = 18\ Om$ ulangan bo‘lib, birlamchi chul-g‘ami $U = 100\ V$ kuchlanishga ulangan. Transformatorning salt ishlash holatida birlamchi va ikkilamchi chulg‘amlaridagi tok, kuchlanish va quvvat qiymatlari: $I_{10} = 10A$, $P_{10} = 100VT$, , $U_{10} = 100\ V$, $U_{20} = 100\ V$, $I_{20} = 2.5\ A$, $P_{20} = 100\ VT$ ga teng. Transformatorning birlamchi W_1 va ikkilamchi W_2chulg‘amlaridan o‘tuvchi tok va foydali ish koeffitsienti aniqlansin.



Yechish. O‘zaro induktiv qarshilik: $x_M = \omega M = 18\ Om$

Birlamchi chulg‘am aktiv qarshiligi: $R_1 = \frac{P_{10}}{I_{10}^2} = 1\ Om$

Birlamchi chulg‘am to‘la qarshiligi: $z_1 = \frac{U_{10}}{I_{10}} = 10\ Om$

Birlamchi chulg‘am reaktiv qarshiligi: $x_1 = \sqrt{z_1^2 - R_1^2} = 9{,}45\ Om$

Ikkilamchi chulg‘am aktiv qarshiligi: $R_2 = \frac{P_{20}}{I_{20}^2} = 16\ Om$

Ikkilamchi chulg‘am to‘la qarshiligi: $z_2 = \frac{U_{20}}{I_{20}} = 40\ Om$

Ikkilamchi chulg‘am reaktiv qarshiligi: $x_2 = \sqrt{z_2^2 - R_2^2} = 36{,}5\ Om$

Kirxgof 2-qonuniga asosan tenglama tuzamiz:

$$\dot{U}_1 = \dot{I}_1(R_1 + jx_1) + \dot{I}_2 jx_M$$

Ikkinchi kontur tenglamadan:

$$\dot{I}_2 = -\dot{I}_1 \frac{jx_M}{(R_1 + R_2) + jx_2}$$

Tok $\dot{I}_2$-qiymatini birinchi tenglamaga qo‘yamiz:

$$\dot{U}_1 = \dot{I}_1(R_1 + jx_1) - \dot{I}_1 \frac{jx_M}{(R_2+R_1)+jx_2} jx_M = \left\{\dot{I}_1\left[R_1 + \frac{x_M^2(R_2+R_1)}{(R_2+R_1)+x_2^2}\right] + j\left[x_1 - \frac{x_M^2 x_2}{(R_2+R_1)+x_2^2}\right]\right\} = \dot{I}_1 \underline{Z}_E$$

Elektr zanjirning ekvivalent to‘la qarshiligi:

$$\underline{Z}_E = (4{,}46 + j8{,}29)\ Om$$

Birlamchi chulg‘amdagi tok : $\dot{I}_1 = \frac{\dot{U}_1}{\underline{Z}_E} = \frac{100}{(4{,}46+j8{,}3)} = 5{,}1 + j2{,}5\ A$

Tokning haqiqiy qiymati: $I_1 = \sqrt{(5{,}1)^2 + (2{,}5)^2} = 10{,}72\ A$

Ikkilamchi chulg‘amdan o‘tuvchi tokni ifodalovchi tenglama:

$$\dot{I}_2 = -\dot{I}_1 \frac{jx_M}{(R_2+R)+jx_2} = -(5{,}1 - j2{,}5)\frac{j18}{(76+j36{,}3)} = (-2{,}3 - j0{,}1)\ A$$

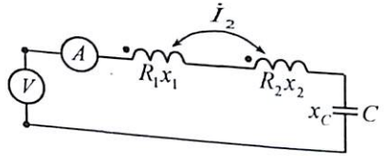
Ikkilamchi chulg‘amdan o‘tuvchi tokning haqiqiy qiymati:

$$I_2 = \sqrt{(2{,}3)^2 + (0{,}1)^2} = 2{,}3\ A$$

Foydali ish koeffitsienti:

$$\eta = \frac{P_2}{P_1} = \frac{I_2^2 R_2}{(I_1^2 R_1)} \cdot 100\% = \frac{(2{,}3)^2 \cdot 16}{(10{,}7)^2 \cdot 1} \cdot 100\% \frac{96}{118} \approx 82\%$$

4.3-Masala. Induktiv bog‘langan ikkita g‘altak sig‘im qarshiligi bilan ketma-ket ulangan bo‘lib, qarshiliklar: $R_1 = 10{,}5\ Om$, $\omega L_1 = 14{,}6\ Om$, $R_2 = 10{,}5\ Om$, $\omega L_2 = 17\ Om$, $\omega M = 32\ Om$, chastotasi $\int = 50\ KG_s$ ga teng. Zanjirdan o‘tuvchi tok $I = 2{,}2\ mA$, kuchlanish $U = 88mV$. Sig‘im qarshiligi va sig‘im C aniqlansin.



Yechish. Aktiv qarshiligi: $R = R_1 + R_2 = 21{,}1\ Om$

To‘la qarshiligi: $z = \frac{U}{I} = \frac{8{,}8 \cdot 10^{-3}}{2{,}2 \cdot 10^{-3}} = 4\ Om$

Reaktiv qarshilik: $x = x_L - x_C = \pm\sqrt{z^2 - R^2} = \pm 34\ Om$

G‘altak induktiv qarshiligi $x_{mos} = \omega L_1 + \omega L_2 + 2\omega M = 38\ Om$

Sig‘im qarshiligi $x_C = x_{mos} - x = 38 \pm 34\ Om$

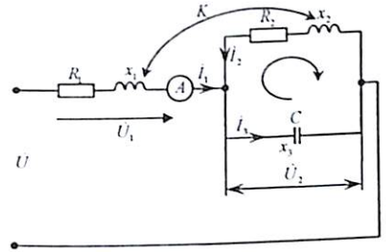
G‘altaklarning o‘zaro ulanish sxemasiga asosan sig‘im ikki xil qarshilikga ega bo‘ladi.

$x'_{C_{mos}} = 38 - 34\ Om$; $x'_{C_{kk}} = 38 + 34\ Om$

yoki: $C' = \frac{1}{\omega x'_C} = 0{,}8 \cdot 10^{-6}\phi = 0{,}8mkF$,

$C'' = \frac{1}{\omega x''_C} = 0{,}044 \cdot 10^{-6}\phi = 0{,}044mkF$

4.4-Masala. Sxemada keltirilgan o‘zaro induktiv bog‘langan elektr zanjirning birlamchi tarmogidan o‘tuvchi tok $I = 10A$, bog‘lanish koeffitsienti $K = 0{,}75$. Parametr qiymati: $R_1 = 2\ Om$, $x_1 = 1\ Om$, $R_2 = 1\ Om$, $x_2 = 4\ Om$, $x_3 = 2\ Om$. G‘altakdagi kuchlanish, umumiy kuchlanish va quvvat qiymati aniqlansin.



Yechish. Kirxgof qonuniga asosan konturdagi tok yo‘nalishi bo‘yicha tenglama tuzamiz:

$$\left.\begin{aligned} \dot{I}_1 + \dot{I}_2 &= \dot{I}_3 \\ \dot{U} = \dot{I}R_1 + \dot{I}_1 j\omega L_1 - \dot{I}_2 R_2 - \dot{I}_2 j\omega L_2 + \dot{I}_1 j\omega M - \dot{I}_2 j\omega M \\ O &= -\dot{I}_2 R_2 - \dot{I}_2 j\omega L_2 - \dot{I}_3\left(-j\frac{1}{\omega C}\right) + \dot{I}_1 j\omega M \end{aligned}\right\}$$

O‘zaro induktiv qarshilik:

$$x_M = \omega M = k\sqrt{x_1 x_2} = 0{,}75\sqrt{1{,}4} = 1{,}5\ Om$$

Tuzilgan tenglamalar sistemasini yechamiz. Bunda $\dot{I}_1 = I_1 = 10A$ bo‘lib, haqiqiy son va kompleks tenglikda haqiqiy o‘q bo‘yicha yo‘naltiriladi.

$$10 + \dot{I}_2 = \dot{I}_3 \quad (1)$$

$$\dot{U} = 10(2 + j2{,}5) - \dot{I}_2(1 + j5{,}5) \quad (2)$$

$$O = -\dot{I}_2(1 + j4) + 15 + \dot{I}_3 \cdot j2 \quad (3)$$

Birinchi tenglamani $10 + \dot{I}_2 = \dot{I}_3$ (3)- tenglamaga qo‘yamiz.

$$-\dot{I}_2(1 + j4) + j15 + \dot{I}_3 \cdot j2 = -\dot{I}_2(1 + j2) + j35 = 0$$

Bundan: $\dot{I}_2 = \frac{j35}{1+j2} = (14 + j7)\ A$

Tokning effektiv qiymati: $I_2 = \sqrt{14^2 + 7^2} = \sqrt{245} = 15{,}6A$

Birinchi tenglamadan:

$$\dot{I}_3 = 10 + \dot{I}_2 = 10 + 14 + j7 = (24 + j7)\ A$$

yoki $I_3 = \sqrt{24^2 + 7^2} = \sqrt{625} = 25\ A$

Ikkinchi tenglamadan, zanjirdagi umumiy kuchlanish:

$\dot{U} = 10(2 + j2.5) - (14 + j7)(1 + j5.5) = (44.5 + j59)\ V$

Kuchlanish effektiv qiymati:

$$\dot{U} = \sqrt{(44.5)^2 + (59)^2} = \sqrt{5461} = 73.9\ V$$

Birinchi g‘altakdagi kuchlanish:

$\dot{U}_1 = \dot{I}_1(R_1 + j\omega L_1) - \dot{I}_2 j\omega M = (10(2 + j) - 14 + j7)j1{,}5 = (30{,}5 - j11)\ V$

Kuchlanish effektiv qiymati:

$$\dot{U}_1 = \sqrt{(30.2)^2 + (11)^2} = \sqrt{1021.2} = 32.4\ V$$

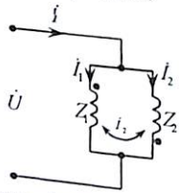
Ikkinchi g‘altak yoki kondensatordagi kuchlanish:

$\dot{U}_2 = \dot{I}_2(R_2 + j\omega L_2) - \dot{I}_1 j\omega M = -(14 + j7)(1 + j4) + j1{,}5 = (14 - j48)\ V$

Effektiv qiymat: $\dot{U}_2 = \sqrt{(14)^2 + (48)^2} = 50\ V$

Zanjir aktiv quvvati: $P = P_1 + P_1 = \dot{I}_1^2 R_1 + \dot{I}_2^2 R_2 = 445\ VT$

4.5-Masala. Induktiv bog‘langan parallel sxemada ulangan tok zanjirining to‘la qarshiligi $z_1 = (5 + j10)\ Om$, $z_2 = (100 + j20)\ Om$, $z_M = 10\ Om$ bo‘lib, $\dot{U} = 120\ V$ kuchlanishga ulangan. Zanjirdan o‘tuvchi tok va quvvat qiymati aniqlansin.



Yechish. Parallel ulangan kompleks ekvivalent to‘la qarshiligi

$$\underline{z}_{1E} = \frac{z_1 z_2 - z_M^2}{\underline{z}_2 - \underline{z}_{1M}} = (6{,}7 + j8{,}9)\ Om$$

$$\underline{z}_{2E} = \frac{z_1 z_2 - z_M^2}{\underline{z}_1 - \underline{z}_{1M}} = (56{,}7 + j6{,})\ Om$$

Tarmoqdagi tok:

$\dot{I}_1 = \frac{\dot{U}}{\underline{z}_1} = (6.4 - j8.6)$ yoki $I_1 = 10.8\ A$

$\dot{I}_2 = \frac{\dot{U}}{\underline{z}_2} = (2.1 - j0.27)$ yoki $I_2 = 2.2\ A$

Umumiy tok: $\dot{I} = \dot{I}_1 + \dot{I}_2 = (8.5 - j8.38)$ yoki $I = 8{,}4 \cdot \sqrt{2} A$

Birinchi g‘altakdagi real aktiv quvvat:

$$P_1 = R_e(\dot{U}\dot{I}_1) = R_e[120(6.4 + j8.6)] = 768\ \text{Vt}$$

G‘altakdagi aktiv quvvat:

$$P'_1 = I_1^2 R_1 = 115 \cdot 5 = 574\ VT$$

Quvvatlar farqi:

$$\Delta P_1 = P_1 - P'_1 = 768 - 574 = 194\ VT$$

Ikkinchi g‘altakdagi real aktiv quvvat:

$$P_2 = R_e(\dot{U}\dot{I}_2) = R_e[120(2.1 + j0.22)] = 252\ Vt$$

G‘altakdagi aktiv quvvat:

$$P'_2 = I_2^2 R_2 = 4.46 \cdot 100 = 446\ VT$$

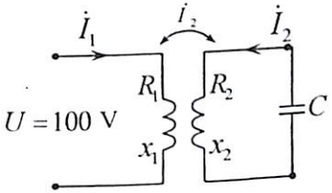
Quvvatlar farqi:

$$\Delta P_2 = P_2 - P'_2 = 252 - 446 = -194\ VT$$

Bunda ikkinchi g‘altakdagi yetishmaydigan $\Delta P_2 = -194\ VT$ aktiv quvvat o‘zaro induksiya hodisasiga asosan energiya bilan ta’minlanadi:

$$P_M = P_{12} = R_e[j\omega M \dot{I}_1 \dot{I}_2] = R_e[j10(11.56 - j19.4)] = 194\ Vt$$

4.6-Masala. O‘zaksiz transformatorning ikkilamchi chulg‘am o‘tuvchi tok $I_2 = 0{,}5A$ bo‘lib, sig‘im qarshiligi ulangan, g‘altak parametrlari $R_1 = 60\ Om$, $\omega L_1 = 80\ Om$, $R_2 = 90\ Om$, $\omega L_2 = 45\ Om$, va sig’im $\frac{1}{\omega C} = 21\ Om$ hamda bog‘lanish koeffitsienti $k = 0{,}5$. Birlamchi chulg‘amdagi tok va kuchlanish qiymati aniqilanib, vektor ifodasi tuzilsin.



Yechish.

O‘zaro induktiv qarshilik: $x_M = \omega M = k\sqrt{\omega L_1 \cdot \omega L_2} = 30\ Om$

Kirxgof qonunlariga asosan konturdagi tok yo‘nalishi bo‘yicha tenglama tuzamiz: $\left[R_2 + j\left(\omega L_2 - \frac{1}{\omega C}\right)\right]\dot{I}_2 + j\omega M \dot{I}_1 = 0$

Bundan $\dot{I}_1 = \dot{I}_2 \frac{R_2 + j\left(\omega L_2 - \frac{1}{\omega C}\right)}{-j\omega M} = \frac{90 + j(45 - 21)}{-j30} \cdot 0{,}5 = 3.14e^{j28^\circ}\ A$

Birlamchi chulg‘amdagi kuchlanish:

$\dot{U}_1 = (R_1 + j\omega L_1)\dot{I}_1 + j\omega M \dot{I}_2 = (60 + j80) \cdot 3.14e^{j28^\circ} + j30 \cdot 0.5 = 328e^{j82^\circ}$

Vektor ifoda tuzish uchun kuchlanishni aniqlash kerak:

$\dot{U}_{R_1} = R_1\dot{I}_1 = (165 + j90)\ (V)$; $\dot{U}_{R_2} = R_2\dot{I}_2 = 45\ (V)$

$\dot{U}_{L_1} = j\omega L_1\dot{I}_1 = (-120 + j220)\ (V)$;

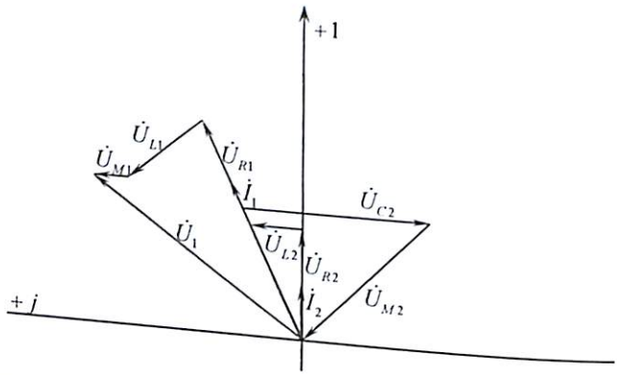
$\dot{U}_{L_2} = j\omega L_2\dot{I}_2 = j22.5\ (V)$

$\dot{U}_{M_1} = j\omega M_1\dot{I}_1 = (-45 + j82.5)\ (V)$;

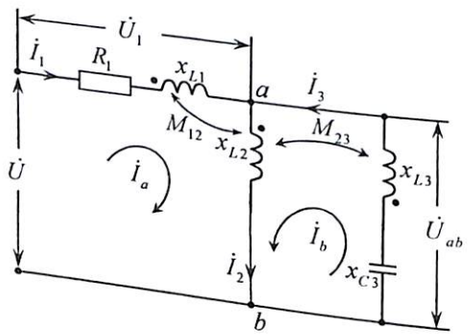
$\dot{U}_{M_2} = j\omega M_2\dot{I}_2 = j15\ (V)$

$\dot{U}_{C_2} = -\frac{1}{j\omega C}\cdot\dot{I}_2 = -j105\ (V)$

Kompleks tekislikda masshtab tanlash bilan vektor ifodasini tuzamiz.



4.7–Masala. Sxemada berilgan elektr zanjirining qarshilik parametri: $R_1 = 2\ Om, x_1 = 10\ Om, R_2 = 1\ Om, X_{M_{23}} = 10\ Om$ bo‘lib, $\dot{U} = 150\ V$ kuchlanishga ulangan. Tarmoqdagi tok $\dot{U}_{ab}$ va kuchlanishni aniqlang.



1. Kirxgof qonuniga asosan yechish.

Kirxgof qonuniga asosan tenglama tuzamiz:

$$\left.\begin{gathered} \dot{I}_1 - \dot{I}_2 + \dot{I}_3 = 0 \\ \underline{z}_1\dot{I}_1 + \underline{z}_{M_{12}}\dot{I}_2 + \underline{z}_{M_{23}}\dot{I}_3 + \underline{z}_2\dot{I}_2 + \underline{z}_{M_{12}}\dot{I}_1 = \dot{U} \\ \underline{z}_2\dot{I}_2 + \underline{z}_3\dot{I}_3 + \underline{z}_{M_{12}}\dot{I}_1 + \underline{z}_{M_{32}}\dot{I}_3 = 0 \end{gathered}\right\}$$

Bunda: $\underline{z}_1 = (50 + j20)$ $\underline{z}_2 = j20$ $\underline{z}_3 = (j20 - j50) = -j30$

$\underline{z}_{M_{12}} = j\omega M_{12} = j10$ $\underline{z}_{M_{32}} = j\omega M_{32} = j10\ Om$

Tenglamaga qarshilik va kuchlanish qiymatini qo‘ysak:

$$\left.\begin{gathered} \dot{I}_1 - \dot{I}_2 + \dot{I}_3 = 0 \\ (5 + j3)\dot{I}_1 + j3\dot{I}_2 + j\dot{I}_3 = 25 \\ \dot{I}_1 + 3\dot{I}_2 - 2\dot{I}_3 = 0 \end{gathered}\right\}$$

Determinant usul bilan yechish natijasi:

$$\Delta = 5(1 + j2), \Delta_1 = 25, \Delta_2 = -75, \Delta_3 = -100$$

Demak: $\dot{I}_1 = \frac{\Delta_1}{\Delta} = (1 + j2)\ (MA)$ $\dot{I}_2 = \frac{\Delta_2}{\Delta} = -3(1 + j2)\ (MA)$

$$\dot{I}_2 = \frac{\Delta_1}{\Delta} = -4(1 + j2)\ (MA)$$

U_{ab} potensial kuchlanish uchun tenglama tuzamiz:

$\dot{U}_{ab} = j\omega M_{12}\dot{I}_2 + j\omega L_2\dot{I}_2 + j\omega M_{23}\dot{I}_3 = (180 - j90)\ (MV)$

2. Konturli tok usuliga asosan yechish.

Kontur toklari yo‘nalishi bo‘yicha tenglama tuzamiz:

$$\begin{cases} (\underline{z}_1 + 2\underline{z}_{M_{12}})\dot{I}_a + (\underline{z}_2 + \underline{z}_{M_{23}} + \underline{z}_{M_{12}})\dot{I}_b = \dot{U} \\ (\underline{z}_2 + \underline{z}_{M_{12}} + \underline{z}_{M_{23}})\dot{I}_a + (\underline{z}_{22} + 2\underline{z}_{M_{23}})\dot{I}_b = 0 \end{cases}$$

Bunda: $\underline{z}_{11} = \underline{z}_1 + \underline{z}_2 = (50 + j40)\ Om$ $\underline{z}_{22} = \underline{z}_3 + \underline{z}_2 = -j100m$

Tenglamalar sistemasini yechish natijasida: $\dot{I}_a = \frac{\dot{U}(\underline{z}_{22} + 2\underline{z}_{M23})}{\Delta}$

$$\dot{I}_b = \frac{-\dot{U}(\underline{z}_2 + \underline{z}_{M12} + \underline{z}_{M23})}{\Delta}$$

Bunda: $\Delta = (\underline{z}_{11} + 2\underline{z}_{M_{12}})(\underline{z}_{22} + 2\,\underline{z}_{M_{23}}) - (\underline{z}_2 + \underline{z}_{M_{12}} + \underline{z}_{M_{23}})^2$

Qarshilik parametr qiymatini qo‘yish bilan $\dot{I}_a$, $\dot{I}_b$tok qiymatlari:

$\dot{I}_a = (1 + j2)$ (mA) $\dot{I}_b = (-4 - j8)$ (mA)

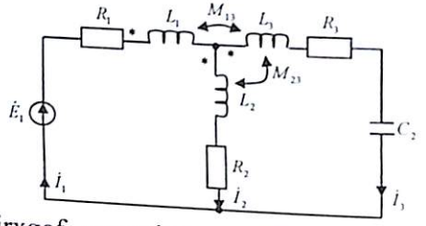
Tarmoqdagi tokning kompleks ifodasi: $\dot{I}_1 = \dot{I}_a(1 + j2)$ (mA)

$\dot{I}_2 = \dot{I}_a + \dot{I}_b = -3(1 + j2)$ (mA)

$\dot{I}_3 = -\dot{I}_b = (4 + j8)$ (mA)

Kuchlanish: $\dot{U}_{ab} = j\omega M_{12}\dot{I}_1 + j\omega L_2\dot{I}_2 + j\omega M_{23}\dot{I}_3 = (180 - j90)$ mV

4.8-Masala. O‘zaro induktiv bog‘langan zanjir parametri: $L_1 = 5\ gn,\ L_2 = 2\ gn, L_3 = 5\ gn,\ M_{13} = 1\ gn, M_{23} = 2\ gn,\ R_1 = 4\ Om,\ R_2 = 8\ Om,\ R_3 = 3\ Om,\ C = 0{,}025$ f. bo‘lib, $U = 100\frac{1}{\sqrt{2}}\cos 2\omega t$ sinusoidal kuchlanishga ulangan. Kirxgof qonuniga asosan tarmoqdagi tok aniqlansin.



Yechish. Kirxgof qonuniga asosan kompleks ifodali tenglama tuzamiz:

$$-\dot{I}_1 + \dot{I}_2 + \dot{I}_3 = 0$$

$$R_1\dot{I}_1 + j\omega L_1\dot{I}_1 + j\omega M_{13}\dot{I}_3 + j\omega L_2\dot{I}_2 + j\omega M_{23}\dot{I}_2 + R_2\dot{I}_2 = \dot{E}$$

$$j\omega L_3\dot{I}_3 + j\omega M_{13}\dot{I}_1 + j\omega M_{23}\dot{I}_2 + R_3\dot{I}_3 + \frac{1}{j\omega C}I_3 - R_2\dot{I}_2 - j\omega L_2 I_2 - jM_{23}\dot{I}_3 = 0$$

tenglamada tok yo‘nalishiga nisbatan $M_{13} > 0;\ M_{23} < 0,$

Bunda $j\omega M_{23} = j2.$

Parametr qiymatlarini qo‘yish bilan:

$$\begin{matrix} \dot{I}_1 & -\dot{I}_2 & -\dot{I}_3 = 0 \\ (4+j10)\dot{I}_1 & +(8+j4)\dot{I}_2 & -j2\dot{I}_3 = 100 \\ -j2I_1 & -(8+j8)\dot{I}_2 & +(3-j6)\dot{I}_3 = 0 \end{matrix}$$

$$\Delta_z = \begin{vmatrix} 1 & -1 & -1 \\ (4+j10) & (8+j4) & (-j2) \\ (j2) & (-8-j8) & (3-j6) \end{vmatrix} = 76 + j82 = 111{,}8e^{j47^\circ}$$

$$\Delta_1 = \begin{vmatrix} 0 & -1 & -1 \\ 100 & (8+j4) & (-j2) \\ 0 & (-8-j8) & (3-j6) \end{vmatrix} = 1100 + j200 = 1118e^{j10^\circ 20^1}$$

Xuddi shunga o‘xshash: $\Delta_2 = 300 - j400,\ \Delta_3 = 800 + j500.$

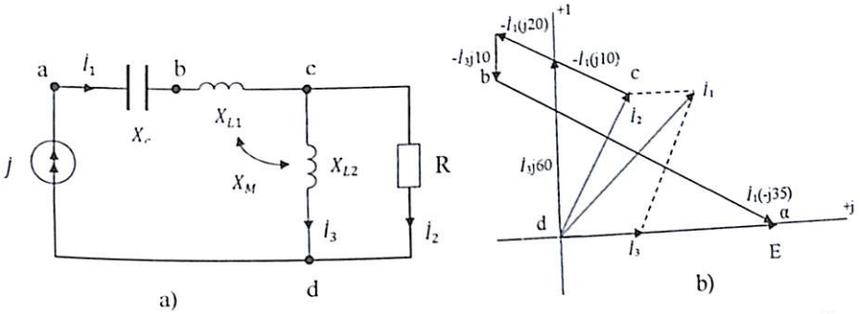
Tarmoqdagi toklarni topamiz:

$$\dot{I}_1 = \frac{\Delta_1}{\Delta_z} = 8 - j6\ A;\ \dot{I}_2 = \frac{\Delta_2}{\Delta_z} = -0{,}8 - j4{,}4\ A;$$

$$\dot{I}_3 = \frac{\Delta_3}{\Delta_z} = 8{,}8 - j1{,}6\ A.$$

Haqiqiy qiymatlari: $I_1 = 10A;\ I_2 = 4{,}472\ A;\ I_3 = 8{,}944\ A.$

4.9-Masala. Zanjir parametrlari: X_M = j10 om $X_c = -j35\ om\ \ X_{L1} = j20\ om\ X_{L2} = j60\ Om\ R = 20\ Om$ bo’lib, I_3= 1A bo’lganda, tarmoq tok qiymatlari topilib, potensial diagrammasi tuzilsin.



a) b)

Yechish: Tok qiymatlarini topish uchun Kirxgofning I- qonuniga asosan : $\begin{cases} \dot{I}_1 = \dot{I}_3 + \dot{I}_2 \\ \dot{U}_2 = \dot{U}_3 - \dot{I}_1 X_M \end{cases}$ yoki: $\begin{cases} \dot{I}_1 = 1 + \dot{I}_2 \\ \dot{I}_2 20 = \dot{I}_3 j60 - \dot{I}_1 j10 \end{cases}$

tenglamani $\dot{I}_2$ tokka nisbatan yechish bilan: $\dot{I}_2 = 1 + j2$ unda $\dot{I}_1 = 1 + \dot{I}_2 = 2 + j2$ Potensial diagramma tuzish uchun φ_d=0 deb, boshqa potensial qiymatlarini topamiz:

$$\varphi_C = \dot{I}_2 R = \dot{I}_3 x_{L2} - \dot{I}_1 x_M = \dot{I}_2 20 = \dot{I}_3 j60 - \dot{I}_1 j10 = 20 + j40\ \text{V}$$

$$\varphi_B = \varphi_c + (\dot{I}_1 j20 - \dot{I}_3 j10) = 20 + j40 + (2+j2)j20 - j60 = -20 + j70\ \text{V}$$

$$\varphi_a = \varphi_B + \dot{I}_1(-j35) = -20 + j70 + (2+j2)(-j35) = 50\ \text{V}$$

Topografik diagramma b rasmda tuzilgan bo’lib, masshtab:

$m_u = 20\text{V/sm}$ $\quad m_I = 0.5\ \text{A/sm}$

4.10-Masala. 4-9 Masaladagi induktiv g’altak birlamchi chulg’amlari mos ikkilamchi chulg’amlari qarama- qarshi sxemada ulangan bo’lib o’zaro induktiv bog’lanishi :$\omega M_1 = 120om,\ \omega M_2 = 45om$ bo’lib, to’klari $I_1 = 0{,}155 + j0{,}486A$, $I_2 = 0{,}322 - j0{,}750A$ bo’lsa chiqishdagi U_{cd} kuchlanishni toping.

Yechish 1) Kirxgo’fni ikkinchi qonuniga asosan ikkilamchi kontur uchun tenglama tuzamiz:

$\dot{I}_1 j\omega M_1 - \dot{I}_2 j\omega M_2 = \dot{U}_{cd}$ son qiymatlarini qo’yamiz:

$\dot{U}_{cd} = (0{,}155 + j0{,}486)\cdot 120 - (0{,}322 - j0{,}750)\cdot j45^\circ = -92 + j4 = 92e^{j177^\circ}.$

Yoki kuchlanishning effektiv qiymati: $\dot{U}_{cd} = 92{,}1 \approx 92V$

4.3. Mustaqil yechish uchun masalalar

4.1-Masala. 4-9 masaladagi chiziqli transformator parametrlari: R_1=1 om R_2=0.5 om L_1=0.01 Gn L_2=0.005 Gn K=0.715 toklari $\dot{I}_1$=(1-j1) A $\dot{I}_2$= j2 A bo'lib chastotasi $\omega=10^3$ rad/sek bo'lganda $\dot{U}_1$ ва $\dot{U}_2$ kuchlanish, kompleks aktiv, reaktiv, to'la quvvat qiymatlari topilsin.

Javob: $\dot{U}_1$ = 3 V $\dot{U}_2$ = 1.5 - j0.5 V $\tilde{S}$ = 3 + j3 VA P =3 Wt Q = 3 VAR.

4.2-Masala. 4-6 masaladagi yechilgan chiziqli transformator parametrlari $\acute{Z}_1$=10+j20 va X_L=20(om) X_C = -4 (om) K=0.4 bo'lib, u= 100sin 314t kuchlanish ulangan. $\dot{I}_1$ va $\dot{I}_2$ toklar va to'la quvvat $\tilde{S}$ qiymati aniqlansin .

Javob : $\dot{I}_1$=1,57- j3,64 A $\dot{I}_2$=0,628- j1,46 A $\tilde{S}$=157+ j364 VA

4.3-Masala. a) Transfarmator parametorlari $\dot{U}_1 = 100V$ $x_1 = x_2 = x_3 = 100om$, $x_c = 110\ om$

$k_{23} = 0{,}9$, $k_{12} = k_{13} = 0{,}8$ teng bo'lganida vo'ltmetordagi kuchlanishlar qiymati topilsin.

Javob: $U_2 = 109V$, $U_3 = 119V$

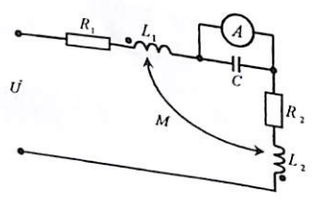
b) agar kondensator uzilsa $(x_c = 0)$ kuchlanishlar qanchaga teng bo'ladi.

Javob: $U_2 = U_3 = 80V$.

4.4-Masala. Parallel sxemada ulangan g'altakning parametri $R_1 = 20Om, R_2 = 20\ Om$, $x_{L_1} = 10\ Om$, $x_{L_2} = 20\ Om$, $x_M = 10\ Om$ ga teng. Zanjirdagi ekvivalent qarshiligi $\underline{z}_0 = \underline{z}_e$ ni aniqlang.

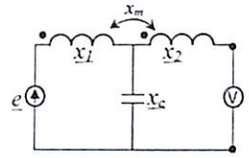
Javob: $\underline{z}_0 = \underline{z}_e = 16{,}27e^{j49°20'}$

4.5-Masala. Elektromagnit zanjir parametri: $C = 43\ mkf, L_1 = 22\ Gn, L_2 = 18\ Gn, M = 6.5\ mGn, R_1 = 10.5\ Om$, $R_2 = 9{,}2\ Om, U =$ $100\ V, f = 200\ Gs$ berilgan sig'imga ulangan voltmetrning ko'rsatish qiymatini aniqlang.



Javob: $U = 48\ V$

4.6-Masala. Agar zanjir parametrlari: $x_1 = 20\ Om, x_2 = 10\ Om, k = 0{,}5\ x_c = -10\ Om\ va\ e = 100sin\omega t$ bo'lganda voltmetr qancha volt kop'rsatadi



Javob: $U = 200\ V$

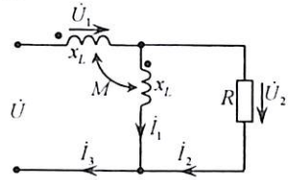
4.7-Masala. Induktiv bog'langan g'altakning parametri $x_{L_1} = 15\ Om$, $x_{L_2} = 2\ Om$, $x_M = 30\ Om$ bo'lganda, bog'lanish koeffitsientini (k) aniqlang.

Javob: $k = 0{,}17$

4.8-Masala. Transformatorning qarshilik parametri $R_2 = 2{,}3\ Om$, $X_{L_1} = 8\ Om$, $X_{L_2} = 10\ Om$, $X_M = 8\ Om$, $\underline{Z}_H = 3{,}35e^{-j50°}\ Om$ bo'lib birlamchi chulg'ami $\dot{U}_1 = 100\ V$ kuchlanishga ulangan. Birlamchi va ikkilamchi chulg'amdan oquvchi tok qiymatini aniqlang.

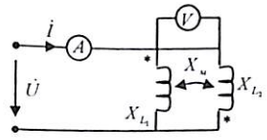
Javob: $\dot{I}_1 = 21{,}9\ A\ ;\ \dot{I}_1 = 22{,}8e^{j15,8°}$

4.9-Masala. Sxemada keltirilgan elektr zanjirning parametri $X_L = 140\ Om$, $X_M = 60\ Om$, $R = 30\ Om$ bo'lib, $\dot{U} = 200\ V$ kuchlanishga ulangan. Tarmoqdagi tok, $\dot{U}_1, \dot{U}_2$ kuchlanish va to'la quvvat tenglamasini aniqlang.



Javob: $U_1 = 171\ V, U_2 = 60\ V,$ $I_1 = 0.67\ A, I_2 = 2\ A, I_3 = 1.43\ A$ $\tilde{S} = \dot{U}I = 120 + j260\ (VA)$

4.10-Masala. O'zaro induktiv bog'langan zanjir qarshiligi: $X_{L_1} = X_{L_2} = 4\ Om$, $X_m = 3\ Om$ bo'lib, ampermetr ko'rsatkichi $1\ A$ bo'lganda voltmetr necha voltni ko'rsatadi?

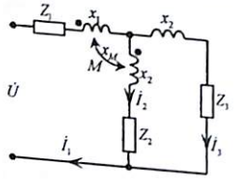


Javob: 7 V

4.11-Masala. O‘zaro induktiv bog‘langan zanjirga ulangan ampermetrdagi tok – $2\,A$, voltmetrdagi kuchlanish – $20\,V$ ga teng. O‘zaro induktiv bog‘lanish qarshiligini X_m aniqlang.

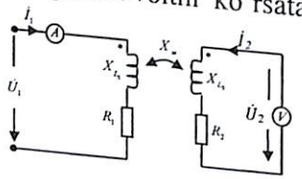
Javob: $X_m = 5\,Om$

4.12-Masala. Berilgan sxemaning parametri: $z_1 = (3+j)Om, z_2 = -j10\,Om,\quad z_3 = (12+j5)Om,\quad x = 3\,Om,$ $x_1 = 2\,Om,\ x_3 = 3\,Om,\ x_M = 8\,Om$ bo‘lib, uchinchi tarmoqdagi tok $\dot{I}_3 = 1\,A$ ga teng. Tarmoq toklari $\dot{I}_1$, $\dot{I}_2$ va $\dot{U}_1$ kuchlanish aniqlanib, topografik diagrammasini tuzing.



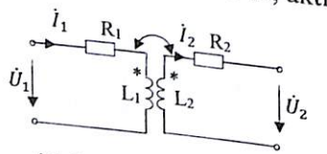
Javob: $\dot{I}_1 = j2\,A,\ \dot{I}_2 = -1 + j2\,A,$ $\dot{U}_1 = j12\,V$

4.13-Masala. Transformator parametri $R_1 = R_2 = 1\,Om,\ X_{L_1} =$ $4\,Om,\ X_{L_2} = 5\,Om,\ X_m = 3\,Om$ bo‘lib, ampermetrdagi tok $1\,A$. Voltmetr qancha voltni ko‘rsatadi?



Javob: $6\,V$

4.14-Masala. Chiziqli transformator parametrlari R_1=1 Om, R_2= 0,5 Om, L_1=0,01Gn, L_2=0,005 Gn k=0,715 bo`lib birlamchi cho`lg`amdan $\dot{I}_1$=(1-j1) A ikkilamchi cho`lg`am esa $\dot{I}_2$=j2 A. $\dot{U}_1$ va $\dot{U}_2$ kuchlanishlari, $Z_{kir}$- to`la qarshilik va to`la, aktiv, reaktiv quvvat qiymatlari topilsin.

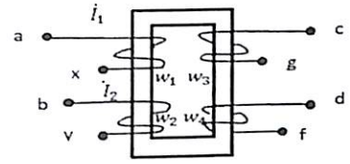


Javob: $\dot{U}_1 = \dot{3}\,V;\ \dot{U}_2 = 1.\dot{5} - 0.5\,V;$ $\dot{S} = 3 + j3\,VA$ yoki P=3Vt, Q=3VAr.

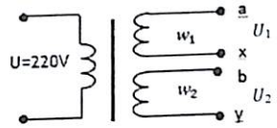
4.14-Masala. Transformator parametri: $R_1 = R_2 = 3\,Om, x_m =$ $x_{L_1} = 4\,Om,\ x_{L_2} = 6\,Om, U_1 = 5\,V$ bo’lib ikkilamchi chulg’am to’la qarshiligi z_2=(1-j6) Om bolganda, transformatorning birlamchi va ikkilamchi chulg’amidan oqib o’tuvchi $\dot{I}_1$, $\dot{I}_2$ toklar topilsin.

Javob: $\dot{I}_1$=(0.54-j0.31) A, $\dot{I}_2$=(0.31+j0.54) A

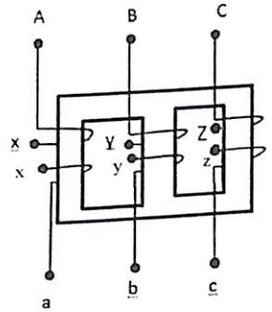
4.15-Masala Induktiv g’altakga ulangan chulg’amlarga **mos** yoki **qarama – qarshi** ulanishni elektir sxemalarini chizing va tenglamasini tuzing.



4.16-Masala. Po`lat o’zakli transfarmatorlarning birlamchi chulg’ami U=220V kuchlanishga ulangan. Agar ikkilamchi chulg’am o’ramlar soni bir hil w_1=w_2 bo’lib ,U_1=U_2 =60V bo’lsa **mos** yoki **qarama- qarshi** sxemada ulanganda chiqishdagi umumiy kuchlanish nimaga teng.



4.17-Masala. Ikkita cho`lg’amli uch fazali transfarmator birlamchi va ikkilamchi chulg’amlari yulduzcha va uchburchak shaklda qanday ulanadi. Bunda chiqishdagi faza yoki liniya kuchlanishlari nimaga farq qiladi va vektor ifodasini chizing.



Nazorat savollari

1. O‘zinduksiya va o‘zaro induksiya hodisalarining fizik ma’nosini tushuntirib bering.
2. Magnit induksiya, magnit oqim va induktivlik tenglamalari qanday ifodalanadi, o‘lchov birligi nima?
3. Elektromagnit induksiya qonunini ifodalovchi tenglamadagi $e = -W\frac{d\phi}{dt}$ «minus» ishorasiga izoh bering.
4. O‘zaro induktiv bog‘lanish koeffitsient ifodasini yozing.
5. O‘zaro induksiya EYK qanday ifodalanadi va yo‘nalishi qanday aniqlanadi?
6. O‘zaro induktiv bog‘langan elektr zanjirlarining ulanish sxemasini chizing.
7. O‘zaro induktiv bog‘langan ketma-ket va parallel sxemada ulangan zanjirning ekvivalent induktivlik tenglamasini tuzing.
8. O‘zaro induktiv bog‘lanish koeffitsienti M tajriba asosida qanday aniqlanadi?
9. Chiziqli havo transformatorini ta’riflab bering.
10. Transformatorning ekvivalent almashlash sxemasini chizing.
11. Transformator vazifasi, tuzilishi va ishlash prinsipini bilasizmi?
12. Transformatorning transformatsiyalash koeffitsienti nima?
13. Transformatorning ishchi holat vektor ifodasini tuzing va tushuntirib bering.
14. Induktivligi $L = 0{,}05\ Gn$ va o‘zaro induktivlik koeffitsienti $M = 0{,}08\ Gn$ bo‘lgan zanjirning o‘zaro induktiv bog‘lanish koeffitsientini (K) aniqlang.
15. Induktivligi $L_1 = 0{,}1\ Gn$, $L_2 = 0{,}1\ Gn$, induktiv bog‘lanish koeffitsienti $K = 0{,}8$ bo‘lgan elektr zanjiri o‘zaro induktivlik koeffitsientini (M) aniqlang.
16. Ekvivalent induktivligi $L_e = L_1 + L_2 - 2M$ tenglama bilan ifodalanuvchi o‘zaro induktiv bog‘langan elektr zanjir sxemasini chizing.
17. O‘zaro induktiv bog‘langan uchta g‘altakdan iborat ikki konturli elektr zanjiri uchun konturli elektr usuliga asosan tenglama tuzing.
18. Mos sxemada ulangan ikkita induktiv bog‘langan (g‘altak) zanjir ifodalangan tenglamasini yozib, topografik vektor diagrammasini chizing.

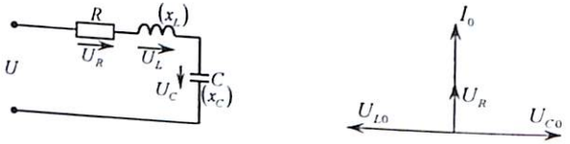
19. Qarama-qarshi sxemada ulangan o‘zaro induktiv bog‘langan zanjir tenglamasini tuzib, vektor ifodasini chizig.
20. Transformatorlarning kuchlanishini kuchaytirish yoki pasaytirish nimaga bog‘liq?
21. Induktiv bog‘langan g‘altakning o‘zaro mos yoki qarama-qarshi ulanishida asosiy magnit oqim ϕ qanday o‘zgaradi?
22. Transformator magnitlovchi kuchlar tenglamasini yozing va fizik ma’nosini tushuntiring.
23. Transformatorning ikkilamchi chulg‘amiga induktivlik yoki sig‘im qarshiligi ulanganda magnit oqim ϕ qanday o‘zgaradi?

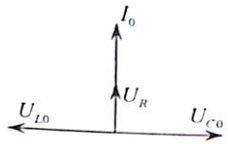
5. ELEKTR TOK ZANJIRDA REZONANS

5.1. Asosiy nazariy tushunchalar

Reaktiv elementlar, induktivlik va sig'im qarshiliklaridan tarkib topgan elektr zanjirda tok va kuchlanish vektorlari ustma-ust tushib, bular orasida burchak $\varphi = 0$ bo'lgan holda, **rezonans hodisasi** yuzaga keladi.

1. Ketma-ket ulangan R, L, C zanjirda kuchlanish rezonansi.





Zanjir rezonans holat vaqtida $X_L = X_C$, yoki $\omega_0 L - \frac{1}{\omega_0 C} = 0$

Bundan rezonans chastota: $\omega_0 = \frac{1}{\sqrt{LC}}\ (rad/sek)$

Rezonans hodisasiga o'zgaruvchan tok chastotasi f, induktivlik L va sig'im C parametrini o'zgartirish bilan erishiladi.

Rezonans holatida reaktiv element qarshiligi: $\omega_0 L = \frac{1}{\omega_0 C} = \rho \gg R$

yoki: $X_L = \omega_0 L = \frac{1}{\sqrt{LC}} \cdot L = \sqrt{\frac{L}{C}} = \rho;\ X_c = \frac{1}{\omega_0 C} = \frac{\sqrt{LC}}{C} = \sqrt{\frac{L}{C}} = \rho;$

$\rho = \sqrt{\frac{L}{C}}$ **to'lqin qarshilik** (Om) da o'lchanadi.

Rezonans holatda $z = R$ bo'lib tok maksimal qiymatga erishadi:

$$I_0 = \frac{U}{R} = I_{max} = \frac{U_\rho}{\rho}$$

Reaktiv elementlardagi kuchlanish: $U_{LO} = U_{CO} = I_O\, \rho$

Agar $\rho > R$ bo'lsa, reaktiv qarshilikdagi kuchlanish manba kuchlanishidan katta bo'ladi. Necha martaga katta bo'lishi quyidagi formula bilan aniqlanadi:

$$Q = \frac{U_{L0}}{U} = \frac{U_{C0}}{U} = \frac{\omega_{OL}}{R} = \frac{\rho}{R}$$

Bunda Q – **kontur saxiyligi yoki aslligi, bazan sifat koeffitsienti ham deyiladi.**

Unga teskari bo'lgan qiymat: $d = \frac{1}{Q} = \frac{R}{\rho}$ - **konturning so'nishi** deyiladi.

Rezonans holatda konturning energiya tebranishiga aktiv qarshilik ta'sirini hisobga olganda, kontur xususiy tebranish chastotasi:

$$f = f_0 \sqrt{1 - \frac{R^2 C}{4L}}$$

Reaktiv qarshiliklardagi kuchlanish U_{Lmax} va U_{Cmax} maksimal qiymatga rezonansdan oldin yoki keyin erishadi va quyidagi ifoda bilan izohlanadi.

$$\omega_L = \frac{\omega_0}{\sqrt{\frac{2}{2-d^2}}} \text{ va } \omega_C = \omega_0 \sqrt{\frac{2}{2-d^2}}$$

Rezonans kontur chastotasi (ω), zanjir parametri, tok va kuchlanishga nisbatan bog'liqlik funksiyasiga **chastotali xarakteristika** deyiladi.

$$f_{(\omega)} = f(I_{(\omega)}, U_{(\omega)}, U_{L(\omega)}, U_{C(\omega)}, X_{L(\omega)}, X_{C(\omega)}, z_{(\omega)})$$

Bu xarakteristikani analiz qilishda tok yoki chastotani nisbiy qiymat orqali ifodalash ancha qulay bo'lib, koeffitsient $\eta = \frac{\omega}{\omega_0}$ ga teng deb olinadi.

Bunda: $\omega_O = \frac{1}{\sqrt{LC}}\ (rad/sek)$; $I_O = \frac{U}{R}$, $R = \rho d$, $h = \frac{\omega}{\omega_0}$, $I = \frac{U}{z}$

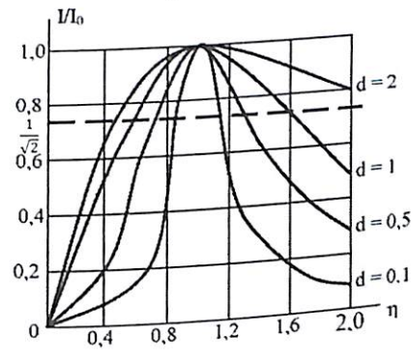
$$\frac{I}{I_0} = \frac{1}{\sqrt{1+[(\eta - \frac{1}{\eta}):d]^2}}$$

So'ndirish koeffitsienti: $d = \eta_1 - \eta_2$ Rezonans konturining ma'lum bir chastotani o'tkazish chegarasi:

$$\omega_0(\eta_2 - \eta_1) = \omega_0 d.$$

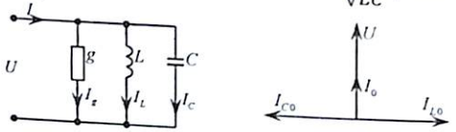
Rezonans holatda tebranuvchan elektromagnit maydon energiyasi o'zgarmas bo'ladi.

$$W_0 = W_M + W_e = \frac{1}{2} L I^2 + \frac{1}{2} C U^2 = const$$



2. Parallel ulangan G,L, C zanjirda toklar rezonansi.

Parallel ulangan elektr zanjir rezonans holatda $B_L = B_C$ bo'lib, rezonans chastota: $\frac{1}{\omega_0 L} - \omega_0 C = 0$ yoki: $\omega_0 = \frac{1}{\sqrt{LC}}\,(rad/sek)$



Reaktiv elementlarning o'tkazuvchanligi: $\frac{1}{\omega_0 L} = \omega_0 C = \gamma = \sqrt{\frac{C}{L}}$ ga teng bo'lib, **to'lqin o'tkazuvchanligi** deyiladi.

Rezonans holatda umumiy tok: $I_0 = Ug$.

Reaktiv elementlardagi tok: $I_{L_0} = I_{C_0} = U\gamma$

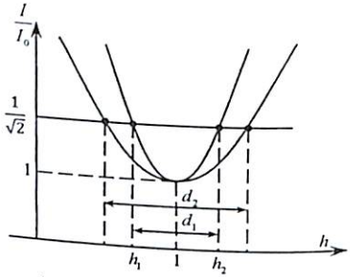
Rezonans vaqtida $Z = R$ bo'lib aktiv quvvat $P = \frac{1}{2} R I_0^2$ yoki tok $I = 0{,}707 I_0$.

Agarda $g < \gamma$ bo'lganda, reaktiv qarshiliklarda tok umumiy tokdan katta bo'lib: $d = \frac{I}{I_{L_0}} = \frac{I}{I_{C_0}} = \frac{Ug}{U\gamma} = \frac{g}{\gamma}$ - **kontur so'nishi** deyiladi.

Teskari qiymat: $Q = \frac{1}{d} = \frac{Ug}{U\gamma}$ - **kontur saxiyligi** yoki **asilligi** deyiladi.

Rezonans holat uchun chastotali xarakteristikalarni tuzishda tok va chastota qiymatiga nisbatan olingan tenglamadan foydalaniladi:

$$\frac{I}{I_0} = \sqrt{1 + \left[\left(\frac{1}{h} - h\right) : d\right]^2}$$



Keltirilgan xarakteristikadan rezonans chastota so'nish chegaralari $d = h_1 - h_2$ bilan ifodalaniladi.

Tok rezonans holatda ham elektromagnit maydon energiyasining tebranishi kuchlanishlar rezonans holatiga o'xshash va o'zgarmas bo'ladi.

$$W = \frac{1}{2} L I^2 = \frac{1}{2} C U^2 = const$$

Radiotexnikada elektromagnit maydon energiya tarqalishi tezligi to'lqin uzunligiga nisbatan o'lchanib: $\lambda = \nu T$, λ – to'lqin uzunligi (m),

ν – to'lqin tarqalish tezligi (m/sek), T – davr (1/sek), bunda: $\lambda = \frac{\nu}{f}$.

f – chastota. Tebranuvchan kontur to'lqin uzunligi:

$$\lambda_0 = \nu \cdot 2\pi\sqrt{LC} = 3 \cdot 10^8 \cdot 2\pi\sqrt{LC}\ (\text{m}).$$

3. Tarmoqlangan elektr zanjirda rezonans.

Tarmoqlangan elektr zanjirda ham rezonans sharti $\varphi = 0$ bo'lib, tok va kuchlanish vektorlari orasidagi burchak nolga teng.

Bir nechta induktivlik va sig'im elementlaridan tuzilgan murakkab elektr zanjirda rezonans hodisasi ba'zi kontur va tarmoqlarda ham hosil bo'lishi mumkin.

Radiotexnika, aloqa, avtomatika va boshqa sohalarda o'zaro bog'langan tebranuvchan konturlarda hosil bo'ladigan rezonans hodisasidan keng foydalanib, bular umumiy zanjir qarshiligi yoki elektromagnit maydon energiyasi orqali bog'langan bo'lishi mumkin.

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Konturlarning o'zaro bog'lanish koeffitsienti: $K = \frac{X_m}{\sqrt{X_1 X_2}}$ (*)

bo'lib: X_m – elementlarning o'zaro bog'lanish qarshiligi.

X_1 – birinchi kontur reaktiv qarshiligi.

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$C_2 = \frac{C_2 C_0}{C_2 + C_0}$ – ikkinchi kontur umumiy sig'imi.

Ushbu qiymatni (*) tenglamaga qo'yish bilan: $K = \sqrt{\frac{C_1 C_2}{(C_1 + C_0)(C_2 + C_0)}}$

Kontur elektr yurituvchi kuch o'zaro induktiv bog'lanishida:

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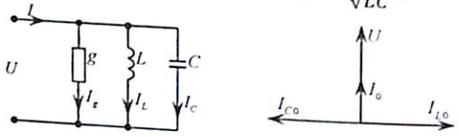

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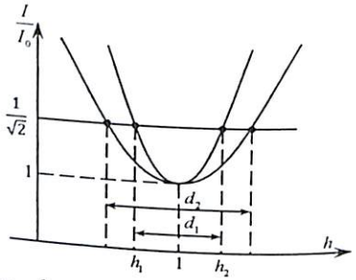

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Kontur elektr yurituvchi kuch o'zaro induktiv bog'lanishida:

$$K = \frac{E_2}{E_{2M}} = \frac{E_2}{I_1 \omega M}.$$

Bunda I_1 – birlamchi konturdagi tok o'zaro induktiv bog'langan (transformator) zanjirda rezonans hodisasini tahlil qilishda ekvivalent keltirilgan aktiv va reaktiv qarshilik tenglamalaridan ham foydalaniladi:

$\Delta R_1 = \frac{\omega^2 M^2}{Z_2^2} R_{22}$ (aktiv qarshilik); $\Delta X_1 = -\frac{\omega^2 M^2}{Z_2^2} X_{22}$ – sig'im xarakterga ega bo'lgan reaktiv qarshilik.

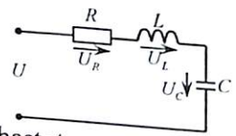
O'zaro induktiv bog'langan kontur quvvat muvozanat tenglamasi:

$$P_2 = I_1^2 \frac{\omega^2 M^2}{R_2} = \frac{E_2^2}{R_2} = I_2^2 R_2 \ (VT).$$

Foydali ish koeffitsienti: $h = \frac{P_2}{P} = \frac{P_2}{P_1 + P_2} = \frac{I_1^2 \Delta R_1}{I_1^2 R_1^2 + I_1^2 \Delta R_1} = \frac{\Delta R}{R + \Delta R_1}$.

5.2. Masalalar yechish va uslubiy ko'rsatmalar

5.1-Masala. Ketma-ket biriktirilgan elektr zanjirning parametri $L = 150 mkGn = 15 \cdot 10^{-5} Gn, C = 470 mkF = 47 \cdot 10^{-7} F, R = 5\ Om$ bo'lib, $U = 10\ V$ kuchlanishga ulangan. Rezonans chastotasi f_0, reaktiv elementlardagi kuchlanish U_L, U_C, to'lqin qarshiligi ρ, kontur asilligi Q va so'nish koeffitsienti d ni aniqlang.



Yechish. Rezonans chastota:

$\omega_0 = \frac{1}{\sqrt{LC}} = \frac{1}{\sqrt{705 \cdot 10^{-16}}} = \frac{1}{26{,}6 \cdot 10^{-8}} = 376 \cdot 10^4\ (rad/sek)$

Bundan: $f_0 = \frac{\omega_0}{2\pi} = \frac{376 \cdot 10^4}{6{,}28} = 6 \cdot 10^5\ (gs)$

Rezonans holatdagi tok: $I_0 = \frac{U}{R} = \frac{10}{5} = 2\ A$

Reaktiv qarshiligi: $x_L = \omega_0 L = 565\ Om$

$$x_C = \frac{1}{\omega_0 C} = \frac{1 \cdot 10^4}{376 \cdot 10^4 \cdot 47} = 565\ Om$$

Reaktiv qarshiliklardagi kuchlanish:

$U_L = IX_L = 565 \cdot 2 = 1130\ V, U_C = IX_C = 1130\ (V)$

To'lqin qarshiligi: $\rho = \sqrt{\frac{L}{C}} = 565\ Om$

Asillik koeffitsienti: $Q = \frac{U_C}{U} = \frac{\rho}{R} = 113$

So'nish koeffitsienti $d = \frac{1}{Q} = \frac{1}{113} = 0{,}885 \cdot 10^2$

5.2-Masala. Ketma-ket zanjir R, L, C qiymatlari: $R = 16\ om, L = 158\ MGn$, $f_0 = 1\ MGs, U = 0{,}8\ V$ bo'lganda. C, I_0, U_C, U_L, P qiymatlar topilsin.

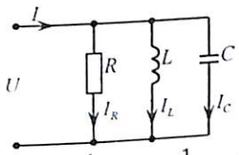
Yechish: Rezonans shartiga asosan: $\omega L = \frac{1}{\omega C}$ bundan $C = \frac{1}{\omega^2 L} = \frac{1}{(6{,}28)^2 \cdot 158} = 0{,}160 \cdot 10^{-3} F = 160\ mkF$

Tok: $I_0 = \frac{U}{R} = \frac{0{,}8}{16} = 0{,}05\ A = 50\ mA$

Kuchlanishlar: $U_L = U_c = I \cdot X_L = 0{,}05 \cdot \omega L = 0{,}05 \cdot 6{,}28 \cdot 158 = 0{,}05 \cdot 10^3 = 50\ V$

Rezonans holatdagi aktiv quvvat: $P_0 = I_0^2 \cdot R = 0{,}0025 \cdot 16 = 0{,}04\ Wt.$

5.3-Masala. Parallel sxemada ulangan elektr zanjir parametri $R = 50\ Om\ (g = 0{,}02 \frac{1}{Om}), L = 16 mGn = 16 \cdot 10^{-3}\ Gn,$ $C = 40\ mkF = 40 \cdot 10^{-6}\ F$, bo'lib, $U = 200\ V$ kuchlanishga ulangan. Rezonans chastota f_0, tok I, I_L, I_C so'nish koeffitsienti d va to'lqin o'tkazuvchanligi γ ni aniqlang.



Yechish. Rezonans chastota: $\omega_0 = \frac{1}{\sqrt{LC}} = \frac{1}{\sqrt{64 \cdot 10^{-8}}} = \frac{1}{8 \cdot 10^{-4}} = 1250 \left(\frac{rad}{sek}\right)$

yoki: $f_0 = \frac{\omega_0}{2\pi} = 199\ (gs)$

Tok: $I = Ug = 200 \cdot 0{,}02 = 4\ (A)$

Induktiv va sig'im reaktiv o'tkazuvchanligi:

$$b_L = \frac{1}{\omega_0 L} = \frac{1}{1250 \cdot 16 \cdot 10^{-6}} = 0{,}05 \left(\frac{1}{Om}\right)$$

$$b_C = \omega_0 L = \frac{1}{1250 \cdot 40 \cdot 10^{-6}} = 0{,}05 \left(\frac{1}{Om}\right)$$

Induktivlik va sig'imdan o'tuvchi tok:

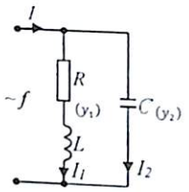
$$I_L = Ub_L = 10\ (A),\ \ I_C = Ub_C = 10\ (A)$$

To'lqin o'tkazuvchanligi: $\gamma = \sqrt{\frac{C}{L}} = 0{,}05 \left(\frac{1}{Om}\right)$

Kontur asilligi: $Q = \frac{\gamma}{g} = 2{,}5$

Kontur so'nish koeffitsienti: $d = \frac{1}{Q} = 0{,}4$

5.4-Masala. Sxemada keltirilgan elektr zanjir chastotasi $f = 400\ Gs$ o‘zgaruvchan tok manbaiga ulangan. Agar aktiv qarshilik $R = 5\ Om$, sig‘im parametri $C = 10{,}5\ mkF$ bo‘lsa, induktivlikning qanday qiymatida rezonans holat yuzaga keladi.



Yechish.

Ushbu elektr zanjir uchun rezonans sharti, reaktiv o‘tkazuvchanlikning yig‘indisi nolga tengligi bo‘ladi. Yani: $y = y_1 + y_2$

Bunda: $y_1 = \frac{1}{z_1} = j\omega c;\ \ y_2 = \frac{1}{z_2} = \frac{1}{R+j\omega L} = \frac{R+j\omega L}{R^2+\omega^2L^2}$

yoki: $y = \frac{R}{R^2+\omega^2L^2} + j\left(\omega c - \frac{\omega L}{R^2+\omega^2L^2}\right)$

Qavs ichidagi reaktiv o‘tkazuvchanlik tenglamasini nolga tenglaymiz:

$$b = \omega c - \frac{\omega L}{R^2+\omega^2L^2} = 0$$

Umumiy maxrajga keltirib ω ga bo‘lib yuborilsa:

$$\omega^2L^2c^2 - L + cR^2 = 0$$

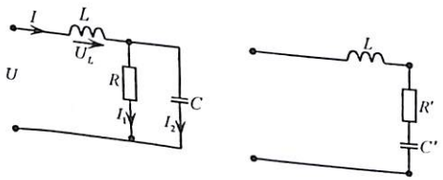
Induktivlikga nisbatan tenglama yechimi:

$$L_{1,2} = \frac{1 \pm \sqrt{1-4\omega^2c^2R^2}}{2\omega^2c} = \frac{1 \pm 0{,}85}{132}$$

Demak zanjirda rezonans holat yuzaga kelishi mumkin bo‘lgan induktivlik qiymati:

$$L_1 = 0.014gn = 14mGn;\ L_2 = 0.00114 = 1.14mGn\ .$$

5.5-Masala. Keltirilgan elektr zanjir uchun rezonans chastota (ω_0) tenglamasi va aktiv qarshilikning (R) qanday qiymatida rezonans holat yuzaga kelishini aniqlang.



Yechish. Zanjirning parallel ulangan qismini ekvivalent sxemasi bilan almashtiriladi.

$$R' = \frac{g}{y^2} = \frac{\frac{1}{R}}{\left(\frac{1}{R}\right)^2 + (\omega c)^2} = \frac{R}{1+\omega^2C^2R^2}$$

$$x' = \frac{b}{y^2} = \frac{\omega C}{\left(\frac{1}{R}\right)^2 + (\omega c)^2} = \frac{\omega CR^2}{1+\omega^2C^2R^2}$$

Ketma-ket ulangan ekvivalent sxema uchun rezonans sharti:

$$x = \omega L - \frac{\omega CR^2}{1+\omega^2C^2R^2}$$

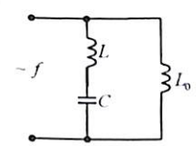
Tenglama umumiy maxraji berilib, (ω) ga bo‘linsa:

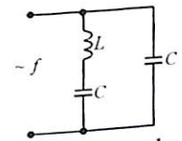
$L + \omega_0^2C^2R^2L - CR^2 = 0$ Bundan: $\omega_0 = \sqrt{\frac{CR^2-L}{C^2R^2L}} = \frac{1}{\sqrt{LC}}\sqrt{1-\frac{\frac{L}{C}}{R^2}}$

Demak: $R > \sqrt{\frac{L}{C}} = \rho$ bo‘lgandagina rezonans holat yuzaga keladi.

Umuman R=const bo‘lganida, induktivlik L sig‘im C yoki chastotani f o‘zgartirish bilan rezonasga erishish mumkin.

5.6-Masala. Berilgan elektr zanjir o‘zgaruvchan tok chastotasi $f = 10^{-5}Gs$ bo‘lgan generatorga ulangan. Induktivligi $L = 100\ mkGn$, sig‘imi $C = 500\ Pf$. Zanjirda kuchlanishlar rezonansini hosil qiluvchi induktivlik qiymati L_0 aniqlanib, zanjirda tok rezonansi yuzaga kelishi uchun $f = 2\ MGs$ bo‘lganda qanday qilib iste’molchiga ulanish mumkin?





Yechish. Ushbu elektr zanjir uchun rezonans shartiga asosan reaktiv qarshiliklari nolga teng: $b = b_1 + b_2 = 0$

Bunda: $b_1 = \frac{\omega C}{\omega^2LC-1} - LC$ zanjir reaktiv o‘tkazuvchanligi

$b_0 = \frac{1}{\omega L_0} - L_0$ induktivligi reaktiv o‘tkazuvchanligi

Demak: $-\frac{\omega C}{\omega^2LC-1} + \frac{1}{\omega L_0} = 0$

Bundan: $\omega^2L_0C + \omega^2LC - 1 = 0$

Tenglamani L_0 ga nisbatan yechish bilan:

$$L_0 = \frac{1-\omega^2 LC}{\omega^2 LC} = \frac{1}{\omega^2 C} - L = 0.0049Gn = 4.9MGn$$

Zanjirda kuchlanishlar rezonansi yuzaga kelishi uchun $L_0 = 4{,}9MGn$ teng bo‘lishi kerak.

Masalaning ikkinchi sharti bo‘yicha yana reaktiv o‘tkazuv-chanliklar tenglamasi nolga tenglanadi: $\mathrm{b} = \frac{\omega C}{\omega^2 LC-1} + \mathrm{b}'_0$

$\omega = 2\pi f = 4\pi \cdot 10^6\ sek^{-1}$– teng bo‘lganda, bunda b'_0 – zanjir tarmog‘iga ulangan reaktiv o‘tkazuvchanlik: $b'_1 = \frac{\omega C}{\omega^2 LC-1} = -9{,}2 \cdot 10^{-4}\ \frac{1}{Om} < 0$

Demak, ushbu elektr zanjirida tok rezonansi hosil bo‘lishi uchun induktivlik L_0 sig‘im elementi bilan almashtirilishi kerak. Sig‘im parametrlari esa $C_0 = \frac{b'_0}{\omega} = \frac{9{,}2\cdot 10^{-4}}{4\pi\cdot 10^6} = 73{,}3\ pf$ ga teng.

5.7-Masala. 5-5 masaladagi zanjir kuchlanishlar rezonans holatida aktiv qarshilik $R = 200\ Om$, umumiy qarshilik esa $Z_{um} = 100\ Om$ bo‘lib, $U = 200\ V$ kuchlanishga ulangan.

Rezonans vaqtidagi induktivlik x_L va sig‘im x_C qarshiligi, tarmoqdagi tok qiymatini toping.

Yechish. Umumiy kompleks qarshilik:

$Z_{um} = jx_L + \frac{R(-jx_C)}{R-jx_C} = \frac{R(-jx_C)R(+jx_C)}{R^2-jx_C^2} + jx_L = \frac{Rx_C^2}{R^2+jx_C^2} + \quad j\left(x_L - \frac{R^2 x}{R^2+jx_C^2}\right) = R_{um} + jx_{um}.$

Bundan $R_{um} = 100\ Om;\quad X_{um} = 0.$

Zanjir aktiv qarshiligi $R = 200\ Om$ bo‘lsa, Ikkita noma’lum tenglama yozamiz:

$R_{um} = 100 = \frac{Rx_C^2}{R^2+x_C^2}$ yoki $100 = \frac{200x_C^2}{(200)^2+x_C^2}$.

Bundan: $x_C = 200\ Om$

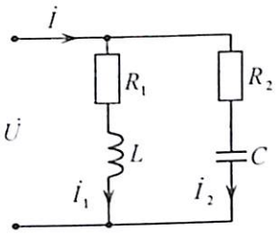
Endi umumiy reaktiv qarshilik: $X_{um} = 0 = X_L - \frac{R^2 x_C}{Z}$;

$x_L = \frac{200^2\cdot 200}{200^2+200^2} = 100\ Om.$

Umumiy tok: $I = \frac{\dot{U}}{Rum} = \frac{200e^{j0}}{100} = 2\ A$

Tarmoqdagi tok: $\dot{I}_1 = \dot{I}\frac{-jx_c}{R-jx_c} = 1 - j1\ A;\quad \dot{I}_2 = \dot{I}\frac{R}{R-jx_c} = 1 + j1\ A.$

5.8-Masala. Parallel ulangan elektr zanjirning parametri: $R_1 = 100\ Om, R_2 = 200\ Om, L = 0{,}2Gn, C = 1\ mkf$, manba kuchlanishi $\dot{E} = 100\ V$. Rezonans chastota, reaktiv qarshiliklar va rezonans holatdagi tok kuchini aniqlang.



Yechish. Umumiy ekvivalent o‘tkazuvchanligi:

$y = y_1 + y_2 = \frac{1}{R_1+j\omega L} + \frac{1}{R_1-\frac{1}{j\omega L}} = \frac{R_1-j\omega L}{R_2^2+\omega^2 L^2} + \frac{R_2-\frac{1}{j\omega C}}{R_2^2+\frac{1}{\omega^2 C^2}} = \frac{R_2}{z_1^2} + \frac{R_2}{z_2^2} -$

$j\left(\frac{\omega L}{R_1^2+\omega^2 L^2} + \frac{-\frac{1}{j\omega C}}{R_2^2+\frac{1}{\omega^2 C^2}}\right) = g - jb$

Parallel ulangan elektr zanjirida tok rezonans sharti $b_L = b_C$ bo‘lib, bundan rezonans chastota tenglamasi:

$\frac{\omega L}{R_1^2+\omega^2 L^2} = \frac{\frac{1}{\omega C}}{R_2^2+\frac{1}{\omega^2 C^2}}$ yoki $\omega_0 = \frac{1}{\sqrt{LC}}\sqrt{\frac{\frac{L}{C}-R_1^2}{\frac{L}{C}+R_2^2}} = 2414\ \frac{1}{sek}$

Reaktiv qarshiliklari: $x_L = \omega_0 L = 483\ (Om), x_C = \frac{1}{\omega_0 C} = 414\ (Om)$

Birinchi tarmoq to‘la qarshiligi:

$$\underline{z}_1 = R_1 + j\omega_0 L = 493 \cdot e^{j78^\circ}\ (Om)$$

$$\underline{z}_2 = R_2 - j\frac{1}{\omega_0 C} = 460 \cdot e^{-j64^\circ}\ (Om)$$

Birinchi tarmoqdagi tok:

$$\dot{I}_1 = \frac{\dot{U}}{\underline{z}_1} = \frac{100e^{j0^\circ}}{493e^{j78^\circ}} = (0{,}04 - j0{,}19)\ (A)$$

Ikkinchi tarmoqdagi tok

$$\dot{I}_2 = \frac{\dot{U}}{\underline{z}_2} = \frac{100e^{j^\circ}}{460e^{-j64^\circ}} = (0{,}09 + j0{,}19)\ (A)$$

Umumiy tok:

$$\dot{I} = \dot{I}_1 + \dot{I}_2 = (0{,}04 - j0{,}19) + (0{,}09 + j0{,}19) = 0{,}13\ (A)$$

Rezonans holatda reaktiv qarshilik nolga teng $(x = 0)$

5.9-Masala. (5.8) masalada berilgan sxemaning qarshiligi $x_L = 40\ Om$, $R_1 = 30\ Om$, $R_2 = 28\ Om$, chastotasi $f = 1000\ Gs$ bo'lgan holatda zanjirda tok rezonansini yuzaga keltiruvchi sig'im qiymatini aniqlang.

Yechish. Rezonans holatda reaktiv qarshilik nolga teng. yani: $x_L - x_C = 0$ yoki: $x_L = x_C$

Bunda induktivlikdagi reaktiv quvvat:

$$Q_L = I_1^2 x_L = \frac{U^2}{R_1^2 + x_C^2} x_L$$

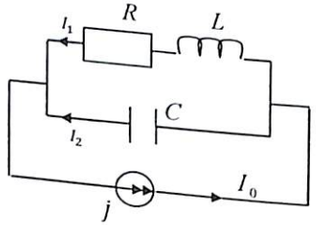
Sig'imdagi reaktiv quvvat: $Q_C = I_1^2 x_C = \frac{U^2}{R_2^2 + x_C^2} x_C$

Demak: $\frac{U^2}{30^2 + x_C^2} \cdot 40 = \frac{U^2}{28^2 + x_C^2} x_C$

Bundan sig'im qarshiligi: $x_C = 17{,}75\ Om$

Sig'im parametri: $C = \frac{x_C}{2\pi f} = \frac{17{,}75}{2 \cdot 3{,}14 \cdot 1000} = 2{,}28 mkf$

5.10-Masala. Parallel sxemada ulangan rezonansli kontur parametri $R = 2\ Om$, $L = 0{,}4\ mg$, $C = 0{,}01\ mkf$ bo'lib, $I_0 = 10\ mA$ tok manbaiga ulangan: Rezonans chastota ω_0, asillik koeffitsienti Q va tok chastota $\pm 2\ \%$ o'zgarganda rezonans kuchlanish va tok I_1, I_2 qiymatini aniqlang.



Yechish. Rezonans shartiga ko'ra: $b_1 = -b_2$ yoki: $\frac{\omega_0 L}{R + (\omega_0 L_0)^2} = \frac{1}{\omega c}$

bundan: $\omega_0 = \frac{1}{\sqrt{LC}} \sqrt{\frac{\rho^2 - R^2}{\rho^2}} \approx 5 \cdot 10^5\ rad/sek$

Kontur to'lqin qarshiligi: $\rho = \sqrt{\frac{L}{C}} = \sqrt{\frac{0{,}4 \cdot 10^{-3}}{10^{-8}}} = 200\ Om.$

Kontur asilligi $Q = \frac{\rho}{R} = 100.$

Rezonans holatda $b = b_1 + b_2 = 0$, bo'lganligi uchun $R_0 = \frac{1}{g_{12}}$; aktiv o'tkazuvchanlik: $g_{12} = g_0 = \frac{R^2}{R^2 + (\omega_0 L)^2} \approx 0{,}5 \cdot 10^{-4} \frac{1}{Om}$.

Demak $R_0 = \frac{1}{0{,}5 \cdot 10^{-4}} = 20 \cdot 10^{-3} Om.$

Rezonans kuchlanish: $U_p = I_0 R_0 = 10 \cdot 10^{-3} \cdot 20 \cdot 10^3 \approx= 200\ V.$

Rezonans holatda $R_1 \ll \omega_0 L$ ekanligini hisobga olinsa:

$I_1 \approx I_2 = \frac{U_p}{\rho} = \frac{200}{200} = 1\ A.$

Agar tok chastotasi 2% ko'paysa reaktiv o'tkazuvchanlik qiymati:

$b_{12} = b_1 + b_2 = \frac{\omega L_1}{R_1^2 + (\omega L_1)^2} - \omega c_2 = -0{,}2 \cdot 10^{-3} \frac{1}{Om.}$

Bunda: $\omega^1 = (\omega_0 + 0{,}02\omega_0) = 5{,}1 \cdot 10^5\ rad/sek.$

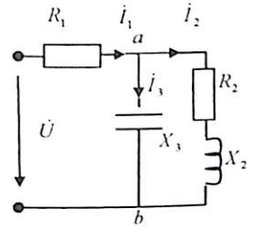
Aktiv o'tkazuvchanlik qiymati: $g_{12} = \frac{R_{12}}{R^2 + (\omega L)^2} = 0{,}5 \cdot 10^{-4} \frac{1}{Om}.$

Kontur to'la o'tkazuvchanligi: $y_{12} = \sqrt{g_{12}^2 + b_{12}^2} = 2{,}06 \cdot 10^{-4} \frac{1}{Om}$

To'la qarshiligi: $Z_{12} = \frac{1}{y_{12}} = 4855\ Om.$

Demak rezonans kuchlanish qiymati chastota 2% o'zgarganda $\frac{R_0}{Z_{12}} = \frac{20 \cdot 10^3}{4855} = 4{,}1$ marta kamayadi. Parallel kontur asilligi ham shunga nisbatan aniqlanadi.

5.11-Masala. Zanjir qarshilik parametrlari $R_1 = 6\ Om$, $R_2 = 4\ Om$, $X_2 = 4\ Om$ bo'lib, $U = 120\ V$ kuchlanishga ulangan kondensator qarshiligini X_3 aniqlab, rezonans shartiga asosan $\varphi = 0$ holat uchun tarmoqdagi tok $\dot{I}_1, \dot{I}_2, \dot{I}_3$ va vektor ifodasini tuzing.



Yechish. Rezonans shartiga asosan tok va kuchlanish vektorlari ustma-ust tushadi va bular orasidagi burchak $\varphi = 0$, shunga asosan zanjirning ekvivalent umumiy reaktiv qarshiligini nolga tenglaymiz.

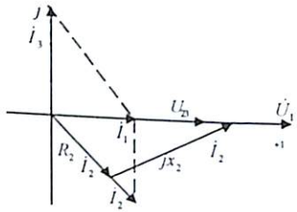
yoki: $Z_{ab} = \frac{(R_2 + jx_2)(-jx_3)}{R_2 + j(x_2 - x_3)} = \frac{R_2 x_3^2}{R_2^2 + (x_2 - x_3)^2} + j \frac{x_2 x_3^2 - x_3 x_3^2 - x_3 R_3^2}{R_2^2 + (x_2 - x_3)^2}$

Mavhum son qismini nolga tenglashtirish bilan:

$$x_2x_3^2 - x_3x_2^2 - x_3R_2^2 = 0 \text{ yoki } x_2x_3 - x_2^2 - R_3 = 0$$

Sig'im qarshiligi: $x_3 = x_2 + \frac{R_2^2}{x_2} = 4 + \frac{16}{4} = 8\ Om.$

Masalaning shartiga asosan R_1 qarshilik $\dot{I}_1$ tok bilan kuchlanish U orasidagi faza burchagiga ta'sir o'tkazmaydi. Shu sababli Om qonuniga asosan:



$$\dot{I}_1 = \frac{\dot{U}}{R_1 + \frac{R_2X_3^2}{R_2^2+(X_2-X_3)^2}} = \frac{120}{6+8} = 8{,}57\ A$$

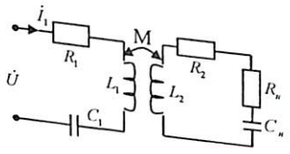
Zanjirning parallel ulangan qismi-dagi kuchlanish:

$\dot{U}_{ab} = \dot{I}_1 \frac{R_2x_3^2}{R_2^2+(X_2+X_3)} = 8{,}57 \cdot 8 = 68{,}5\ V$ Yoki tarmoqdagi tok:

$\dot{I}_1 = \frac{\dot{U}_{ab}}{R_2+jx_2} = \frac{68{,}5}{4+j4} = \frac{68{,}5}{4\cdot\sqrt{2}e^{j45°}} = 8{,}57 - j8{,}57\ A;\ \dot{I}_3 = \frac{\dot{U}_{ab}}{jx_3} = \frac{68{,}5}{-j8} = j8{,}57\ A$

Tuzilgan vektor ifodadan $\dot{I}_1$ tok bilan $\dot{U}_{ab}$ va $\dot{U}$ kuchlanish vektorlari ustma-ust tushadi va R_1 qarshilik faza siljishiga ta'sir o'tkazmaydi.

5.12-Masala. O'zaro induktiv bog'langan rezonans zanjir parametri: $K = 0{,}42$, $R_1 = 5\ Om$, $R_2 = 10\ Om$, $R_H = 20\ Om$, $X_{L_1} = 30\ Om$, $X_{L_2} = 80\ Om$, $X_{c_1} = 25\ Om$, $X_{c_n} = 45\ Om$ bo'lib, $U = 60\ V$ kuchlanishga ulangan. O'zaro induktiv bog'langan reaktiv qarshilik, transformatorning «orttirma» kiritilgan aktiv ΔR va reaktiv ΔX qarshiliklari, umumiy to'la qarshilik I_1, I_2 tok qiymati hamda ekvivalent sxema parametri va rezonans holatdagi X_{c_n} – sig'im qarshilik qiymatini aniqlang.



Yechish. a) transformatorning bog'lanish koeffitsienti tenglama-siga asosan:

$$K = \frac{M}{\sqrt{L_1 \cdot L_1}} = \frac{\omega M}{\sqrt{\omega L_1 \cdot \omega L_2}}$$

Bundan: $X_M = \omega M = K\sqrt{\omega L_1 \cdot \omega L_2} = 0{,}42\sqrt{30 \cdot 80} = 20{,}6\ Om$

Ikkilamchi kontur xususiy to'la qarshilikning kompleks ifodasi.

$$Z_{22} = X_{L_2} + R_2 + R_H - jx_c = j80 + 10 + 20 - j45\ \ Om$$

Yoki xususiy qarshilik: $Z_{22}^2 = 30^2 + 35^2 = 2125\ Om$

Shunga asosan birinchi konturga nisbatan kiritilgan qarshilik ifodasi:

$\Delta R = \frac{x_M^2}{Z_{22}^2} R_{22} = \frac{(20{,}6)^2 \cdot 30}{2125} = 6\ Om$ $\Delta X = \frac{x_M^2}{Z_{22}^2} X_{22} = \frac{(20{,}6)^2 \cdot 35}{2125} = -7\ Om$

Zanjirning kirish qismidagi to'la qarshilik:

$$Z = R_1 + jx_1 + \Delta R_2 + j\Delta x - jx_{c_1} = 5 + j30 + 6 - j7 - j25$$
$$= 11 - j2 = 11e^{-j10°}\ Om$$

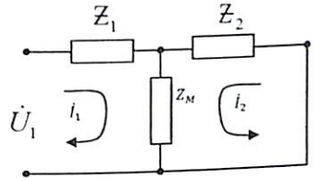
Birlamchi konturdagi tok:

$$\dot{I}_1 = \frac{\dot{U}}{Z} = \frac{60}{11e^{-j10°}} = 5{,}5e^{10°} = 5{,}3 + 0{,}95A$$

Ikkilamchi konturdagi tok:

$$\dot{I}_2 = -\dot{I}_1 \frac{jx_M}{Z_{22}} = -5{,}5e^{10°} \frac{j20{,}6}{46e^{j49°}} = -2{,}42e^{j51°} = -1{,}53 - j1{,}9A$$

Transformatorning keltirilgan ekvivalent sxemasini chizamiz:



Birinchi kontur to'la qarshiligi:

$$Z_1 = Z_{11} - Z_M = (R_1 + jx_{L_1} - jx_{C_1}) - jx_M = 5 + j30 - j25 - j20{,}6$$
$$= 5 - j15{,}6$$

Ikkinchi kontur to'la qarshiligi:

$$Z_2 = Z_{22} - Z_M = (R_2 + R_H + jx_{L_2} - jx_H) - jx_M = (20 + 20 +$$
$$j80 - j45) - j20{,}6 = 30 + j14{,}5\ Om$$
$$va\ Z_M = jx_M = j20{,}6\ Om$$

b) rezonans holatdagi sig'im qarshiligi (X_{C_H})ni topish uchun umumiy to'la qarshilik ifodasini yozamiz:

$$Z = Z_1 + \frac{Z_2 \cdot Z_M}{Z_2 + Z_M} R_1 + j(X_{L_1} - X_{C_1} - X_M) +$$
$$\frac{[(R_2+R_H)+j(X_{L_1}-jx_{C_H}-jX_M]\cdot X_M}{[(R_2+R_H)+j(X_{L_1}-jx_{C_H}-jX_M]+jX_M} = 5 + j(30 - 25 - 20{,}6) +$$
$$\frac{[(10+20)+j(80-X_{C_H}-20{,}6)]\cdot j20{,}6}{[(10+20)+j(80-X_{C_H}-20{,}6)]+j20{,}6} = 5 - j15{,}6 + \frac{[30+j(60-X_{C_H})]\cdot j20{,}6}{[30+j(60-X_{C_H})]+j20{,}6}$$

$60 - X_{c_H} = X$ deb belgilash bilan maxrajdagi mavhum sondan qutilgan holda:

$$Z = 5 - j15{,}6 + \frac{12670 + j(20{,}6x^2 + 423x + 18{,}5)}{x^2 + 41x + 1{,}32}$$

Tenglamaning chap tomonini umumiy maxrajga keltirish bilan kompleks ifodaning haqiqiy va mavhum son ko‘rinishda ifodalanadi:

$$Z = \frac{5x^2+205{,}5x+19{,}3}{x^2+41x+1{,}32} = +j\frac{5x^2-216x2055)}{x^2+41x+1{,}32} = R + jx$$

Kuchlanishlar rezonans shartiga asosan $x = 0$:

$5x^2 - 216x - 2055 = 0$ yoki: $x^2 - 43{,}2x - 411 = 0$

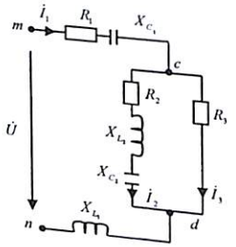
Tenglamani yechish:

$$x = \frac{43{,}2}{2} \pm \sqrt{(\frac{43{,}2}{6})^2 + 411} = 21{,}6 \pm 29{,}6;$$

$$x_1 = 51{,}2\ Om; \qquad x_2 = -8\ Om$$

Bundan: $x_1 = 51.2\ Om$ qiymatni olsak, birlamchi konturda rezonans holat $x_{e1} = \frac{1}{\omega C_1} = 60 - x = 60 - 51{,}2 = 8{,}8$ Om qarshilikka teng bo‘lganda rezonans holat yuzaga keladi.

5.13-Masala. Rezonansli elektr zanjir parametri $R_1 = 5\ Om$, $X_{c1} = 7\ Om$, $X_{L1} = 10\ Om$, $R_2 = 3\ Om$, $X_{L2} = 20\ Om$, $R_3 = 12\ Om$, $I_1 = 0{,}2\ A$ bo‘lganda, sig‘im qarshilik qiymati X_{c2} va I_2 tarmoqdagi tok qiymatini aniqlang.



Yechish. Parallel ulangan qismdagi cd potensiallarga nisbatan kompleks to‘la qarshilik.

$$Z_{cd} = \frac{[(R_2 + j(X_{L_2} - X_{C_2}] \cdot R_3}{R_2 + j(X_{L_2} - X_{C_2}) + R_3}$$

Surat va maxrajlarini kompleks (manfiy) qiymatga ko‘paytirish bilan haqiqiy va mavhum qismlardan iborat tenglama hosil qilamiz:

$$\frac{[(R_2R_3+j(X_{L_2}-X_{C_2})\cdot R_3][(R_2+R_3)-j(X_{L_2}-X_{C_3})]}{(R_2R_3+j(X_{L_2}-X_{C_2})\cdot(R_2+R_3)-j(X_{L_2}-X_{L_3})} = \frac{R_2R_3(R_2+R_3)+(X_{L_2}-X_{C_2})^2R_3}{(R_2+R_3)^2+(X_{L_2}-X_{C_2})^2} +$$
$$j\frac{(X_{L_2}-X_{C_2})\cdot R_3(R_2+R_3)-R_2R_3(X_{L_2}-X_{C_3})}{(R_2+R_3)^2+(X_{L_2}-X_{C_2})^2} = R_{cd} + jx_{cd} \text{ yoki } Z_{cd} = R_{cd} + jx_{cd}$$

Bundan: $X_{cd} = \frac{(X_{L_2}-X_{c_2})R_3^2}{(R_2+R_3)^2+(X_{L_2}-X_{c_2})^2}$

Zanjir umumiy kompleks qarshilik ifodasini yozamiz:

$$Z = R_1 - jx_{C_1} + Z_{cd} + jx_{L_1} = R_1 - jx_{C_1} + (R_{cd} + jx_{cd}) + jx_{L_1}$$
$$= (R_1 + R_{cd}) + j(X_{L_2} - X_{C_2} + X_{cd}) = R + jx$$

Ushbu zanjirda rezonans shartiga asosan $X = 0$ bo‘lganda:

$$X_{L_1} - X_{C_1} + X_{cd} = 0$$

$$\text{yoki: } X_{L_1} - X_{C_1} \cdot \frac{(X_{L_2}-X_{C_2})R_3^2}{(R_2+R_3)^2+(X_{L_2}-X_{L_3})} = 0$$

Bundan:

$$(X_{L_1} - X_{C_1})(R_2 + R_3)^3 + (X_{L_1} - X_{C_1})\,(X_{L_2} - X_{C_2})^2 + (X_{L_2} - X_2)R_3^2 = 0$$

Sig‘im qarshiligi (X_{C_2}) ni topish uchun:

$$(X_{L_2} - X_{C_2})^2 + \frac{R_3^2}{X_{L_1} - X_{C_1}}(X_{L_2} - X_{C_2}) + (R_2 + R_3)^2 = 0$$

Qarshilik qiymatini qo‘yish bilan:

$$(20 - X_{C_2})^2 + 48(20 - X_{C_2}) + 225 = 0$$

Kvadrat tenglamani yechish bilan:

$$(20 - X_{C_2}) = -\frac{48}{2} \pm \sqrt{(\frac{48}{2})^2 + 225} = -24 \pm 18{,}7$$

Bundan: $(20 - X_{C_2}) = -24 + 18{,}7 = -5{,}27\ Om$

yoki: $X_C = 20 - 5{,}27 \approx 25{,}3\ Om$

$$\dot{I}_2 = \dot{I}_1 \frac{Z_3}{Z_2+Z_3} = \dot{I}_1 \frac{R_3}{[R_2+j(X_{L_2}-X_{C_3})]+R_3} = 0{,}2 \cdot \frac{12}{3+j(20-25{,}3)+12} =$$
$$(142{,}5 + j50) \cdot 10^{-3}\ A.$$

$\dot{I}_2$ tokning haqiqiy qiymati:

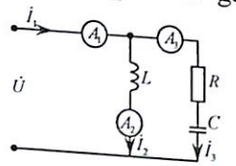
$$\dot{I}_2 = \sqrt{(142{,}5010^3)^2 + (50 \cdot 10^{-3})^2} = 151 \cdot 10^{-3} \approx 0{,}151\ A$$

5.3. Mustaqil yechish uchun masalalar

5.1-Masala. Ketma-ket ulangan elektr zanjirning parametri $R = 100Om, L_1 = 0{,}2\ Gn, C = 1\ mkF$, kuchlanishi $U = 100\ mV$ ga teng bo‘lganda; rezonans chastota ω_0, tok I_0, kuchlanish U_{Cmax}, U_{Lmax} qiymatga erishgan holatdagi ω_C va ω_L chastota, U_{Cmax}, U_{Lmax} qiymatlari, kontur asilligi Q, rezonans chastota chegaralarini d=(ω_2-ω_1) aniqlang.

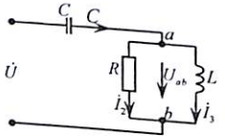
Javob: $\omega_0 = 2236\frac{1}{sek}, I_0 = 1\ MA, \omega_L = 2264\frac{1}{sek}, \omega_C = 2207\frac{1}{sek}, U_{C_{max}} = 0{,}45\ V, \quad U_{L_{max}} = 0{,}45\ V, \quad Q = 4{,}47, \quad \omega_2 - \omega_1 = 500, \omega_1 = 2000\frac{1}{sek}, \Delta f = 79{,}6\ gs.$

5.2-Masala. Keltirilgan sxemada rezo-nans holatda tarmoqdagi toklar $I_1 = 4\ A, I_2 = 3\ A$ ga teng bo‘lib, I_3 tok qiymati aniqlansin.



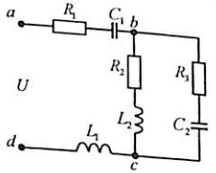
Javob: $I_3 = 5A$

5.3-Masala. Rezonans holatdagi elektr zanjir parametri $R = 20\ Om, X_L = 20\ Om$ va $U = 300\ V$ bo‘lganda, sig‘im qarshiligi, umumiy ekvivalent qarshiligi va tok qiymati aniqlansin.



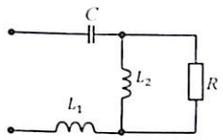
Javob: $x_c = 10\ Om,$
$\underline{Z}_e = 10\ Om, U_{ab} = 300\sqrt{2}e^{j45°},$
$I_1 = 30e^{j0}\ A, I_2 = 15 + j15\ (A),$
$I_3 = 15 - j15\ A$

5.4-Masala. Elektr zanjir parametri $C_2 = 10 \cdot 10^{-6}\ F, L_2 = 18 \cdot 10^{-3}\ Gn, R_2 = 40\ Om, R_3 = 30\ Om$ bo‘lganda, tok rezonansini yuzaga keltiruvchi rezonans chastotasini (ω_0) aniqlang.



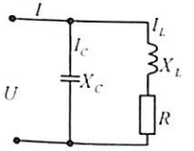
Javob: $\omega_0 = 1560\ rad/sek$

5.5-Masala. Induktiv galtakga, aktiv qarshilik R parallel va sig‘im qarshiligiga $X_C = 20\ Om$ ketma-ket ulangan. Chastota $f = 50\ Gs$ qarshiliklari esa $R = 40\ Om$ va $X_{L2} = 80\ Om$ bo‘lganda rezonans hosil qiluvchi induktivlik L_2 qiymatini aniqlang va qanday hollarda umumiy qarshilik Z_{min} minimal bo‘ladi.



Javob: 1) $R = 40\ Om$ bo‘lganda, rezonans induktivlik $L_1 = 0{,}0128Gn$, umumiy qarshiligi $Z = Zmin, L_2 = 0{,}052\ Gn.$
2) $X_{L2} = 80\ Om$ bo‘lganda rezonans induktivlik
$L_1 = 0{,}069Gn$ va $L_2 = 0{,}95\ Gn, Z = Zmin;\ L_2 = 0{,}061\ Gn.$

5.6-Masala. Elektr tok zanjir rezonans holatda bo‘lib, umumiy tok $I = 10\ A$, qarshilik $R = 6\ Om, x_L = 8\ Om$. Sig‘imdan o‘tuvchi tok I_C, reaktiv qarshilik va kuchlanishni aniqlang.

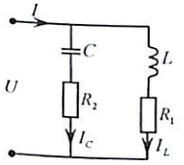


Javob: $I_C = 13{,}3\ A, \quad x_C = 12{,}5\ Om,$
$U = 166{,}7\ V.$

5.7-Masala. 5.6 masalada berilgan sxemaning induktiv qarshiligi $X_L = R$ va tok $I = 10\ A$. Rezonans holatdagi I_C, I_L, X_C, U tok qiymatini aniqlang.

Javob: $I_C = 10\ A, I_L = 10\sqrt{2}A, X_C = 2XL, U = 20\ V$

5.8-Masala. Parametri $L = 6{,}4\ Gn, R = 10m$ bo‘lgan parallel zanjir chastotasi $f = 50\ Gs, U = 100\ V, I = 75\ A$ tokka ulangan. Rezonans holatdagi R_2, C qiymatlarini aniqlang.

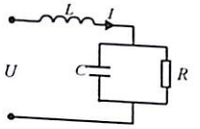


Javob: $R_2 = 1{,}16\ Om, \quad C = 3540\ mkF$

5.9-Masala. Ketma-ket ulangan elektr zanjirning parametri $R = 40\ Om, L = 0{,}2\ Gn, C = 10\ mkF$ ga teng bo‘lgan holat uchun rezonans, chastota f_0 induktivlikdagi U_{Lmax} kuchlanishi va manba kuchlanishiga nisbatan necha marta katta bo‘lishini aniqlang.

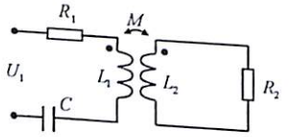
Javob: $f_0 = 112\ Gs, X_L = 140\ Om\ U_{Lmax} = 3{,}5\ V$

5.10-Masala. Elektr zanjir rezonans holatda bo‘lib chastotasi $\omega_0 = 0$ bo‘lganda $Z_{um(0)} = 50\ Om$ va rezonans chastota $\omega = \omega_0$ da $Z_{um(0)} = 2{,}5\ Om$. Qarshilik parametri: R_1, X_L va X_C aniqlang hamda vektor ifodasini tuzing.



Javob: $R_1 = 5\ Om, X_L = 2{,}5\ Om, X_C = 5\ Om$

5.11-Masala. Induktiv bog‘langan elektr zanjiri parametri: $R_1 = 2\ Om$, $X_{L_1} = 10\ Om$, $X_C = 8\ Om, X_{L_2} = 9\ Om$, $X_M = 6\ Om$, bo‘lib, $U = 100\ V$ kuchlanish ulangan. R_2 ning qaysi qiymatida zanjirda rezonans holat yuzaga keladi.

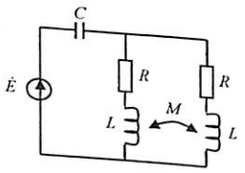


Javob: $R_2 = 9\ Om.$

5.12-Masala. Ikkita o‘zaro induktiv bog‘langan zanjir parametri: $L_1 = 100mkgn$, $L_2 = 250mkgn$, $R_2 = 80\ Om$, $M = 50mkgn$, $f = 800kgs$ va $C_2 = 1000pf$. Birlamchi kontur sig‘im C_1 qiymati aniqlansin.

Javob: $C_1 = 440 \cdot 10^{-12}\ f = 440pf.$

5.13-Masala. Parametrlari R, L, C bo‘lgan o‘zaro induktiv bog‘langan zanjir chastotasi f bo‘lgan sinusoidal kuchlanishga ulangan. M koeffitsient qanday qiymatida rezonans holat yuzaga keladi?



Javob: $M = L - \frac{2}{\omega^2 C}$

5.4. Nazorat savollari

1. Elektr zanjirda rezonans holat qanday yuzaga keladi?
2. Rezonans hosil qilish uchun elektr zanjir qaysi elementlardan tuzilgan bo‘lishi zarur va sharti nimada?
3. Rezonans hodisasidan amalda qaysi sohalarda foydalaniladi?
4. Rezonans chastota tenglamasini yozib, rezonans holatga qanday erishilishini tushuntiring.
5. Tebranuvchan kontur induktivligi $L = 25\ MGn$, sig‘imi $C = 4\ mkF$ bo‘lganda, rezonans chastota f_0 qancha bo‘ladi?
6. Kuchlanishlar rezonansi qanday hosil bo‘ladi? Vektor ifodasini chizing. Tok va quvvat tenglamalarini yozing.
7. Tok rezonansi qanday hosil bo‘ladi? Tok va quvvat tenglamalarini yozing.
8. Nima sababdan kuchlanishlar rezonans paytida sig‘im va induktivlikdagi kuchlanishlar umumiy kuchlanishga nisbatan katta bo‘ladi?
9. Chastotaga nisbatan reaktiv qarshilik yoki o‘tkazuvchanlik qanday o‘zgaradi? Chastota xarakteristikasini chizing.
10. Rezonans holatda quvvat koeffitsienti nimaga teng?
11. Kontur saxiyligi yoki kontur so‘nishi nima va qanday ifodalanadi?
12. To‘lqin qarshiligi yoki o‘tkazuvchanligi nima, qanday ifodalanadi?.
13. Rezonans holatda elektr zanjirning tarmoqlanmagan qismidagi tok qanday qiymatga erishadi?
14. Rezonans kontur reaktiv qarshiliklari $X_L > X_C, X_L = X_C\ X_L < X_C$ holatlar uchun vektor ifodasini tuzing va qanday xarakterga ega ekanligini tushuntiring.
15. Rezonans holatda elektromagnit maydon energiyasi tebranishi fizik ma’nosini tushuntiring.
16. Tok rezonans hodisasi bilan kuchlanish rezonansida qanday o‘xshashliklar bor?
17. Rezonans holatda aktiv, reaktiv va to‘la quvvatlar qanday bog‘langan?
18. Qanday konturda va qaysi shartlar bajarilganda rezonans hodisasi yuzaga keladi?
19. Kuchlanishlar rezonansi vaqtida nima uchun tok maksimal qiymatga erishadi?

20. Tok rezonansi holatida nima uchun kuchlanish maksimal qiymatga erishadi?

21. Rezonans holatida sarf bo‘lgan elektr energiyasi nimaning hisobiga to‘ldiriladi?

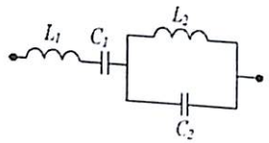
22. Murakkab elektr zanjirida rezonans hosil bo‘lish shartini tushintiring.

23. Rezonans holatda to‘la qarshilik yoki o‘tkazuvchanlik nimaga teng?

24. Rezonansli kontur parametri $R = 10\ Om$, $L = 400\ mkgn$ va $C = 400\ pf$ bo‘lsa, to‘lqin uzunligi λ va Q nimaga teng? (Javob: $\lambda = 750m$, $Q = 100$)

25. Parallel sxemada ulangan zanjir rezonans holatda umumiy tarmoqdagi tok $I = 1{,}1A$, sig‘imdagi tok $I_C = 6A$ ga teng. Agar kontur aktiv qarshiligi $R = 1\ Om$ bo‘lsa, aktiv quvvat qancha bo‘ladi? (Javob: $P = 37{,}21\ VT$).

26. Reaktiv qarshiliklardan tuzilgan zanjir chastotaviy xarakteristikasini tuzing.



6. UCH FAZALI SINUSOIDAL O‘ZGARUVCHAN ELEKTR ZANJIR

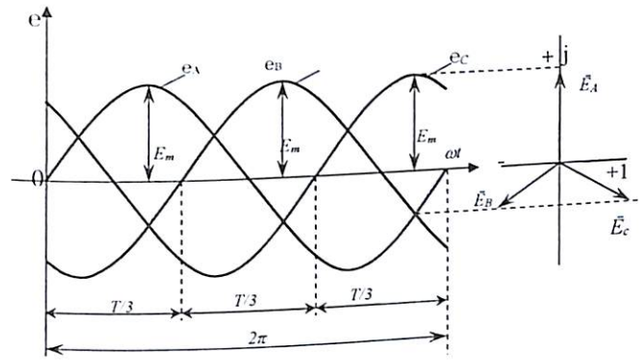
6.1. Asosiy nazariy tushunchalar

Fazalari bilan 120° farq qiluvchi, chastota va amplitudalari bir xil bo‘lgan uchta bir fazali sinusoidal o‘zgaruvchan elektr zanjirga **uch fazali tok tizmlari** yoki **zanjirlari** deyiladi.

Uch fazali tok manbai uch fazali **sinxron generatori** bo‘lib, yakor aylanma harakatlanish natijasida stator qismida 120° farqi bilan joylashtirilgan chulg‘amlarda induksiyalanadigan EYK analitik ifodasi quyidagicha ifodalanadi.

$$\begin{aligned} e_A &= E_m \sin \omega t \\ e_B &= E_m \sin(\omega t - 120^o) \\ e_C &= E_m \sin(\omega t + 120^o) \end{aligned} \qquad (6.1)$$

Uch fazali sinusoidal o‘zgaruvchan tok vaqt bo‘yicha o‘zgaruvchan grafigi va vektor ifodasi quyidagicha ifodalanadi:



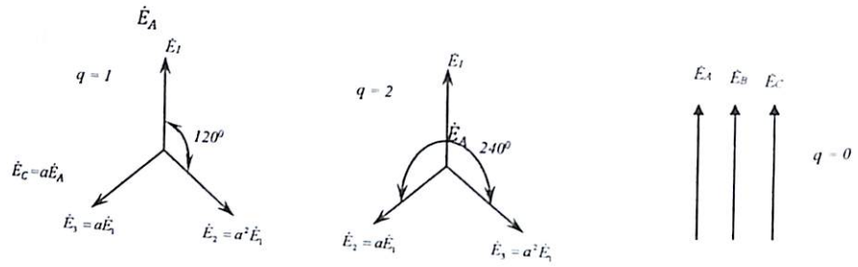
EYK (kuchlanish, tok) kompleks shakldagi ifodasi.

$$\dot{E}_A = E;\ \ \dot{E}_B = Ee^{-j\frac{2\pi}{3}};\ \ \dot{E}_C = Ee^{j\frac{2\pi}{3}} \qquad (6.2)$$

Vektorlarni kompleks shaklda qisqa yozish uchun fazoviy ko‘paytiruvchi (buruvchi) belgilash kiritiladi yoki:

$\alpha = e^{j\frac{2\pi}{3}} = (\cos 120° + j \sin 120°) = -\frac{1}{2} + j\frac{\sqrt{3}}{2}$, faza burchagi $\varphi = 120°$ ga teng. $\alpha^2 = e^{j\frac{4\pi}{3}} = \cos 290° + j \sin 240° = -\frac{1}{2} - j\frac{\sqrt{3}}{2}$

U holda: $q = 1, \dot{E}_1 = E;\ \dot{E}_2 = E\alpha^2;\ \underline{\dot{E}_3} = \alpha E$ - ***to'g'ri ketma-ketlik***. $q = 2,\ \dot{E}_1 = E;\ \dot{E}_2 = \alpha E;\ \dot{E}_3 = \alpha^2 E$ - ***teskari ketma-ketlik*** bo'ladi. $q = 0,\ \dot{E}_1 = \dot{E}_2 = \dot{E}_3 -$ ***nol*** ketma-ketlik bo'ladi



Yoki: $\alpha^2 = e^{-j\frac{2\pi}{3}};\qquad \alpha^3 = e^{-j2\pi} = 1;\qquad \alpha^4 = \alpha = e^{j\frac{2\pi}{3}}$

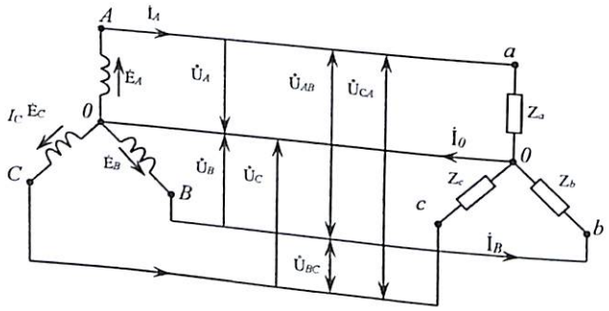
Shu ma'noda $1 + \alpha + \alpha^2 = 0$.

Demak, vektorni «α» operatorga ko'paytirish, $\varphi = \frac{2\pi}{3}$ burchakga burish bilan barobar.

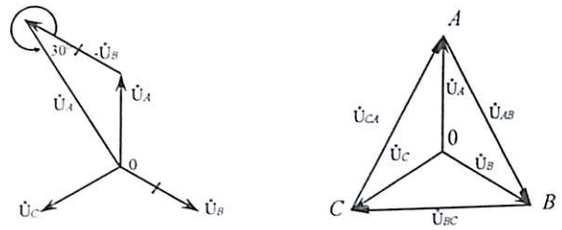
Uch fazali elektr zanjirda generator (manba) bilan iste'molchilar o'zaro yulduzcha, uchburchak shaklida ulanishi mumkin.

1.Yulduzcha shaklida ulanishi.

Simmetrik yulduzcha shaklida ulangan elektr zanjirdagi $\overline{U}_Л$ liniyadagi kuchlanishi fazadagi kuchlanishga nisbatan: $\overline{U}_Л = \overline{U}_{AB} = \overline{U}_A - \overline{U}_B$.



yoki: $\dot{U}_Л = \sqrt{3}\dot{U}_\phi$ $\qquad \dot{I}_Л = \dot{I}_\phi$

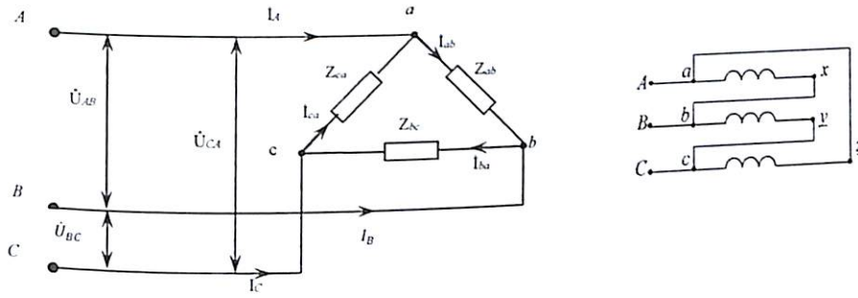


2. Uchburchak shaklda ulanish.

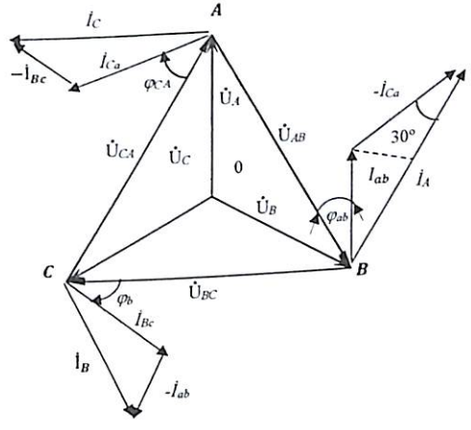
Liniyadagi tok fazadagi tok orqali ifodalanganda.

$\dot{I}_A = \dot{I}_{ab} - \dot{I}_{ca}\ ,\ \dot{I}_B = \dot{I}_{BC} - \dot{I}_{AB}\ ,\ \dot{I}_C = \dot{I}_{ca} - \dot{I}_{BC}$ (6.3)

Bunda: $\dot{I}_A = \sqrt{3}\dot{I}_F;\ \dot{U}_L = \dot{U}_{AB} = \dot{U}_F$



a)



b)

Agar neytral simli uch fazali elektr zanjirning faza kuchlanish va iste'molchi qarshiliklari berilgan bo'lsa:

$$\dot{U}_a = \dot{U}_A - \dot{U}_O; \quad \dot{U}_b = \dot{U}_B - \dot{U}_O; \quad \dot{U}_c = \dot{U}_C - \dot{U}_O .$$

Tugun potensiallar usuliga asosan manba bilan iste'molchi orasidagi 00^I nuqtalar potensiali:

$$\varphi_0 - \varphi_{0'} = \dot{U}_{00} = \frac{\dot{U}_A \underline{y}_a + \dot{U}_B \underline{y}_b + \dot{U}_C \underline{y}_c}{\underline{y}_a + \underline{y}_b + \underline{y}_c + \underline{y}_0} \qquad (6.4)$$

Neytral simsiz uch fazali elektr zanjirning liniya kuchlanishi ma'lum bo'lsa, faza kuchlanishi uchun tenglama:

$$\dot{U}_A = \frac{\dot{U}_{AB}\underline{y}_b - \dot{U}_{CA}\underline{y}_c}{\underline{y}_a + \underline{y}_b + \underline{y}_c} \qquad \dot{U}_B = \frac{\dot{U}_{BC}\underline{y}_c - \dot{U}_{AB}\underline{y}_b}{\underline{y}_a + \underline{y}_b + \underline{y}_c}$$

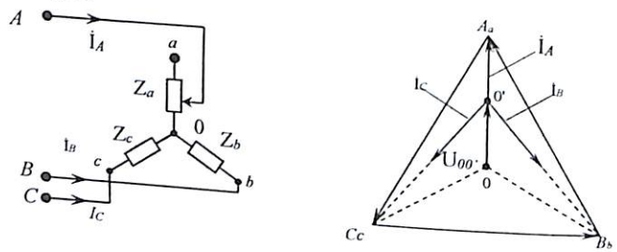
$$\dot{U}_C = \frac{\dot{U}_{CA}\underline{y}_a - \dot{U}_{BC}\underline{y}_b}{\underline{y}_a + \underline{y}_b + \underline{y}_c} \qquad (6.6)$$

Har qanday uch fazali tizimlarning kompleks liniya kuchlanishlari:

$$\dot{U}_{AB} + \dot{U}_{BC} + \dot{U}_{CA} = 0$$

1. Simmetrik yulduzcha yoki uchburchak shaklda ulangan uch fazali elektr zanjirlarni hisoblashda bir fazali elektr zanjirlar qoida va usullaridan foydalaniladi.

2. Yulduzcha sxemada ulangan nosimmetrik uch fazali elektr zanjir.



a) iste'molchi qarshiliklari nosimmetrik: $\underline{Z}_a = var, \underline{Z}_b = \underline{Z}_c = const.$

Bunday holatda I_A tok generator bilan iste'molchi potensiallari orasida

$U_{00'}$ kuchlanish (0) nuqta bo'yicha siljiydi, hamda:

$$\Sigma \dot{I} = \dot{I}_a + \dot{I}_b + \dot{I}_c = 0 \quad \underline{Z}_a > R$$

b) $\mathring{U}_A$ – fazada qisqa tutashuv:

$(\underline{Z}_a = 0, \underline{Y}_a = \infty, \underline{Z}_b = \underline{Z}_c = R = const, \underline{y}_b = \underline{y}_c = \frac{1}{R} = y = const)$

Qisqa tutashuv holatda $\dot{U}_{00'}$ – kuchlanish:

$$\dot{U}_{00'} = \frac{\dot{U}_A \underline{y}_a + \dot{U}_B \underline{y}_b + \dot{U}_C \underline{y}_c}{\underline{y}_a + \underline{y}_b + \underline{y}_c} = \frac{\dot{U}_A}{2}$$

$\dot{U}'_A$ – faza kuchlanishi: $\dot{U}'_A = \dot{U}_A - \dot{U}_O = \dot{U}_A - \dot{U}_A$

$\dot{U}'_B$ va $\dot{U}'_C$– fazadagi kuchlanish tenglamasi:

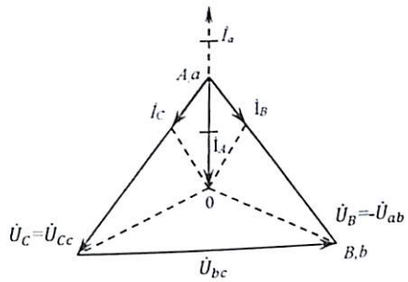
$$\dot{U}'_B = \dot{U}_B - \dot{U}_O = \dot{U}_B - \dot{U}_A = \dot{U}_{BA} = -\dot{U}_{AB} = -\dot{U}_{ab}$$

$$\dot{U}'_C = \dot{U}_C - \dot{U}_O = \dot{U}_C - \dot{U}_A = \dot{U}_{CA} = \dot{U}_{CA} = \dot{U}_{ca}$$

Fazadagi tok: $\dot{I}_b = \dot{I}_c = \frac{\dot{U}_Л}{Z_Ф} = \sqrt{3}\dot{I}_f$

A – fazadagi tok: $\dot{I}_a = -(\dot{I}_b + \dot{I}_C) = \sqrt{3}\dot{I}_b = 3I_3$

Demak, A faza qisqa tutashtirilganda fazadagi tok 3 martaga ortadi va fazadagi kuchlanish $\dot{U}_A = 0$ bo'lib, bu fazaga ulangan lampochka o'chadi.



d) $\mathring{U}_A$ – fazaga uzilishi:

$\underline{Z}_a = \infty; \underline{Z}_b = \underline{Z}_c = R = const; \underline{y}_a = 0; \underline{y}_a = \underline{y}_c = \frac{1}{R}$

Tugunlar orasidagi kuchlanish:

$$\dot{U}_{00'} = \frac{\dot{U}_A \underline{y}_a + \dot{U}_B \underline{y}_b + \dot{U}_C \underline{y}_c}{\underline{y}_a + \underline{y}_b + \underline{y}_c} = \frac{(\dot{U}_B + \dot{U}_C)\underline{y}_b}{2\underline{y}_b} = -\frac{\dot{U}_A}{2} = -\frac{\dot{U}_\Phi}{2}$$

Demak, iste'molchi kuchlanishi 00' nuqta bo'ylab pastga yo'naladi va $\overline{CB}$ vektor o'rtasini kesadi. Bunda $\dot{U}_A = 0; \dot{I}_A = 0$ bo'lib:

$$\dot{U}_{aA} = \dot{U}_{A0'} = \dot{U}_A - \dot{U}_0 = \dot{U}_A - (-\frac{\dot{U}_A}{2}) = \frac{2}{3}\dot{U}_A$$

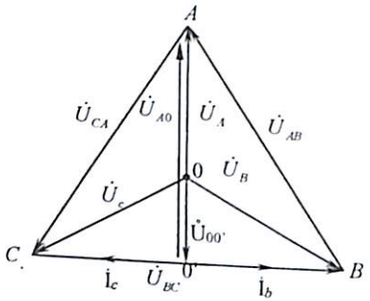
A va B fazadagi kuchlanish: $\dot{U}_B = \dot{U}_C = \frac{\dot{U}_Л}{2}$

yoki $\dot{U}_f = \frac{\dot{U}_Л}{\sqrt{3}}; \frac{\dot{U}_Л}{\dot{U}_B} = \frac{\dot{U}_A}{\sqrt{3}} \div \frac{\dot{U}_Л}{2} = \frac{2}{\sqrt{3}}\dot{U}_f;$

B va C fazadan o'tuvchi tokga teng bo'lib:

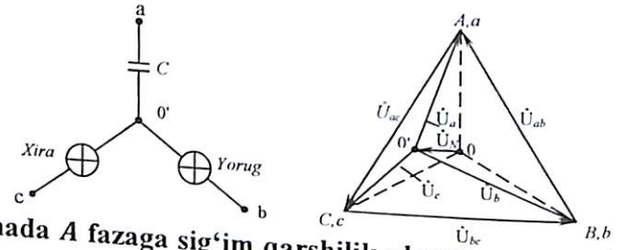
$$\dot{I}_B = \dot{I}_C - \frac{\frac{\dot{U}_L}{2}}{\underline{Z}_b} = \frac{\sqrt{3}U_f}{2\underline{Z}_f} = \frac{\sqrt{3}}{2}\dot{I}_f$$

Demak, fazaga ulangan iste'molchi (lampa) A fazada o'chadi, B va C fazada xira yonadi.



e) uch fazali zanjirda fazalar ketma-ketligini aniqlash.

Bunda uch fazali elektr zanjirning A fazasiga sig'im C yoki induktivlik L ulanib, qolgan ikkita fazasiga bir xil qarshilikdagi lampochkalar ulanadi.



1) sxemada A fazaga sig'im qarshilik ulangan: $\underline{z}_a = -j\underline{x}_c$; $z_b = \underline{z}_c = R$ yoki $\underline{y}_a = \frac{1}{-j\underline{X}} = b$; $\underline{y}_b = \underline{y}_c = \frac{1}{R} = g$

Demak:

$$\dot{U}_{00'} = \frac{\dot{U}_A\underline{y}_a+\dot{U}_B\underline{y}_b+\dot{U}_C\underline{y}_c}{\underline{y}_a+\underline{y}_b+\underline{y}_c} = \frac{U_A jb+\left(-0{,}5-j\frac{\sqrt{3}}{2}\right)\dot{U}_A g+(-0{,}5+j\frac{\sqrt{3}}{2})\dot{U}_A g}{jb+g+g} =$$

$$0{,}63\dot{U}_A e^{j105°26'} = (-0{,}2+j0{,}6)\,\dot{U}_A$$

Iste'molchilardagi faza kuchlanishi:

$$\dot{U}_a = \dot{U}_A - \dot{U}_0 = \dot{U}_A - (-0{,}2+j0{,}6)\,\dot{U}_A = 1{,}34\dot{U}_A e^{-\underline{26}°34'}$$

$$\dot{U}_b = \dot{U}_B - \dot{U}_0 = (-0{,}5-j\tfrac{\sqrt{3}}{2})\,\dot{U}_A - (-0{,}2+j0{,}6)\,\dot{U}_A = 1{,}5\dot{U}_A e^{-j101°33'}$$

$$\dot{U}_C = \dot{U}_C - \dot{U}_0 = (-0{,}5-j\tfrac{\sqrt{3}}{2})\,\dot{U}_A - (-0{,}2+j0{,}6)\,\dot{U}_A = 0{,}4\dot{U}_A e^{j138°20'}$$

2) A fazaga induktiv qarshilik ulaymiz:

$$\underline{z}_a = j\underline{x}_L = j\underline{R};\ \underline{z}_b = \underline{z}_c = R$$

yoki $\underline{y}_a = \frac{1}{j\underline{R}} = -j\underline{g}$; $\underline{y}_b = \underline{y}_c = \frac{1}{R} = g$

Tugun kuchlanishlar tenglamasiga asosan:

$$\dot{U}_{00'} = \frac{\dot{U}_A\underline{y}_a+\dot{U}_B\underline{y}_b+\dot{U}_C\underline{y}_c}{\underline{y}_a+\underline{y}_b+\underline{y}_c} = \frac{U_A(-jb)+\left(0{,}5-j\frac{\sqrt{3}}{2}\right)\dot{U}_A g+(0{,}5+j\frac{\sqrt{3}}{2})\dot{U}_A g}{j\underline{b}+g+g} =$$

$$0{,}63\dot{U}_A e^{j105°26'} = (-0{,}2-j0{,}6)\,\dot{U}_A$$

Faza kuchlanishlari:

$$\dot{U}_a = \dot{U}_A - \dot{U}_0 = \dot{U}_A - (-0{,}2-j0{,}6)\,\dot{U}_A = (1{,}2-j0{,}6)\,\dot{U}_A$$

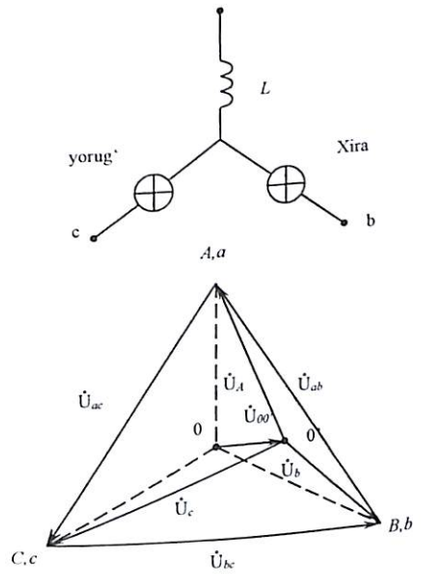
$$= 1{,}34\dot{U}_A e^{-\underline{26}°34'}$$

$$\dot{U}_b = \dot{U}_B - \dot{U}_0 = (-0{,}5-j\frac{\sqrt{3}}{2})\,\dot{U}_A - (-0{,}2-j0{,}6)\,\dot{U}_A$$

$$= 0{,}4\dot{U}_A e^{j138°20'}$$

$$\dot{U}_C = \dot{U}_C - \dot{U}_0 = (-0{,}5+j\frac{\sqrt{3}}{2})\,\dot{U}_A - (-0{,}2+j0{,}6)\,\dot{U}_A$$

$$= (0{,}3+j1{,}47\dot{U}_A) = 1{,}5\dot{U}_A e^{-j101°33'}$$

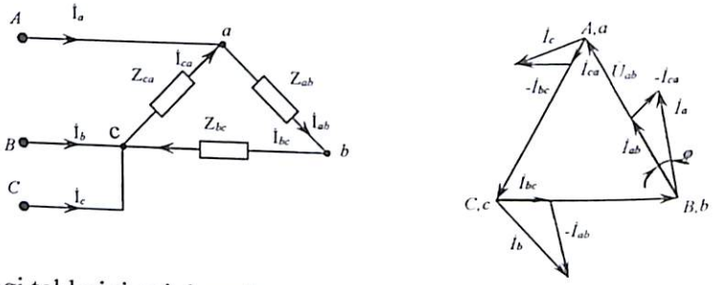


3. Uchburchak shaklida ulangan uch fazali elektr zanjir.

a) Simmetrik holat:

Simmetrik uchburchak shakilda ulangan elektr zanjirni hisoblashda bir fazali elektr zanjirni hisoblash usulidan foydalaniladi.

b) Nosimmetrik holat: $(\underline{Z}_{ab} = \frac{R}{2};\ \underline{Z}_{bc} = \underline{Z}_{ca} = R = const)$



Fazadagi toklarini aniqlaymiz:

$$\dot{I}_{ab} = \frac{\dot{U}_{ab}}{\underline{Z}_{ab}} = 2\frac{\dot{U}_{ab}}{R};$$

$$\dot{I}_{bc} = \frac{\dot{U}_{bc}}{\underline{Z}_{bc}} = 2\frac{\dot{U}_{ab}}{R}e^{-j120^\circ} = (-0{,}5 - \underline{j}\frac{\sqrt{3}}{2})\ \frac{\dot{U}_{ab}}{R}$$

$$\dot{I}_{ca} = \frac{\dot{U}_{ca}}{\underline{Z}_{ca}} = 2\frac{\dot{U}_{ca}}{\underline{Z}_{ca}}e^{-j120^\circ} = (-0{,}5 + \underline{j}\frac{\sqrt{3}}{2})\ \frac{\dot{U}_{ab}}{R}$$

Liniyadagi tok:

$$\dot{I}_a = \dot{I}_{ab} - \dot{I}_{ca} = (2{,}5 - \underline{j}\frac{\sqrt{3}}{2})\ \frac{\dot{U}_{ab}}{2} = 2{,}65\frac{\dot{U}_{ab}}{R}e^{-j19^\circ}$$

$$\dot{I}_b = \dot{I}_{bc} - \dot{I}_{ab} = (-2{,}5 - \underline{j}\frac{\sqrt{3}}{2})\ \frac{\dot{U}_{ab}}{R} = 2{,}65\frac{\dot{U}_{ab}}{R}e^{-j161^\circ};$$

$$\dot{I}_c = \dot{I}_{ca} - \dot{I}_{bc} = \underline{j}\sqrt{3}\ \frac{\dot{U}_{ab}}{2} = 1{,}73\frac{\dot{U}_{ab}}{R}e^{-j90^\circ}\ ;$$

d) *A* fazada qisqa tutashuv:

$\underline{Z}_{ab} = 0;\ \underline{Z}_{bc} = \underline{Z}_{ca} = R = const;$

Qisqa tutashuvda $\dot{I}_{ab} = \infty$ bo‘lib $\dot{I}_{ab}$ faza simi (saqlagich) uzilishi mumkin yoki $Z_{ab} = \infty;\ \ \underline{Z}_{bc} = \underline{Z}_{ca} = R = const;$

Bunda fazadagi tok: $\dot{I}_{ab} = \frac{\dot{U}_{ab}}{\underline{Z}_{ab}} = 0;$

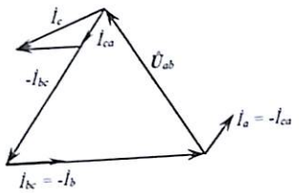
$$\dot{I}_{bc} = \frac{\dot{U}_{bc}}{\underline{Z}_{bc}} = \frac{\dot{U}_{ab}}{R}e^{-j120^\circ} = (-0{,}5 - j\frac{\sqrt{3}}{2})\ \frac{\dot{U}_{ab}}{R};$$

$$\dot{I}_{ca} = \frac{\dot{U}_{ca}}{\underline{Z}_{ca}} = \frac{\dot{U}_{ab}}{R}e^{j120^\circ} = (-0{,}5 + j\frac{\sqrt{3}}{2})\ \frac{\dot{U}_{ab}}{2};$$

Liniyadagi tok: $\dot{I}_a = \dot{I}_{ab} - \dot{I}_{ca} = -\dot{I}_{ca};$

$\dot{I}_b = \dot{I}_{bc} - \dot{I}_{ab} = -\dot{I}_{bc};$

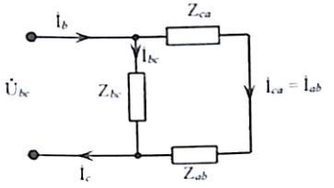
$\dot{I}_c = \dot{I}_{ca} - \dot{I}_{bc}\ ;$

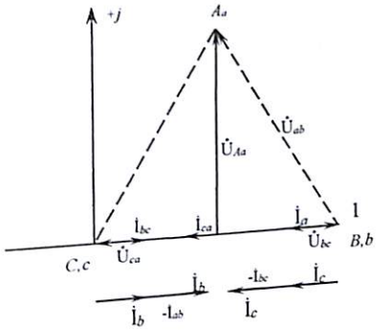


Tekshiruv:

$$\dot{I}_a + \dot{I}_b + \dot{I}_c = -\dot{I}_{ca} + \dot{I}_{bc} + \dot{I}_{ca} - \dot{I}_{bc} = 0$$

e) *A* liniya simidagi uzilish:





$\underline{Z}_{ab} = \underline{Z}_{bc} = \underline{Z}_{ca} = R = const$

Ekvivalent sxemadan BC – faza kuchlanishi, liniya kuchlanishiga $\dot{U}_{bc} = \dot{U}_{Л}$ va $\underline{Z}_{ab}$, $\underline{Z}_{bc}$, qarshiliklar ketma-ket ulangan holda bo‘lib $\dot{U}_{ab} = \frac{\dot{U}_L}{2};\ \dot{U}_{ca} = \frac{\dot{U}_L}{2}$ ga teng bo‘ladi

Bunda tok 2 marta kamayadi: $\dot{I}_{ca} = \dot{I}_{ab} = -0{,}5\dot{I}_{bc};$

O‘z navbatida liniyadagi tok $\dot{I}_b$ va $\dot{I}_c$ kamayadi:

$$\dot{I}_b = \dot{I}_{bc} - \dot{I}_{ab} = 1{,}5\dot{I}_{bc};$$

$$\dot{I}_c = \dot{I}_{ca} - \dot{I}_{bc} = -1{,}5\dot{I}_{bc};$$

Uzilgan liniya simlari orasidagi kuchlanish potensiali:

$$\dot{U}_{Aa} = \dot{U}_{AB}\cos 30^\circ = \frac{\sqrt{3}}{2}\dot{U}_L;$$

4. Uch fazali tok elektr quvvat tenglamalari va o’lchash usullari

a) Simmetrik uch fazali zanjirdan umumiy quvvatlarni quydagicha ifodalash mumkin:

$$P = 3P_F = 3U_F I_F \cos\varphi = \sqrt{3}U_L I_L \cos\varphi$$

$$Q = 3Q_F = 3U_F I_F \sin\varphi = \sqrt{3}U_L I_L \sin\varphi$$

$$\tilde{S} = 3\tilde{S}_F = 3U_F I_F = \sqrt{3}U_L I_L$$

Agar uch fazali zanjir simmetrik bo’lsa bitta vattmetr yordamida o’lchash bilan faza quvvatini 3 ga yoki liniya quvvatini $\sqrt{3}$ ga ko’paytirish kifoya qiladi.

b) Agarda uch fazali zanjir nosimmetrik bo'lsa, elektr energiya quvvatini uchta vattmetr yordamida o'lchash mumkin bo'lib, umumiy quvvat ularning algebrik yig'indisiga teng:

$$P = P_A + P_B + P_C = U_A I_A \cos\varphi_A + U_B I_B \cos\varphi_B + U_C I_C \cos\varphi_C$$

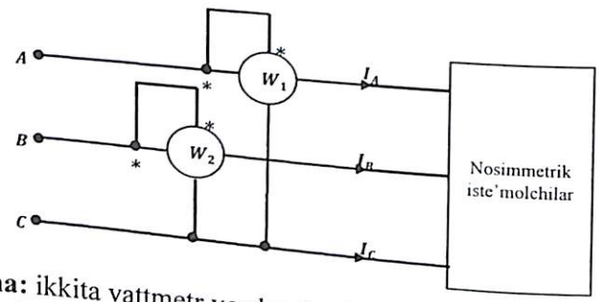
$$Q = Q_A + Q_B + Q_C = U_A I_A \sin\varphi_A + U_B I_B \sin\varphi_B + U_C I_C \sin\varphi_C$$

$$\tilde{S} = \tilde{S}_A + \tilde{S}_B + \tilde{S}_C = \dot{U}_A \dot{I}_A + \dot{U}_B \dot{I}_B + \dot{U}_C \dot{I}_C$$

Lekin uch fazali zanjirlarda: $\dot{I}_A + \dot{I}_B + \dot{I}_C = 0$ va $\dot{U}_{BC} = \dot{U}_L = \dot{U}_B - \dot{U}_C$ yoki ekanligi inobatga olsak, biror linya tokning hisobga olmagan holda (masalan I_C), umumiy to'la quvvatni shunday ifodalash mumkin.

$$\tilde{S} = \dot{U}_A \dot{I}_A + \dot{U}_B \dot{I}_B + \dot{U}_C(-\dot{I}_A - \dot{I}_B) = (\dot{U}_A - \dot{U}_C)\dot{I}_A + (\dot{U}_B - \dot{U}_C)\dot{I}_B = \dot{U}_{AC}\dot{I}_A + \dot{U}_{BC}\dot{I}_B$$

Ushbu kompleks tenglamanng haqiqiy son qismi uch fazali tok aktiv quvvatni ifodalaydi, ya'ni: $Re[\tilde{S}] = P = \dot{U}_{AC}\dot{I}_A \cos(U_{AC}\hat{}I_A) + U_{BC}I_B \cos(U_{BC}\hat{}I_B)$ yoki: $P = P_1 + P_2$. Demak nosimmetrik uch fazali tok aktiv quvvatini o'lchashda ikkita vattmetrdan ham foydalanish mumkin.



Eslatma: ikkita vattmetr yordami uch fazali tok quvvatini o'lchash bilan quvvat koeffutsienti va iste'molchi qaysi xarakteriga ega ekanligini ham aniqlash mumikin:

$$tg\,\varphi = \sqrt{3}\frac{P_1 - P_2}{P_1 + P_2}$$

5. Simmetrik tashkil etuvchilar usuli.

Amalda uch fazali generator, dvigatel, tarnsfarmatorlar ish rejimlari linya yoki fazadagi tok va kuchlanishlar simmetrik darajasi bilan uzviy bog'liq bo'ladi.

Bunday holatda uch fazali nosimmetrik EYUK tok va kuchlanishlar vektorlarini belgilangan tartibda simmetrik tashkil etuvchilar yig'indisi ko'rinishida almashtirish bilan hisoblash mumkin.

Umumiy holda (6-3) keltirilgan ifodalarga asosan vektorlarni $(1 + a + a^2)$ ko'paytirish bilan nol, to'g'ri yoki teskari tartibdagi simmetrik tashkil etuvchilarga ajratish bilan quyidagicha yozish mumkin:

$$\begin{aligned} \bar{A} &= \bar{A}_0 + \bar{A}_1 + \bar{A}_2 \\ \bar{B} &= \bar{B}_0 + \bar{B}_1 + \bar{B}_2 \\ \bar{C} &= \bar{C}_0 + \bar{C}_1 + \bar{C}_2 \end{aligned} \qquad (6.7)$$

(6-3) dagi shartlarga binoan (6-7) tenglamani shunday ifodalanadi

$$\begin{aligned} \bar{A} &= \bar{A}_0 + \bar{A}_1 + \bar{A}_2 \\ \bar{B} &= A_0 + a^2 A_1 + a A_2 \\ \bar{C} &= \bar{A}_0 + a\bar{A}_1 + a^2\bar{A}_2 \end{aligned} \qquad (6.8)$$

(6-8) tenglamaga asosan, agar A, B, C nosimmetrik kattaliklar (EYUK, tok, kuchlanishlar) berilgan bo'lsa, u holda nol, to'g'ri va teskari tashkil etuvchilari quyidagicha yozish mumkin:

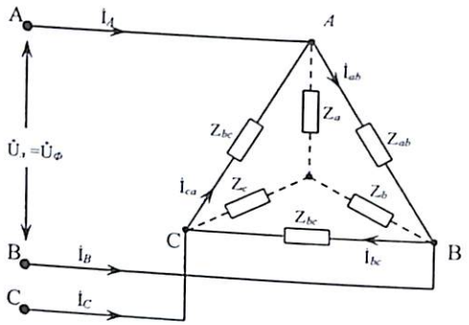
$$\begin{aligned} \bar{A}_0 &= \frac{1}{3}(\bar{A} + \bar{B} + \bar{C}); \\ A_1 &= \frac{1}{3}(\bar{A} + a\bar{B} + a^2\bar{C}); \\ A_2 &= \frac{1}{3}(\bar{A} + a^2\bar{B} + a\bar{C}) \end{aligned} \qquad (6.9)$$

Uch fazali nosimmetrik tizimlarni simmetrik tashkil etuvchilariga ajratishni analitik hamda grafik usullarga bajarish mumkin.

6.2. Masalalar yechish va uslubiy ko‘rsatmalar

6.1-Masala. Liniya kuchlanishi $U_L = 6600\,V$ uch fazali elektr zanjirga iste‘molchi qarshiligi $\underline{z}_{ab} = \underline{z}_{bc} = \underline{z}_{ca} = \underline{z} = (12 + \underline{j}10)$ uchburchak shaklda biriktirilgan holatda faza va liniyadagi tokni aniqlang.

Yechish. Uchburchak shaklda ulangan uch fazali elektr zanjirda:
Fazadagi tok:



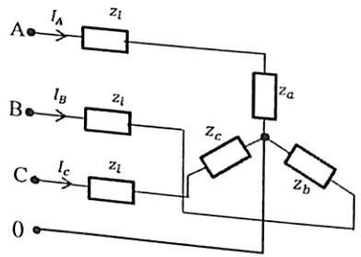
$$\dot{I}_{ab} = \frac{\dot{U}_{ab}}{\underline{z}_{ab}} = \frac{6600}{12+\underline{j}10} = (198 - \underline{j}264)\ A;$$

yoki $\dot{I}_{ab} = \dot{I}_\Phi = \sqrt{(198)^2 + (264)^2} = 330\ A;$

Liniyadagi tok $\dot{I}_L = \dot{I}_A = \sqrt{3}\dot{I}_{ab} = \sqrt{3} \cdot 330 = 571\ A;$

Sistema simmetrik bo‘lganligi uchun uch fazali elektr elektr zanjirning har uchala faza va liniyasidan bir xilda tok o‘tadi.

6.2-Masala. Simmetik yulduzga sxemada ulangan zanjir parametirlari: z=(5+j10), $z_a=z_b=z_c=z_f$=(35+20)om bo’lib. U_f=3300 V kuchlanishga ulangan. Faza to’klari kuchlanishlari va foydali ish koeffitsientini toping.



Yechish: Faza tokini topamiz:

$I_A = I_\varphi = \frac{U_f}{z_L+z_f} = \frac{3300}{50e^{j37}} = 66e^{-j37}$

Demak zanjir simmetrik bo’lgani uchun: $I_B = 66e^{-j157^\circ}$; $I_c = 66e^{j83^\circ}$

Faza kuchlanishlari: $U_A = I_A \cdot z_\varphi = 66e^{-j37} \cdot 40{,}5e^{j30^\circ} = 2680e^{-j7^\circ}$

$U_B = 2680e^{-127^\circ}$; $U_c = 2680e^{j113^\circ}$

Istemolchilarda sarf boladigan aktiv quvvat:

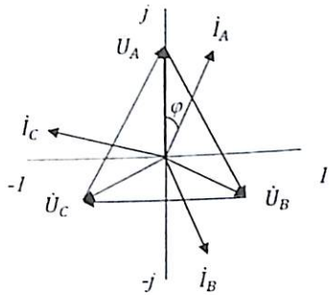
$P_{ist} = 3\dot{U}_A \cdot I_A \cos(\varphi_u - \varphi_i) = 3 \cdot 2680 \cdot 66 cos30^\circ = 460 kVt$

Generatorning aktiv quvvati:

$P_{gen} = 3U_A I_A cos\varphi = 3 \cdot 3300 \cdot 66 \cdot 0{,}87 = 525 kVt$

Demak F.I.K $\eta = \frac{R_{ist}}{R_{gen}} \cdot 100\% = \frac{460}{525} = 87{,}5\%$

6.3-Masala. Neytral simsiz simmetrik uch fazali zanjir faza qarshiliklari $Z = (8 + j6)om$ bo’lib, $U_L = 220\,V$ kuchlanishga ulangan. Faza tok va kuchlanishlari va aktiv quvvat qiymati topilsin.



Yechish: Faza kuchlanish effektiv qiymati: $U_F = \frac{U_L}{\sqrt{3}} = 127\ V$

Demak uchala fazalari simmetrik bo’lganligi uchun:

$\dot{U}_A = 127e^{j0}\ V,\quad \dot{U}_B = 127e^{-j120^0}\ V,\quad \dot{U}_C = 127e^{j120^0}\ V$

Toklar: $\dot{I}_A = \frac{\dot{U}_A}{Z_a} = \frac{127}{8+j6} = \frac{127}{10e^{j37^0}} = 12{,}7e^{-j37^0}\ A$

$$\dot{I}_B = \frac{\dot{U}_B}{Z_b} = \frac{127e^{-j120^0}}{10e^{j37^0}} = 12{,}7e^{-j162^0}\ A$$

$$\dot{I}_C = \frac{\dot{U}_C}{Z_c} = \frac{127e^{j120^0}}{10e^{j37^0}} = 12{,}7e^{j83^0}\ A$$

Umumiy Aktiv quvvati: $P = \sqrt{3}U_L I_L \cos\varphi = 1{,}73 \cdot 220 \cdot 12{,}7 \cos 37^0 = 3867 = 3{,}867\ kWt$

6.4-Masala. Iste'molchilari yulduzcha shaklida biriktirilgan simmetrik uch fazali elektr zanjirning liniya qarshiligi $\underline{z}_{Л} = (1 + \underline{j}1{,}73)\ Om$ va faza qarshiligi $\underline{z}_{Ф} = (4 + \underline{j}5634)\ Om$ bo'lib, liniya kuchlanishi $\mathring{U}_l = 6600\ V$ ga ulangan. Liniya va fazadagi tok hamda kuchlanishni aniqlang.

Yechish.

Liniya va iste'molchilarning umumiy qarshiligini aniqlaymiz:

$Z_A = Z_{Ф} + \underline{Z}_{Л} = (5 + \underline{j}7{,}07)\ Om;$

Fazadagi kuchlanish: $\dot{U}_a = \frac{\dot{U}_{Л}}{\sqrt{3}} = \frac{6600}{\sqrt{3}} = 3810\ V$

Fazadagi tok: $\dot{I}_A = \frac{\dot{U}_A}{\underline{z}_a} = \frac{3810}{5+\underline{j}359} = (254 - \underline{j}359)\ A;$

yoki $\dot{I}_a = \sqrt{(254)^2 + (359)^2} = 439\ A;$

Liniya qarshiligidagi kuchlanish:

$\Delta\dot{U}_A = \dot{I}_A\underline{Z}_{Л} = (254 - \underline{j}359)(1 + \underline{j}1{,}73) = (872 + \underline{j}80)\ V;$

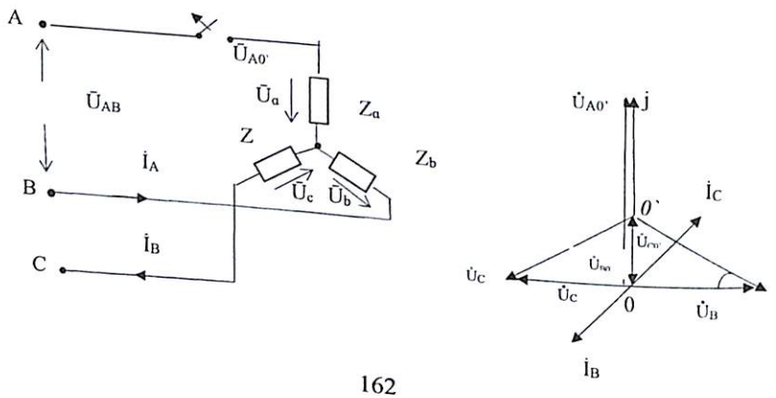
Fazadagi kuchlanish:

$\dot{U}_A = \dot{I}_A\underline{Z}_f = (254 - \underline{j}359)(4 + \underline{j}5{,}34) = (2935 + \underline{j}80)\ V$

Liniyadagi kuchlanish:

$\dot{U}_{AB} = \dot{U}_L = \dot{U}_A - \dot{U}_B = \left(2935 - \underline{j}80\right)\left(1 - \underline{a}^2\right) = \left(2935 - -\underline{j}80\right)\left(1{,}5 + \underline{j}0{,}867\right) = \left(4470 + \underline{j}2430\right)V\ ;$

6.5-Masala. Qarshilik parametrlari R=0,6 Om, X_L= 0,8Om bo`lgan uch fazali elektrodvigatel simmetrik yulduzga sxemadagi U_L = 380 V liniya kuchlamishga ulangan . A fazadagi liniya simi uzilgan holatda, faza kuchlanishlari va liniya toklari topilib, vektor ifodasi tuzilsin.



Yechish. masalani yechishda vektor ifodasidan foydalanamiz : Simmetrik yulduzga uch fazali zanjir A fazasi uzilgan holda U_{BC}= 380 V liniya kuchlanishi ikkita bir xil faza kuchlanishga taqsimlanadi $U = U_B = U_c = \frac{U_{BC}}{2} = \frac{380}{2} = 190\ V.$ Natijada istemolchi neytral nuqta 0` $\overline{U_{BC}}$ – vektor o`rtasiga joylashgan holda uchburchak kateti hisoblanib, φ=30° teng. Demak $\dot{U}_{00`} = \frac{U_B}{2} = \frac{220}{2}V = 110$ bo`lib vektor ifodadasidan: $\dot{U}_{AO`} = \dot{U}_{OO`} + \dot{U} = 110 + 220 = 330\ V;$ toklar esa

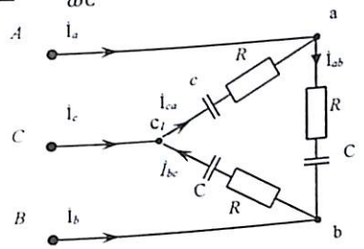
$Ic = \dot{I}_B = \dot{U}_b Y\varphi = \frac{\dot{U}}{\sqrt{R^2+X^2_L}} = \frac{220}{\sqrt{(0{,}6^2+0{,}8^2}} = 190 \cdot 0{,}65 = 123{,}5$ A.

Faza burchagi: $\varphi = arccos\frac{R}{Z} = \arccos 0{,}6$ yoki φ=53°.

6.6-Masala. Iste'molchilari uchburchak shaklida ulangan simmet-rik uch fazali elektr zanjirning parametlari $R = 25\ Om,\ C = 100\ mkF$ bo'lib, o'zgaruvchan tok kuchlanishi $e_A = 141\sin(400t + 30°)$ ulangan. Liniya va fazadagi tokni aniqlang.

Yechish. A fazadagi kuchlanish kompleks ifodasi: $\dot{E}_A = 100e^{j30°}$

Sig'im qarshiligi: $\underline{x}_c = \frac{1}{\omega C} = 25\ Om$



Uchburchak shaklda ulangan uch fazali tok zanjirda: $\dot{E}_A = \dot{U}_{AB}$ bo'lib, birinchi fazadagi tok: $\dot{I}_{ab} = \frac{\dot{U}_{ab}}{\underline{z}} = \frac{100e^{j30°}}{25-\underline{j}25} = 2\sqrt{2}e^{j75°}\ A\ ;$

Ikkinchi fazadagi tok – 120° farq qilib:

$\dot{I}_{bc} = a^2\dot{I}_{ab} = \left(-0{,}5 - \underline{j}\frac{\sqrt{3}}{2}\right)\cdot 2\sqrt{2}e^{j75°} = 2\sqrt{2}e^{-j45°}\ A;$

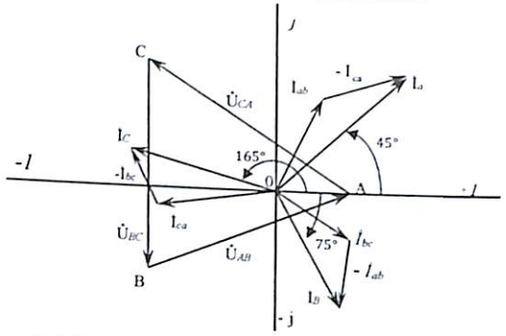
Uchinchi fazadagi tok +120° farq qilib:

$\dot{I}_{ca} = a\dot{I}_{ab} = \left(-0{,}5 + \underline{j}\frac{\sqrt{3}}{2}\right)\cdot 2\sqrt{2}e^{j75°} = 2\sqrt{2}e^{j195°}\ A$

Kirxgof 1-qonuniga asosan liniyadagi tok:

$\dot{I}_a = \dot{I}_{ab} - \dot{I}_{ca} = 2\sqrt{2}e^{j75°} - 2\sqrt{2}e^{-j195°} = 2\sqrt{2}\cdot\sqrt{3}e^{j45°}\ A\ ;$

$\dot{I}_b = \dot{I}_{bc} - \dot{I}_{ab} = 2\sqrt{2}e^{-j45°} - 2\sqrt{2}e^{-j75°} = 2\sqrt{2}\cdot\sqrt{3}e^{-j75°}\ A$;
$\dot{I}_c = \dot{I}_{ca} - \dot{I}_{bc} = 2\sqrt{2}e^{-j195°} - 2\sqrt{2}e^{+j45°} = 2\sqrt{2}\cdot\sqrt{3}e^{j165°}\ A$;
Kompleks tekislikda vektor ifodasini tuzamiz:



6.7-Masala. Uchburchak shaklda ulangan uch fazali tok generator liniyadagi kuchlanishlari nosimmetrik: $\dot{U}_{AB} = 100\ V$, $\dot{U}_{BC} = (-50 - j100)\ V$ va $\dot{U}_{CA} = (-50 + j100)\ V$ bo‘lib, qarshiligi $\underline{Z}_a = 100\ Om$, $\underline{Z}_b = -j100\ Om$, $\underline{Z}_c = j100\ Om$ ga teng va yulduzcha shaklda biriktirilgan iste’molchiga ulangan. Fazadagi kuchlanish va liniyadagi tokni aniqlang.

Yechish. Iste’molchilar to‘la o‘tkazuvchanligi aniqlanadi:

$\underline{y}_a = \frac{1}{\underline{Z}_a} = 0{,}01\frac{1}{Om}$ $\underline{y}_b = \frac{1}{\underline{Z}_b} = j0{,}01\frac{1}{Om}$ $\underline{y}_c = \frac{1}{\underline{Z}_c} = j0{,}01\frac{1}{Om}$

(6-6) tenglamaga asosan.

Fazadagi kuchlanishni liniya kuchlanishlari orqali ifodalovchi tenglama:

$$\dot{U}'_A = \frac{\dot{U}_{AB}\underline{y}_b - \dot{U}_{CA}\underline{y}_c}{\underline{y}_a + \underline{y}_b + \underline{y}_c} = (-100 + j50)V$$

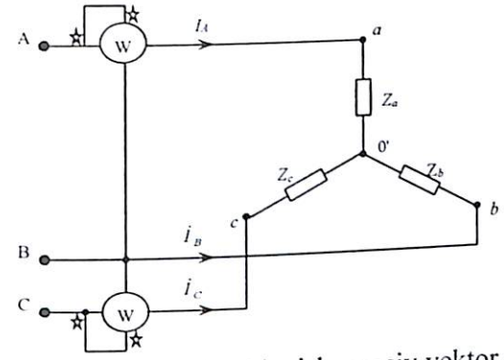
$$\dot{U}'_B = \frac{\dot{U}_{BC}\underline{y}_c - \dot{U}_{AB}\underline{y}_a}{\underline{y}_a + \underline{y}_b + \underline{y}_c} = \frac{(-50-100j)(-j0{,}01) - 100(0{,}01)}{0{,}01} = (-50 - j200)V$$

$$\dot{U}'_C = \frac{\dot{U}_{CA}\underline{y}_a - \dot{U}_{BC}\underline{y}_b}{\underline{y}_a + \underline{y}_b + \underline{y}_c} = \frac{(-50+100j)\cdot 0{,}01 - (-50-j100)\cdot j0{,}01}{0{,}01} = (-150 + j150)V$$

Liniyadagi tok aniqlaymiz. Bunda iste’molchilar yulduzcha shaklda ulanganligi uchun $\dot{I}_A = \dot{I}_\phi$

$$\dot{I}_A = \dot{U}'_A \cdot Y_a = (-1 + j0{,}5)A\ ;$$
$$\dot{I}_B = \dot{U}'_B \cdot Y_b = (-0{,}5 - j2)A\ ;$$
$$\dot{I}_C = \dot{U}'_C \cdot Y_c = (1{,}5 + j1{,}5)A\ ;$$

6.8-Masala. Yulduzcha shaklda ulangan simmetrik uch fazali elektr zanjirda iste’molchi qarshiligi $(Z = 5 + j5)$ bo‘lib, fazadagi kuchlanish $U_\phi = 220V$ generatorga ulangan. Sxemaga ulangan vattmetr ko‘rsatish qiymati aniqlanib, vektor ifodasi tuzilsin.



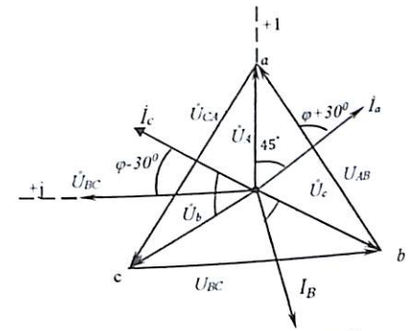
Yechish. Birinchi fazadagi kuchlanish asosiy vektor qilib tanlanadi.

Bunda : $\dot{U}_A = \dot{U}_\phi = 220\ V$,

Fazadagi tok $\dot{I}_A = \frac{\dot{U}_A}{Z} = \frac{220}{5+j5} = (22 - j22)A$

yoki $I_a = \sqrt{22^2 + 22^2} = 31{,}1\ A$ $tg\varphi = 1$, $\varphi = 45°$

Vektor ifodasi: Tok va kuchlanishlar uchun masshtab tanlash bilan.



Bunda birinchi vattmetr quvvat tenglamasi:

$\dot{P}_1 = \dot{U}_л \cdot \dot{I}_л \cos(U_{aB}\hat{}I_a) = \dot{P}_I = \dot{U}_л \cdot \dot{I}_л \cos(U_{aB}\hat{}I_a) = \sqrt{3}\cdot 220 \cdot 31{,}1\cos(30° + \varphi) = 220\sqrt{3\cdot 31{,}1\cos 75°} = 3060 = 3{,}06\ kVt$

Ikkinchi vattmetr tenglamasi:

$\dot{P}_2 = \dot{U}_л \cdot \dot{I}_л \cos(U_{CB}\hat{}I_c) = 220\cdot\sqrt{3}\cdot 31{,}1\cos(30° - \varphi) = 380 \cdot 31{,}1\cdot\cos 15° = 11460\ Vt = 11{,}46\ kVt$

Demak: $P_{istem} = P_1 + P_2 = 3{,}06 + 11{,}46 = 14{,}52\ kVt$

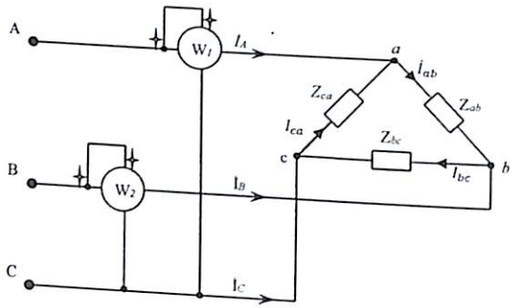
Uch fazali tok quvvat tenglamasi.

$$P = \sqrt{3} \cdot I_л \cdot U_л \cos\varphi = \sqrt{3} \cdot 31{,}1 \cdot 380 \frac{\sqrt{2}}{2} = 14{,}49 \approx 14{,}5 kVt$$

6.9-Masala. Uch fazali elektr zanjirda iste'molchi qarshiligi nosimmetrik: $Z_{ab} = 38\,Om$, $Z_{bs} = 38e^{j45°} Om$, $Z_{ca} = 38e^{-j45°}\,Om$ bo'lib, uchburchak shaklda ulangan. Fazadagi kuchlanish $U_ф = 220\,V$ bo'lganda, sxemaga ulangan vattmetning ko'rsatish qiymatini aniqlang.

Yechish. Iste'molchi qarshiligi:

$\underline{Z}_{ab} = 38(Om)$, $\underline{Z}_{bc} = 38e^{j45°} = (30 + j30)Om$, $\underline{Z}_{ca} = 38e^{-j45°} = (30 - j30)Om$



Fazadagi kuchlanishning vektor ifodasi:

$\dot{U}_a = \dot{U}_ф = 220\,V$

$\dot{U}_b = \dot{U}_ф \cdot a^2 = 220\,e^{-j120} = (-100 + j190)(V)$

$\dot{U}_c = \dot{U}_ф \cdot a = 220\,e^{-j120} = (-100 - j190)(V)$

Liniyadagi kuchlanish:

$$\dot{U}_{ab} = \dot{U}_a - \dot{U}_b = 220(1 - a^2) = 220\sqrt{3} \cdot e^{j30} = 380e^{j30}(V)$$

$$\dot{U}_{bc} = \dot{U}_b - \dot{U}_c = 220(a^2 - a) = 220\sqrt{3} \cdot e^{-j90} = 380e^{-j90}(V)$$

$$\dot{U}_{ca} = \dot{U}_c - \dot{U}_a = 220(a - 1) = \sqrt{3} \cdot 220e^{j150} = 380e^{j150}(V)$$

Fazadagi tok:

$$\dot{I}_{ab} = \frac{\dot{U}_{ab}}{Z_{ab}} = \frac{380e^{j30}}{38} = 10e^{j30°} = (8{,}67 + j5)A$$

$$\dot{I}_{bc} = \frac{\dot{U}_{bc}}{Z_{bc}} = 10e^{-j135°} = (-7 - j7)A$$

$$\dot{I}_{ca} = \frac{\dot{U}_{ca}}{Z_{ca}} = 10e^{j95°} = (9{,}65 - j2{,}6)A$$

Liniylaradagi tok:

$$\bar{I}_a = \bar{I}_{ab} - \bar{I}_{ca} = (18{,}3 + j7{,}6) = 20e^{j22°30'}$$

$$\bar{I}_b = \bar{I}_{bc} - \bar{I}_{ab} = (-15{,}7 + j12) = 19{,}8e^{j217°30'}$$

$$\bar{I}_c = \bar{I}_{ca} - \bar{I}_{bc} = (-2{,}6 + j4{,}5) = 5e^{j120°}$$

Birinchi va ikkinchi vattmetrlarning quvvat tenglamasi:

$$P_1 = R_e[\bar{I}_a \cdot \overline{U}_{ca}] = R_e\left[20e^{j22°30'} \cdot 380e^{j30°}\right] = 7550\cos 52°30' = 4580(Vt)$$

$$P_2 = R_e[\bar{I}_b \cdot \overline{U}_{bc}] = 7550\ \cos 52°30' = 4570(Vt)$$

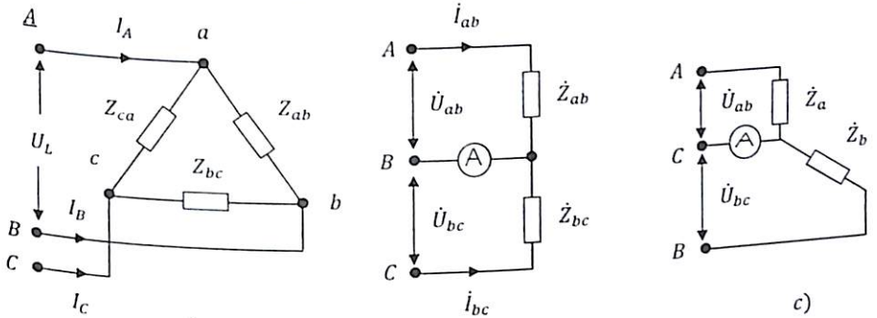
Uch fazali tok to'la quvvati

$$P = P_1 + P_2 = 4{,}58 + 4{,}58 = 9{,}16(kVt)$$

Tekshiruv: Har bir iste'molchida sarf bo'lgan quvvat yig'indisi:

$$P = R_{ab}\,I_{ab}^2 + R_{bc}\,I_{bc}^2 + R_{ca}\,I_{ca}^2 = 38.102 + 30.102 + 30.102 \approx 9{,}2(kVt)$$

6.10-Masala. Uchburchak shaklida ulangan uch fazali transformator Z_{ca} faza simi uzilgan holatda $Z_{ca} = 8 - j6$ va $Z_{bc} = 3 + j4$ bo'lib, $\dot{U}_L = 200\,V$ ga teng. Ampermetr qancha tok ko'rsatadi?



a) b) c)

Yechish: Agar uchburchak sxemada ulangan zanjir Z_{ca} fazasi uzilsa b-rasm ko'rinishdagi ekvivalent sxema hosil bo'ladi:

Kuchlanishni $\dot{U}_{ab} = 200\,V$ haqiqiy o'qqa yo'nalgan desak:

$\dot{U}_{bc} = 200(-0{,}5 - j0{,}87) = (-100 - j174)\,V$

$\dot{U}_{ca} = 200(-0{,}5 + j0{,}87) = (-100 + j174)\,V$

Demak: $\dot{I}_{ab} = \frac{\dot{U}_{ab}}{Z_{ab}} = \frac{200}{8-j6} = (16 + j12)A$

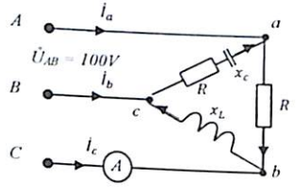
$\dot{I}_{bc} = \frac{\dot{U}_{bc}}{Z_{bc}} = \frac{-100-j174}{3+j4} = (-40 - j5)A$; $\quad \dot{I}_{ca} = 0$

Liniya toki: $\dot{I}_2 = \dot{I}_{bc} - \dot{I}_{ab} = -40 - j5 - 16 - j12 = (-56 - j17)A$

Ampermetr ko'rsatishi: $\dot{I}_2 = \sqrt{56^2 + 17^2} \approx 58\ A$

Eslatma: c-rasmdagi sxema yulduzcha shaklida ulangan bo'lsa, uch fazali zanjirning C-fazasini qisqa tutashtirilgan holatiga mos.

6.11-Masala. Uchburchak shaklida biriktirilgan uch Z_{CA} fazali elektr zanjir iste'molchi qarshiliklari $Z_{ab} = (3 - j4)\ Om, Z_{bc} = j10Om. Z_{ca} = 10\ Om$ ga teng bo'lib, liniyadagi kuchlanish $U_l = 100V$ bo'lgan generatorga ulangan. Sxemaga ulangan ampermetr qiymati va sarf bo'ladigan quvvat aniqlansin.



Yechish. Liniyadagi kuchlanishni aniqlaymiz:

$$\dot{U}_{ab} = 100\ (V)$$

$$\dot{U}_{bc} = 100 \cdot a^2 = (-50 - j \cdot 87)(V)$$

$$\dot{U}_{ca} = 100 \cdot a = (-50 + j \cdot 87)(V)$$

Fazadagi tok:

$$\dot{I}_{ab} = \frac{\dot{U}_{ab}}{Z_{ab}} = \frac{100}{3-j4} = \frac{100\cdot(3-j4)}{9+16} = (12 - j16)A$$

$$\dot{I}_{bc} = \frac{\dot{U}_{bc}}{Z_{bc}} = \frac{(-50-j87)\cdot(-j10)}{100} = (-8{,}7 + j5)A$$

$$\dot{I}_{ca} = \frac{\dot{U}_{ca}}{Z_{ca}} = \frac{-50+j87}{10} = (-5 + j8{,}7)A$$

Liniyadagi toklar:

$$\dot{I}_a = \dot{I}_{ab} - \dot{I}_{bc} = (12 + j16) + (5 - j8{,}7) = (17 + j7{,}3)A$$

$$\dot{I}_b = \dot{I}_{bc} - \dot{I}_{ab} = (-8{,}7 + j5) - (12 - j16) = (-20{,}7 - j11)A$$

$$\dot{I}_c = \dot{I}_{ca} - \dot{I}_{bc} = (-5 + j8{,}7) - (j5 + 8{,}7) = (3{,}7 - j3{,}7)A$$

Ampermetr ko'rsatish qiymati: $\dot{I}_c = \sqrt{(3{,}7)^2 + (3{,}7)^2} = 5{,}2\ A$

To'la quvvatilar:

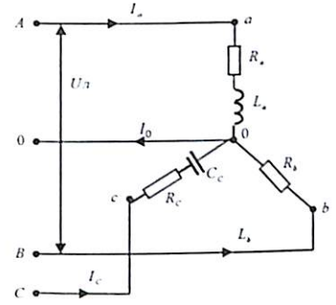
$$\tilde{S}_{ab} = \dot{U}_{ab} \cdot \dot{I}_{ab} = 100(12 - j16) = (1200 - j1600)\ (VA)$$

$$\tilde{S}_{bc} = \dot{U}_{bc} \cdot \dot{I}_{bc} = (-50 - j87)(-8{,}7 - j5) = j1000\ (VA)$$

$$\tilde{S}_{ca} = \dot{U}_{ca} \cdot \dot{I}_{ca} = (-50 - j87)(-5 - j8{,}7) = 1000\ (VA)$$

Aktiv quvvat: $P = P_{ab} + P_{ca} = 1200 + 1000 = 2200\ Vt$

6.12-Masala. To'rt simli yulduzcha shaklda ulangan uch fazali elektr zanjirning parametri: $R_a = 80sm, L_a = 0{,}18gn, R_b = 70sm, R_c = 40sm, C_c = 30mkF$ bo'lib, chastotasi $f = 50\ Gs$, liniyadagi kuchlanishi $U_l = 380V$ bo'lgan generatorga ulangan. Tok va iste'molchidagi to'la quvvat aniqlansin.



Yechish.

Fazadagi kuchlanish: $U_F = \frac{380}{\sqrt{3}} = 220\ V$

Fazadagi to'la qarshilik:

$$Z_a = \sqrt{R_a^2 + x_{L_a}} = \sqrt{80^2 + (314 \cdot 0{,}18)^2} = 100\ Om$$

$$Z_b = R_b = 70\ Om$$

$$Z_c = \sqrt{R_a^2 + x_{C_c}^2} = \sqrt{(40)^2 + (\frac{1\cdot10^6}{314\cdot30})^2} = 110\ Om$$

Fazadagi tok:

$$I_A = \frac{U_a}{Z_a} = \frac{220}{100} = 2{,}2\ A\ I_B = \frac{U_b}{Z_b} = \frac{220}{70} = 3{,}15\ A\ \ I_C = \frac{U_c}{Z_c} = \frac{220}{110} = 2\ A$$

Aktiv quvvat: $P_a = I_a^2 \cdot R_a = (2{,}2)^2 \cdot 80 = 400\ Vt$

$$P_b = I_b^2 \cdot R_b = (3{,}15)^2 \cdot 70 = 700\ Vt$$

$$P_c = I_c^2 \cdot R_c = (2)^2 \cdot 40 = 160\ Vt$$

Yoki umumiy aktiv quvvat: $P = P_a + P_b + P_c = 400 + 700 + 160 = 1260\ Vt$

$$Q_a = I_a^2 \cdot x_L = (2{,}2)^2 \cdot 56{,}6 = 285\ VAR$$

$$Q_b = 0$$

$$Q_c = -I_c^2 \cdot x_c = -(2 \cdot 106)^2 = 425\ VAR$$

Yoki umumiy reaktiv quvvat:

$$Q = Q_a + Q_c = 285 - 425 = -140\ VAR$$

Sarf bo'ladigan to'la quvvat:

$$S = \sqrt{P^2 + Q^2} = \sqrt{(1260)^2 + (140)^2} = 1280\ VA = 1{,}28\ kVA$$

6.13-Masala. Nosimmetrik, nitral simmetrik yulduzcha shaklidagi sxema parametirlari : $R_a = 1om,\quad R_b = 20om,\quad R_c = 3om$ va $R_0 = 3om$ bo'lib, simmetrik $U_\varphi = 220V$ ulangan. Faza va netral sim toklari va kuchlanishlar hisoblab topilsin:

Yechish: (6-12) tenglamaga asosan ikki turg'un potensiyallar usuliga asosan :

$$\dot{U}_{00'} = \frac{\dot{E}_a Y_a + \dot{E}_b Y_b + \dot{E}_c Y_c}{Y_a + Y_b + Y_c + Y_0} = \frac{220\cdot 1 + (-110 - j190) + 0{,}5 + (-110 + j190^\circ)\cdot 0{,}34}{1 + \frac{1}{2} + \frac{1}{3} + \frac{1}{3}} = (59{,}2 - j14{,}7) = 61e^{-j14^\circ}$$

Faza kuchlanishlari :

$$\dot{U}_a = \dot{E}_a - \dot{U}_{00'} = 220 - (59{,}2 - j14{,}7) = 161e^{j50}\,V$$

$$\dot{U}_b = \dot{E}_b - \dot{U}_{00'} = a^2\dot{E}_b - \dot{U}_{00'} = (-110 + j190) - (59{,}2 - j14{,}7) == 244e^{-j136^\circ}$$

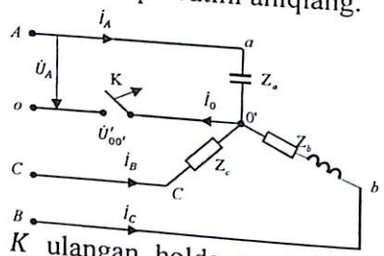
$$\dot{U}_c = \dot{E}_c - \dot{U}_{00'} = a\dot{E}_c - \dot{U}_{00'} = (-110 + j190^\circ) - (59{,}2 - j14{,}7) == 266e^{j130^\circ}$$

Faza va neytral simdagi toklar :

$$\dot{I}_a = Y_a\dot{U}_a = 161e^{j50}\ ; \quad \dot{I}_b = Y_b\dot{U}_b = 122e^{-j136^\circ};$$

$$\dot{I}_c = Y_c\,\dot{U}_c = 88{,}5e^{j30^\circ}; \quad \dot{I}_0 = Y_0\,\dot{U}_0 = \frac{1}{3} * 61e^{-j14^\circ} = 20{,}3e^{-j14^\circ}$$

6.14-Masala. Yulduzcha shaklida biriktirilgan neytral simli uch fazali elektr zanjirning parametri: $Z_1 = -j8\ Om;\ Z_2 = 10\ Om;\ Z_3 = (3 + j4)Om$. Liniyadagi kuchlanish simmetrik bo'lib: $U_{AB} = U_{BC} = U_{CA} = 173\ (V)$. Neytral sim toki I_0, neytral sim uzilgandagi potensial kuchlanish U_{oo} va iste'molchi quvvatini aniqlang.



Yechish. Kalit K ulangan holda neytral sim yulduzcha shaklda ulangan bo'lib, fazadagi kuchlanishning kompleks ifodasi:

$$\dot{U}_\phi \frac{\dot{U}_L}{\sqrt{3}} = 100V;$$

$$\dot{U}_B = \dot{U}_A \cdot a^2 = (50 - j87)(V);\ \dot{U}_C = \dot{U}_A \cdot a = (-50 - j87)(V)$$

Fazadagi tok:

$$\dot{I}_a = \frac{\dot{U}_a}{\underline{Z}_a} = \frac{100}{-j8} = j12{,}5A$$

$$\dot{I}_b = \frac{\dot{U}_b}{\underline{Z}_b} = \frac{-50 - j87}{10} = (-5 - j8{,}7)A$$

$$\dot{I}_c = \frac{\dot{U}_c}{\underline{Z}_c} = \frac{-50 + j87}{3 + j4} = (7{,}9 + j18{,}4)A$$

$$j12{,}5 + (-5 - j8{,}7) + (7{,}9 + j18{,}4)$$

Neytral simdagi tok: $\dot{I}_0 = \dot{I}_a + \dot{I}_b + \dot{I}_c = (2{,}9 + j22{,}2)\ A$

Effektiv yoki haqiqiy qiymat: $\dot{I}_0 = \sqrt{(2{,}9)^2 + (22{,}2)^2} = 22{,}4\ A$

Potensiallar orasidagi kuchlanish: $U_{oo'} = \dot{I}_0 \cdot Z_0 = 0$

To'la quvvat:

$$\tilde{S}_a = \dot{U}_a \cdot I_a^* = 100 \cdot (-j12{,}5) = -j1250\ (VA)$$

$$\tilde{S}_b = \dot{U}_b \cdot I_b^* = (-50 - j87) \cdot (-5 + j8{,}7) = 100\ (VA)$$

$$\tilde{S}_c = \dot{U}_c \cdot I_c^* = (-50 + j87) \cdot (7{,}9 - j18{,}4) = (1250 + j1600)\ (VA)$$

Aktiv quvvat: $P = 1000 + 1200 = 2200\ (Vt) = 2{,}2\ kVt$

2) kalit K uzilgan holda, neytral simsiz yulduzcha shaklidagi sxema hosil bo'ladi.

Yechish. Iste'molchi o'tkazuvchanligi:

$$\underline{y}_a = \frac{1}{\underline{Z}_a} = \frac{1}{-j8} = j0{,}125\ \frac{1}{Om}$$

$$\underline{y}_b = \frac{1}{\underline{Z}_b} = \frac{1}{10} = 0{,}1\ \frac{1}{Om}$$

$$\underline{y}_c = \frac{1}{\underline{Z}_c} = \frac{3 - j4}{9 + 16} = (0{,}12 - j0{,}16)\ \frac{1}{Om}$$

Generator bilan iste'molchi o'rtasidagi potensial kuchlanish:

$$\dot{U}'_{00'} = \frac{\dot{U}_a\underline{y}_a + \dot{U}_b\underline{y}_b + \dot{U}_c\underline{y}_c}{\underline{y}_1 + \underline{y}_2 + \underline{y}_3} = (-2{,}8 + j100)\ V$$

Fazadagi kuchlanishlar:

$$\dot{U}_a = \dot{U}_A - \dot{U}'_{00'} = 100 - (-2{,}8j + 100) = (102{,}8 - j100)V$$

$$\dot{U}_b = \dot{U}_B - \dot{U}'_{00'} = -50 - j87 - (-2{,}8j + 100) = (-47{,}8 - j187)V$$

$$\dot{U}_c = \dot{U}_C - \dot{U}'_{00'} = -50 + j87 - (-2{,}8j + 100) = (102{,}8 - j13)V$$

Fazadagi toklar. $\dot{I}_\phi = \dot{I}_A$

$$\dot{I}_A = \dot{U}_a\underline{y}_a = (102{,}8 - j100) \cdot j0{,}125 = (12{,}5 + j12{,}8)\ A$$

$$\dot{I}_B = \dot{U}_b\underline{y}_b = (-47{,}8 - j187) \cdot 0{,}1 = (-47{,}8 - j187)\ A$$

$$\dot{I}_C = \dot{U}_c\underline{y}_c = (-47{,}8 - j13) \cdot (0{,}12 - j0{,}16) = (-7{,}82 + j6{,}1)\ A$$

Tokning algebraik yig'indisi $\sum \dot{I}_q = 0$; Haqiqiy qiymati

Liniyadagi tok: $I_л = \sqrt{(12{,}5)^2 + (12{,}8)^2} = 17{,}8\ A$

Neytral nuqtadagi potensiallarning effektiv qiymati:

$$\dot{U}'_{00'} = \sqrt{(-2{,}8)^2 + 100^2} \approx 100\ V$$

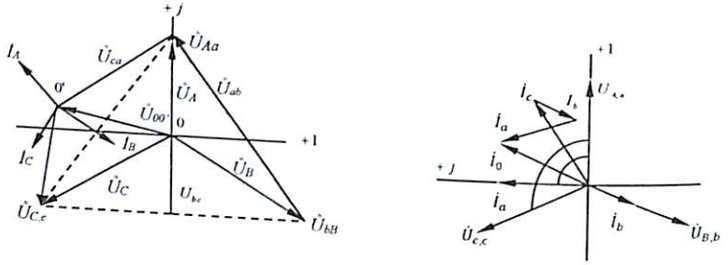
To‘la quvvat:

$$\tilde{S}_A = \dot{U}_a I_a^* = (102{,}8 - j100)(12{,}5 - j12{,}84) = -j2560\ VA$$

$$\tilde{S}_A = \dot{U}_b I_b^* = (-47{,}8 - j187)(4{,}78 - j18{,}7) = 3720\ VA$$

$$\tilde{S}_A = \dot{U}_c I_c^* = (-47{,}8 - j13)(-7{,}8 - j6) = (293 + j393{,}5)\ VA$$

Iste’molchilardagi sarf bo‘ladigan aktiv quvvatning o‘rtacha qiymati: $P = 3720 + 293 = 4013\ (Vt)$. Masshtab tanlash bilan vektor ifodasini tuzamiz.



6.15-Masala. Fazadagi kuchlanish $\dot{U}_a = 220\ V$; $\dot{U}_b = (-110 - j150)\ V$; $\dot{U}_c = (-110 + j150)$ bo‘lgan neytral simsiz uch fazali elektr zanjirning kompleks qarshiligi $Z_a = (2 + j3)(Om)$; $Z_b = (3 + j2)(Om)$ va $Z_c = (3 - j2)(Om)$ga teng. Manbadagi kuchlanish to‘g‘ri, teskari va nol tashkil etuvchilari hamda faza toklari va kuchlanishlari aniqlansin.

Yechish. Nosimmetrik kuchlanish sistemalarni simmetrik tashkil etuvchilarga ajratish tenglamasiga asosan:

$$\dot{U}_0 = \frac{1}{3}(\dot{U}_a + \dot{U}_b + \dot{U}_c) = \frac{1}{3}[220 + (-110 - j150) + (-110 + +j150)] = 0\ ;$$

$$\dot{U}_1 = \frac{1}{3}(\dot{U}_a + a\dot{U}_b + a^2\dot{U}_c) = \frac{1}{3}\left[220 + \left(-0{,}5 + j\frac{\sqrt{3}}{2}\right)\cdot(-110 - -j150) + \left(-0{,}5 - j\frac{\sqrt{3}}{2}\right)\cdot(-110 + j150)\right] = 197\ V\ ;$$

$$\dot{U}_2 = \frac{1}{3}(\dot{U}_a + a^2\dot{U}_b + a\dot{U}_c) = \frac{1}{3}\left[220 + \left(-0{,}5 - j\frac{\sqrt{3}}{2}\right)\cdot(-110 - -j150) + \left(-0{,}5 + j\frac{\sqrt{3}}{2}\right)\cdot(-110 + j150)\right] = 23\ V.$$

Neytral simsiz bo’lganligi uchun nol ketma-ketligi: $\dot{I}_0 = 0$

Bunda toklar tenglamasi:

$$\dot{I}_1 = \frac{(Z_a + Z_b + Z_c)\dot{U}_1 - (Z_a + a^2 Z_b + aZ_c)\dot{U}_2}{Z_a Z_b + Z_b Z_c + Z_c Z_a} = (50 - j15)A$$

$$\dot{I}_2 = \frac{(Z_a + a^2 Z_b + aZ_c)\dot{U}_1 - (Z_a + Z_b + Z_c)\dot{U}_2}{Z_a Z_b + Z_b Z_c + Z_c Z_a} = (38 + j6{,}4)A$$

Fazadagi tok:

$$\dot{I}_a = \dot{I}_1 + \dot{I}_2 = 87{,}8 - j8{,}6 = 88{,}2e^{-j5^\circ}A$$

$$\dot{I}_b = a^2\dot{I}_1 + a\dot{I}_2 = -62{,}4 - j6{,}1 = 62{,}6e^{j185^\circ}A$$

$$\dot{I}_c = a\dot{I}_1 + a^2\dot{I}_2 = -(\dot{I}_a + \dot{I}_b)\cdot a = -25{,}4 + j14{,}7 = 29{,}4e^{j150^\circ}A$$

Iste’molchilardagi kuchlanish:

$$\dot{U}_a = \underline{Z}_a\dot{I}_a = 3{,}6\cdot 88{,}2 = 318\ V;$$

$$\dot{U}_b = \underline{Z}_b\dot{I}_b = 3{,}6\cdot 62{,}6 = 225\ V;$$

$$\dot{U}_c = \underline{Z}_c\dot{I}_c = 3{,}6\cdot 29{,}4 = 106\ V;$$

6.16-Masala. Uch fazali elektr generatorning simmetrik tashkil etuvchilari $\dot{E}_1 = 100\ V$; $\dot{E}_2 = 25e^{j120}\ V$; $\dot{E}_0 = 100\cdot e^{-j1200}\ V$ ga teng bo‘l-ganda, nosimmetrik EYKning tashkil etuvchilari analitik va vektor ifodasi aniqlansin.

Yechish. $\dot{E}_1 = 100\ V$; $\dot{E}_2 = 25e^{j\frac{\pi}{3}} = (12{,}5 + j21{,}7)\ (V)$

$$\dot{E}_0 = 100e^{-j\frac{\pi}{3}}(50 - j86)\ (V)$$

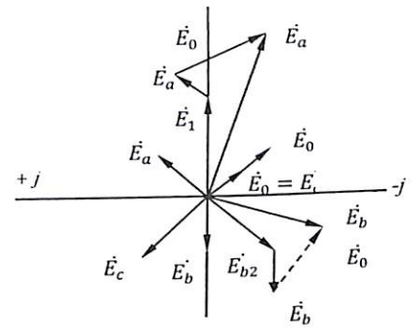
Nosimmetrik uch fazali tok sistemalarining simmetrik tashkil etuvchilarga ajratish tenglamasiga asosan:

$\dot{E}_a = \dot{E}_0 + \dot{E}_1 + \dot{E}_2 = (50 - j86) + 100 + (12{,}5 + j21{,}7) = (62{,}5 - j65)\ V$

$\dot{E}_b = \dot{E}_0 + a^2\dot{E}_1 + a\dot{E}_2 = (50 - j86{,}7) - 50 + (-86{,}7 + 25) = (+25 - j173{,}4)\ V$

$\dot{E}_c = \dot{E}_0 + a\dot{E}_1 + a^2\dot{E}_2 = (50 - j86{,}7) + (-50 + j86{,}7) + 25 = (2{,}5 + j21{,}7)\ V$

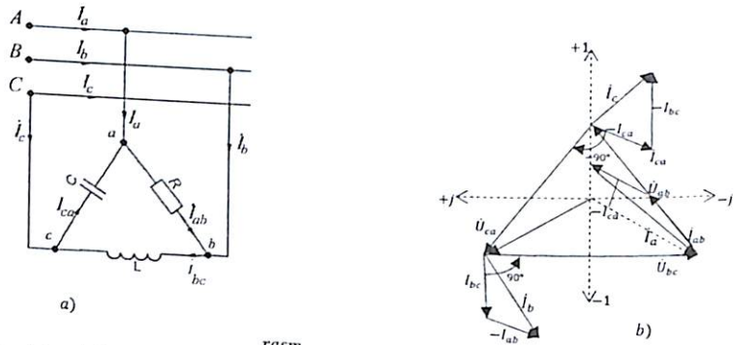
Vektor ifodasi:



6.17-Masala. Uchburchak shaklda ulangan uch fazali elektr zanjirdagi kuchlanish $\dot{U}_n = 380\ V$ bo'lib faza qarshiligi $R = \dot{X}_L = \dot{X}_C = 10\ Om$ ga teng. Liniya va fazadagi tokni hisoblab, tok va kuchlanish topografik diagrammasi tuzilsin.

Yechish. Fazadagi qarshilik modullari bir xil bo'lib, argumenti bilan farqli.

$$\dot{Z}_{ab} = R = 10\ Om;\ \dot{Z}_{bc} = jx_L = j10 = 10^{j90^\circ}\ Om;$$
$$\dot{Z}_{ca} = -jx_c = -10 = 10^{-j90^\circ}\ Om;$$



a) b)

rasm

Liniya kuchlanish kompleks ifodasi:

$$\dot{U}_{ab} = 380e^{j30^\circ}V;\ \dot{U}_{bc} = 380e^{-j90^\circ}V;\ \dot{U}_{bc} = 380e^{j150^\circ}V$$

Fazadagi tok:

$$\dot{I}_{ab} = \frac{380e^{j30^\circ}}{10} = 38e^{j30^\circ}A;\ \dot{I}_{bc} = \frac{380e^{-j90^\circ}}{10^{j90^\circ}} = 38e^{-j180^\circ}A;\ \dot{I}_{ca} = \frac{-380e^{j150^\circ}}{10e^{-j90^\circ}} = 38e^{j240^\circ}A.$$

Liniyadagi toki:

$$\dot{I}_a = \dot{I}_{ab} - \dot{I}_{ca} = 38e^{j30^\circ} - 38e^{j240^\circ} = 38\left[\frac{\sqrt{3}}{2} + j\frac{1}{2} - \left(-\frac{1}{2}\right) - j\left(-\frac{\sqrt{3}}{2}\right)\right] = 51{,}9 + j51{,}9 = 73{,}4e^{(j45^\circ)}$$

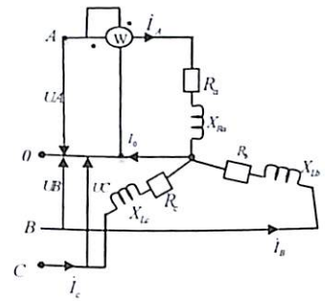
$$\dot{I}_b = \dot{I}_{bc} - \dot{I}_{ab} = 38e^{-j180^\circ} - 38e^{j30^\circ} = 38\left(-1 - j0 - \frac{\sqrt{3}}{2} - j\frac{1}{2}\right) = 70{,}9 - j19 = 73{,}4e^{j195^\circ}$$

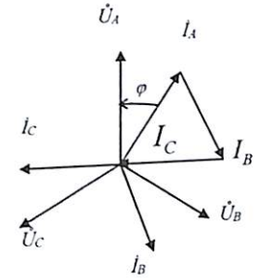
$$\dot{I}_c = \dot{I}_{ca} - \dot{I}_{bc} = 38e^{j240^\circ} - 38e^{-j180^\circ} = 38\left[-\frac{1}{2} - \frac{\sqrt{3}}{2} - j(-1 - j0)\right] = 19 - j32{,}9 = 38e^{(j300^\circ)}$$

Tok va kuchlanish qiymatlari bo'yicha topografik kompleks vektor ifodasini tuzish uchun masshtab tanlanadi: $\mathrm{m_u} = \left[\frac{B}{sm}\right]$: $\mathrm{m_I} = \left[\frac{A}{sm}\right]$.

Fazadagi tok vektorini $\dot{I}_{ab}, \dot{I}_{bc}, \dot{I}_{ca}$ liniyadagi kuchlanish vektorlariga $\dot{U}_{ab}, \dot{U}_{bc}, \dot{U}_{ca}$ nisbatan, $\varphi_{ab} = 0$; $\varphi_{bc} = 90^\circ$; $\varphi_{sa} = -90^\circ$ burchak asosida yo'naltiramiz. Endi fazadagi tok vektorini parallel ko'chirish bilan liniyadagi tok vektori $\dot{I}_a, \dot{I}_b, \dot{I}_c$ hosil qilinadi (rasm b).

6.18-Masala. Yulduzcha shaklda ulangan uch fazali elektr zanjirga uchta bir xil induktiv g'altak ulangan bo'lib, aktiv qarshiligi $R = 16\ Om$, induktiv qarshilik $X_L = 12\ Om$. Bitta fazadagi aktiv quvvat: $P = 1{,}2\ kvt$ bo'lganda, faza va liniyadagi kuchlanish $U_Ф$, $U_Л$, tok hamda to'la va reaktiv quvvatini aniqlang.





Yechish. To'la qarshilik:

$$Z_Ф = \sqrt{R^2 + X_L^2} = \sqrt{16^2 + 14^2} = 20\ Om.$$

Quvvat koeffitsienti: $\cos\varphi = \frac{R}{Z} = \frac{16}{20}0{,}8$

Fazadagi kuchlanish quvvat ifodasida:

$$P_\phi = U_\phi I_\phi \cos\varphi = U_\phi \frac{U_\phi}{Z_\phi}\cos\varphi = \frac{U_\phi^2}{Z_\phi}\cos\varphi$$

Bundan: $U_\phi = \sqrt{\frac{PZ_\phi}{\cos\varphi}} = 175V.$

Liniyadagi kuchlanish: $U_l = \sqrt{3}\cdot 175 = 305\ V$

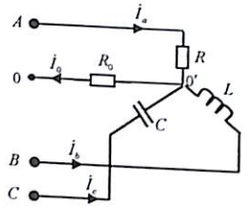
Fazadagi tok:

$$\dot{I}_\phi = \frac{U_\phi}{Z_\phi} = \frac{175}{20} = 8{,}8A$$

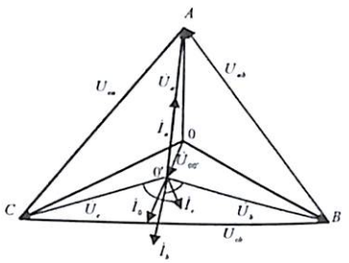
Reaktiv quvvat: $Q_\phi = U_\phi I_a \sin\varphi = 175\cdot 8{,}8\cdot 0{,}6 = 924\ VAR$

To'la quvvat: $S = U_\phi I_\phi = 175\cdot 8{,}8 = 1540VA$

6.19-Masala. Yulduzcha sxema neytral sim qarshiligi $Z_0 = 0{,}1R$ yoki o'tkazuvchanligi $y_0 = 10g$ bo'lgan fazadagi tok va neytral simdagi tok aniqlansin.



a)



b)

Yechish. Neytral sim qarshiligi hisobiga tugun potensiallari orasidagi kuchlanish:

$$\dot{U}_{00'} = \frac{\dot{U}_A y_a + \dot{U}_B y_b + \dot{U}_C y_c}{y_a + y_b + y_c + y_0} = \frac{\dot{U}_A \cdot g\left(-0{,}5 - j\frac{\sqrt{3}}{R}\right)\dot{U}_A(-j2g) + \left(-0{,}5 + j\frac{\sqrt{3}}{R}\right)\dot{U}_A(0{,}333g)}{g - j2g + j0{,}333g + 10g} =$$

$(-0{,}102 + j0{,}06)\dot{U}_A = 0{,}118\dot{U}_A e^{j149°33^1}$

Fazadagi kuchlanish:

$$\dot{U}_a = \dot{U}_A - \dot{U}_{00'} = \dot{U}_A - (-0{,}102 + j0{,}06)\dot{U}_A = (1{,}102 -$$

$j0{,}06)U_A = 1{,}104\dot{U}_A e^{-j3°07'}$

$$\dot{U}_b = \dot{U}_B - \dot{U}_{00'} = \left(-0{,}5 - j\frac{\sqrt{3}}{R}\right)\dot{U}_A - (-0{,}102 + j0{,}06)\dot{U}_A =$$

$(-0{,}398 - j0{,}927)U_A = 1{,}01\dot{U}_A e^{-113°14'}$

$$\dot{U}_c = \dot{U}_C - \dot{U}_{00'} = \left(-0{,}5 + j\frac{\sqrt{3}}{R}\right)\dot{U}_A - (-0{,}102 + j0{,}06)\dot{U}_A =$$

$(-0{,}398 - j0{,}807)U_A = 0{,}9\dot{U}_A e^{j116°15'}$

Fazadagi tok:

$$\dot{I}_a = \frac{\dot{U}_A}{Z_a} = \frac{\dot{U}_A}{R} = 1{,}104\frac{\dot{U}_A}{R}e^{-j3°07'} = (1{,}102 - j0{,}06)\frac{\dot{U}_A}{R}$$

$$\dot{I}_b = \frac{\dot{U}_b}{Z_b} = \frac{1{,}01\dot{U}_A e^{-j113°14'}}{j\frac{R}{2}} = 2{,}02\frac{\dot{U}_A}{R}e^{-203°14'} = (-1{,}853 + j0{,}794)\frac{\dot{U}_A}{R}$$

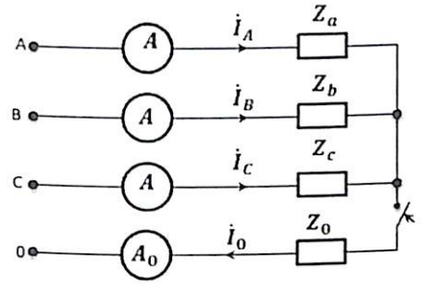
$$\dot{I}_C = \frac{\dot{U}_{00'}}{Z_c} = \frac{0{,}9\dot{U}_A e^{j116°15'}}{-j3R} = 0{,}3\frac{\dot{U}_A}{R}e^{j206°15'} = (-0{,}269 - j0{,}134)\frac{\dot{U}_A}{R}$$

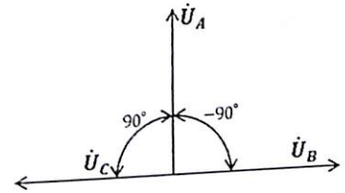
Neytral simdagi tok:

$$\dot{I}_0 = \frac{\dot{U}_{00'}}{Z_0} = \frac{0{,}118\dot{U}_A e^{j149°33'}}{0{,}1R} = 1{,}18\frac{\dot{U}_A}{R}e^{j149°33'} = (-1{,}02 + j0{,}6)\frac{\dot{U}_A}{R}$$

Neytral sim qarshiligini hisobga olganda tugun potensiallari orasidagi siljish hisobiga $\dot{U}_{00'}$ kuchlanish hosil bo'ladi.

6.20-Masala. Yulduzga sxemada ulangan uch fazali tok zanjir to'la qarshiliklari bir xil : tog'ri ketma-ketlikda $z_1 = 3 + j1om$, teskari ketma ketlikda $z_2 = 1 + j3om$ va nol ketma ketlikda esa $z_0 = j\,1\,om$ teng bo'lganda , nosimmetrik generatordagi kuchlanish fazalari bilan - $90^\circ, 180\ va\ 90^\circ$ farq qiluvchi $U_f = 120V$ ulangan. Simmetrik tashkil etuvchilar usuliga asosan ampermetirlargi tok qiymatlarini hisoblab toping.





Yechish: I- neytral simsiz : uch fazali nosimetrik tuzimlarni simetrik tashkil etuvchilarga yoyish usuliga asosan.

a) Nol ketma- ketlik bolganda $\dot{U}_{A0} = \dot{U}_{B0} = \dot{U}_{C0} = \frac{1}{3}(\dot{U}_A +$

$\dot{U}_B + \dot{U}_C) = \frac{1}{3}(\dot{U}_A - j\dot{U}_A + j\dot{U}_A) = \frac{1}{3}\dot{U}_A = \frac{120}{3} = 40V.$

b) To'g'ri ketma-ketlik uchun :

$$\dot{U}_{A_1} = \frac{1}{3}(\dot{U}_A + a\dot{U}_B + a^2\dot{U}_c) = \frac{1}{3}U_A(1 + ja - ja^2) =$$

$$= \frac{1}{3}U_A\left(1 - \frac{1}{2} + j\frac{\sqrt{3}}{2} + \frac{1}{2} + j\frac{\sqrt{3}}{2}\right) = \frac{1}{3}U_A = \left(1 + \sqrt{3}\right) \approx 110V.$$

$$\dot{U}_{B_1} = \dot{U}_{A_1}a^2 = \dot{U}_{A_1}e^{-j120°} = 110(-\frac{1}{2} - j\frac{\sqrt{3}}{2}) \approx (-55 - j95)V$$

$$\dot{U}_{C_1} = \dot{U}_{A_1}a = \dot{U}_{A_1}e^{j120°} = 110(-\frac{1}{2} + j\frac{\sqrt{3}}{2}) \approx (-55 + j95)V$$

v) Teskari ketma–ketlik bo'lganida :

$$\dot{U}_{A_2} = \frac{1}{3}(\dot{U}_A + a^2\dot{U}_B + a\dot{U}_C) = \frac{1}{3}\dot{U}_A(1 - ja^2 + ja) =$$

$$= \frac{1}{3}\dot{U}_A\left(1 - \sqrt{3}\right) = \frac{120}{3}\left(1 - \sqrt{3}\right) \approx -29V$$

$$\dot{U}_{B_2} = \dot{U}_{A_2}a = -29(-\frac{1}{2} + j\frac{\sqrt{3}}{2}) \approx (14{,}5 - j25)V$$

$$\dot{U}_{c_2} = \dot{U}_{A_2}a^2 = -29\left(-\frac{1}{2} - j\frac{\sqrt{3}}{2}\right) = (14{,}5 + j25)V$$

Istemolchi qarshiliklari to'g'ri va teskari ketma-ketliklari uchun bir hil bo'lgani sababli manbaning faza kuchlanishlari istemolchilardagi

kuchlanishka teng va neytral $00'$ nuqtalarda patensiat kuchlanish ham faza kuchlanishka teng bo'ladi:

$\dot{U}_{00'} = U_{A_0} = 40V$ neytral sim bo'lmaganligi uchun nol ketma-ketlik toki $\dot{I}_0 = 0$. Endi faza toklarini topamiz:

a) to'g'ri ketma-ketlik faza toki :

$$\dot{I}_{A_1} = \frac{\dot{U}_{A_1}}{Z_1} = \frac{110}{3+j1} = (33 - j11)A$$

$$\dot{I}_{B_1} = \frac{\dot{U}_{B_1}}{z_1} = \frac{-55-j95}{3+j1} = (-26 - j23)A$$

$$\dot{I}_{C_1} = \frac{\dot{U}_{C_1}}{z_1} = \frac{-55+j95}{3+j1} = (-7 + j34)A$$

Tekshirish: $\dot{I}_{A_1} + \dot{I}_{B_1} + \dot{I}_{C_1} = 33 - j11 - 26 - j23 - 7 + j34 = 0$

b) teskari ketma-ketlik bo'lganida :

$$\dot{I}_{A_2} = \frac{\dot{U}_{A_2}}{Z_2} = \frac{-29}{1+j3} = (-2{,}9 + j8{,}7)A$$

$$\dot{I}_{B_2} = \frac{\dot{U}_{B_2}}{Z_2} = \frac{14{,}5-j25}{1+j3} = (-6{,}05 - j6{,}85)A$$

$$\dot{I}_{C_2} = \frac{\dot{U}_{C_2}}{Z_2} = \frac{14{,}5+j25}{1+j3} = (8{,}95 - j1{,}85)A$$

Tekshirish: $\dot{I}_{A_2} + \dot{I}_{B_2} + \dot{I}_{C_2} = -2{,}9 + j8{,}7 - 6{,}05 - j6{,}85 + 8{,}95 - j1{,}85 = 0$

Demak faza toklari haqiqiy qiymatlari :

$\dot{I}_A = \dot{I}_{A_1} + \dot{I}_{A_2} = 33 - j11 - 2{,}9 + j8{,}7 = (30{,}1 - j2{,}3)A$

$\dot{I}_B = \dot{I}_{B_1} + \dot{I}_{B_2} = -26 - j23 - 6{,}05 - j6{,}85 = (-32{,}05 - j29{,}85)A$

$\dot{I}_c = \dot{I}_{C_1} + \dot{I}_{C_2} = -7 + j34 + 8{,}95 - j1{,}85 = (1{,}95 + j32{,}15)A$

Ampermetirlar ko'rsatish qiymatlari esa:

$I_A = \sqrt{30,1^2 + 2,3^2} = 30{,}2A$; $I_B = \sqrt{32,05^2 + 29,85^2} = 43{,}8A$;

$I_c = \sqrt{1{,}95^2 + 32{,}15^2} = 32{,}2A$

Endi neytral sim ulangan holdagi ampermetirlardagi tok qiymatlarni aniqlaymiz. Bu holda neytral simdan nol ketma-ket tok oqib otadi, yani:

$$\dot{I}_0 = \frac{\dot{U}_{A_0}}{Z_0} = \frac{40}{j1} = -j40A$$

Bunda umumiy faza toklari esa :

$\dot{I}_A = \dot{I}_{A_1} + \dot{I}_{A_2} + \dot{I}_0 = 30{,}1 - 2{,}3 - j40 = (30{,}1 - j42{,}3)A$

$\dot{I}_B = \dot{I}_{B_1} + \dot{I}_{B_2} + \dot{I}_0 = -32{,}05 - j29{,}85 - j40 = (-32{,}05 - j69{,}85)A$

$\dot{I}_c = \dot{I}_{C_1} + \dot{I}_{C_2} + \dot{I}_0 = 1{,}95 + j32{,}15 - j40 = (1{,}95 - j7{,}85)A$

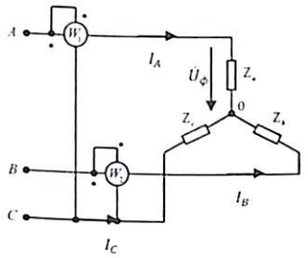
Demak ampermetorlar ko'rsatadigan faza toklari :

$I_A = \sqrt{30,1^2 + 42,3^2} = 52A$: $I_B = \sqrt{32{,}05 + 69{,}85^2} = 75{,}9A$

$I_c = \sqrt{1{,}95^2 + 7{,}85^2} = 8{,}09A$

6.3. Mustaqil yechish uchun masalalar

6.1-Masala. Yulduzcha shaklida ulangan uch fazali elektr zanjirning fazadagi kuchlanishi $U_\phi = 127\,V$ bo'lib, kompleks qarshiligi $Z_a = Z_\phi = 10 + j10$ bo'lgan simmetrik iste'molchiga ulangan. Sxemada ko'rsatilgan ulanish bo'yicha vattmetr qiymati va uch fazali tok quvvati aniqlanib, vektor ifodasi tuzilsin.



Javob: $P_1 = 805{,}8\,Vt$; $P_2 = 805{,}8\,Vt$.

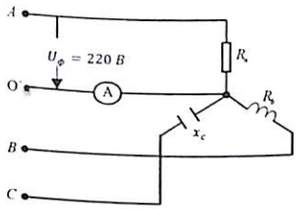
6.2-Masala. Yulduzcha sxemada ulangan uch fazali zanjir aktiv qarshiliklari: $R_a = R_b = R_c = 10\,om$ bo'lib, $U_L = 380\,V$ ulangan. B-fazasi uzilgan yoki qisqa tutashtirilgan holatlar uchun faza toklari va kuchlanishlari topilsin.

Javob: a) B –faza uzilganda: $I_F = 19\,A$, $U_F = 190\,V$

b) qisqa tutashtirilganda: $I_F = 38\,A$, $U_F = 380\,V$

6.3-Masala. To'rt simli yulduzcha shaklda ulangan uch fazali elektr zanjirning faza kuchlanishi $U_l = 220\,V$, iste'mol-chi, qarshiliklari $R_a = x_{Lb} = x_c = 100\,Om$ .Ampermetr tokini toping.

Javob: $I_0 = 1{,}6\,A$.

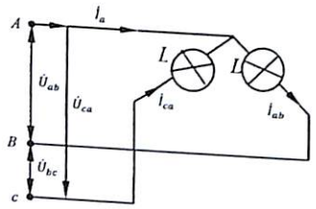


6.4-Masala. Liniyadagi kuchlanish $U_L = 220\,V$ bo'lgan neytral simsiz yulduzcha shaklida ulangan uch fazali elektr zanjirning iste'molchi qarshiligi $R_a = 40\,Om$; $R_b = 50\,Om$; $R_c = 20\,Om$. Aktiv quvvati $P_a =$

$40\ Vt$; $P_b = 100\ Vt$; $P_c = 60\ Vt$. Fazadagi tok va kuchlanishi aniqlanib, vektor ifodasi tuzilsin.

Javob: $I_a = 1\ A$; $\dot{I}_b = 1.41\ A$; $I_c = 1.73\ A$. $U'_a = 40\ V$; $U'_b = 70.5\ V$; $U'_c = 34.6\ V$.

6.5-Masala. Berilgan sxemada A va B fazaga $P = 40\ Vt$ bo'lgan 21 dona lampa, C va A fazaga $P = 60\ Vt$ 10 dona lampa ulangan bo'lib, liniya kuchlanishi $U_L = 120\ V$. liniyadagi va fazadagi tok aniqlanib, vektor ifodasi tuzilsin.



Javob:
$\dot{I}_{ab} = 7\ A; I_{bc} = 5A$; $I_A = I_L = 2\ A$.

6.6-Masala. Induktivligi $L_1 = L_2 = L_3 = 126\ mGn$ bo'lgan uch fazali asinxron dvigatel chasto-tasi $f = 50\ Gs$, faza kuchlanishi $U_A = 120\ V$ simmetrik generatorga ulangan. Fazadagi tok to'la quv-vati aniqlansin.

Javob: $I_\varphi = 3\ A$; $P = 0$;
$S = Q = 1076\ VA$.

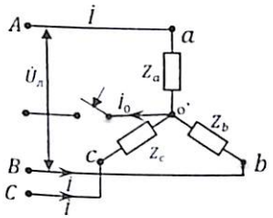
6.7-Masala. Uchburchak shaklida biriktirilgan elektr zanjir iste'molchi qarshiligi $X_L = 22\ Om$ bo'lib $\dot{U}_A = 220e^{j45°}$kuchlanishga ulangan. Faza va liniyadagi tok aniqlanib, kompleks topografik diagrammasi tuzilsin.

Javob: $I_\Phi = 10e^{-j45}$; $I_L = 17{,}3\ e^{-j45}$.

6.8-Masala. Simmetrik yulduzcha shaklida ulangan uch fazali zanjir parametirlari : E=127V generator ichki qarshiligi $z_0 = (0{,}3 + j0{,}9)$ om liniya qarshiligi $z_L = (0{,}5 + j1)\ om$ faza qarshiligi $z_\varphi = (10 + j16)om$ teng: faza va liniya toklari va kuchlanishlari , sarf boladigan aktiv quvvat va F.I.K topilsin

Javob: $I_A 9{,}5e^{-36°10'}$; $\dot{U}_{A0} = 119{,}7e^{-2°30'}$; $\dot{U}_L = 192e^{j250°}$
$P_{gen} = 2920Vt$; $P_{ist} = 2710$, η=93%.

6.9-Masala. Yulduzcha shaklida birlashtirilgan 4 ta simli uch fazali elektr zanjir iste'molchi kompleks qarshiliklari: $Z_a = (40 + j30)\ Om$; $Z_b = 50\ Om, Z_c = (25 - j25)Om$ ga teng bo'lib, $\dot{U} = 380\ V$ liniya kuchlanishi ulangan. Kalit ulangan yoki uzilgan holatlar uchun liniya va neytral simdagi tok hamda neytral nuqtalar orasidagi $\dot{U}_{00'}$ kuchlanish aniqlanib, vektor ifodasi tuzilsin.



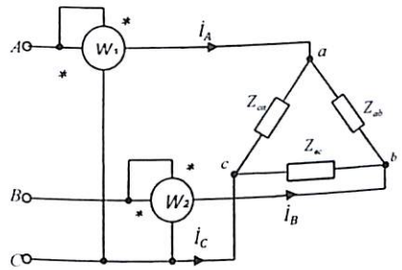
Javob: a) kalit ulanganda:
$\dot{I}_a = 3{,}52 - j2{,}64\ A$; $\dot{I}_b = -2{,}2 - j3{,}78\ A$;
$\dot{I}_c = -2{,}75 - j0{,}56\ A$,
$\dot{I}_0 = \dot{I}_a + \dot{I}_b + \dot{I}_c = -2{,}71 - j0{,}56$
$\dot{U}_{00'} = 0$

b) kalit uzilganda: $\dot{U}_{00'} = -35 - j175B, \dot{I}_a = 6{,}18 - j0{,}26\ A$,
$\dot{I}_a = 1{,}5 - j0{,}3\ A$; $\dot{I}_a = 4{,}68 - j0{,}56\ A$

6.10-Masala. Yulduzcha sxemada ulangan uch fazali elektr zanjirga parametri $R = 7\ Om$, $X_L = 24\ Om$ bo'lgan uchta bir xil g'altak ulan-gan (6.8-masala). Liniya kuchlanishi $U_n = 220V$. OA fazasidagi g'altak qisqa tutashganda tok qiymati aniqlanib, vektor ifodasi chizilsin.

Javob: $\dot{I}_A = 15A$, $\dot{I}_B = \dot{I}_C = 8{,}8A$.

6.11-Masala. Uchburchak shaklda ulangan uch fazali elektr zanjir iste'molchilari: $Z_{ab} = 20 + j20\ Om$; $Z_{bc} = 50\ Om$, $Z_{ca} = -j40\ Om$ teng bo'lib, $U_L = 200\ V$ liniya kuchlanishiga ulangan. Liniyadagi tok va iste'molchilarda sarf bo'ladigan elektr quvvatni aniqlang.

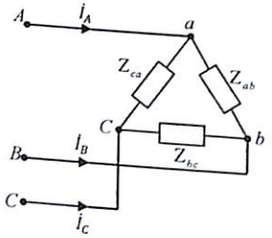


Javob: $\dot{I}_a = 9{,}33 - j2{,}5\ A$, $\dot{I}_b = -7 + j1{,}54\ A$;
$\dot{I}_c = -2{,}33 + j0{,}96\ A$;
$P = P_1 + P_2 = 1366 + 434 = 1800\ Vt$.

6.12-Masala. Yulduzcha shaklda ulangan uchta simli uch fazali elektr zanjirning liniyadagi kuchlanishi $380V$, iste'molchi qarshiligi $R_a = X_b = 10\ Om$, $X_C = -10\ Om$ bo'lganda, fazadagi tok aniqlanib, tok va kuchlanish topografik vektor diagrammasi tuzilsin.

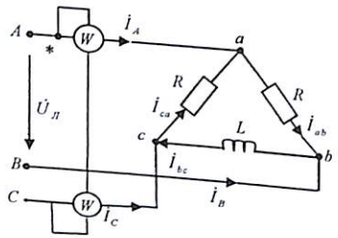
Javob: $\dot{I}_a = 16A,\ \dot{I}_b = 16e^{-210^\circ}A,\ \dot{I}_c = 16e^{j210^\circ}A.$

6.13-Masala. a) uchburchak shaklda ulangan simmetrik uch fazali elektr zanjir faza qarshiligi: $Z_{ab} = Z_{bc} = Z_{ca} = -j\frac{1}{\omega c}$ bo'lib, $\dot{I}_{ca} = 8\ A$ ga teng. ZZ_{bc} faza uzilgan holatda liniyadagi tok $\dot{I}_A$, I_B va fazadagi $\dot{I}_{ca}$ tokni aniqlang. b) C liniya simi uzilgan holatda. $\dot{I}_B$ liniyadagi tok va $\dot{I}_{ca}$ fazadagi tokni aniqlang:



Javob: a) $\dot{I}_A = 8\ A,$
$\dot{I}_Л = 13{,}8\ A,\ \dot{I}_{ca} = 13{,}8\ A.$
$b)\ \dot{I}_B = 12\ A,\quad \dot{I}_{ca} = 4\ A$

6.14-Masala. Uchburchak shaklda ulangan uch fazali tok parametri: $R_{ab} = x_{ca} = x_{bc} = 10\ Om$ bo'lib, simmetrik $\dot{U}_Л = 220\sqrt{3}\ V$ kuchlanishga ulangan. Vitmetr quvvati va umummiy quvvat qiymati topilsin.

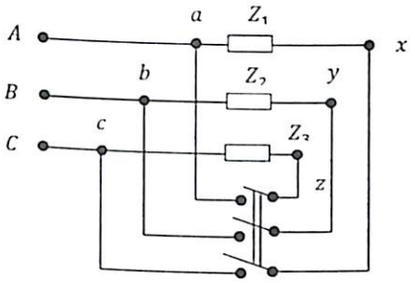


Javob: $P_1 = 1{,}654\ kVT;$
$P_2 = 1{,}9\ kVT;\ P_{um} = 3{,}55\ kVT.$

6.15-Masala. Simmetrik yulduzcha shaklida ulangan uch fazali zanjir parametirlari : E=127 V, generator ichki qarshiligi $z_0 = (0{,}3 + j0{,}9)$ Om liniya qarshiligi $z_L = (0{,}5 + j1)\ om$ faza qarshiligi $z_\varphi = (10 + j16)Om$ teng: faza va liniya toklari va kuchlanishlari , sarf boladigan aktiv quvvat va F.I.K topilsin

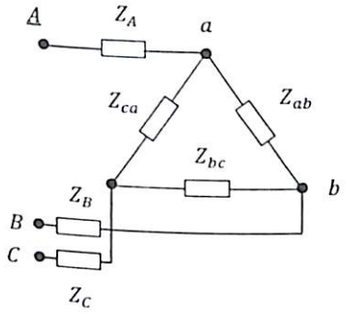
Javob: $I_A = 9{,}5e^{-36°10'};\quad \dot{U}_{A0} = 119{,}7e^{-2°30'};\quad \dot{U}_L = 192e^{j250^\circ}$
$P_{gen} = 2920Vt;\quad P_{ist} = 2710\ V,\ \eta$=93%.

6.16-Masala. 152 betdagi 6-3 masala shartiga asosan zanjir uchburchak sxemaga ulansa tok va kuchlanishlar qanday o'zgaradi?



Javob: $I_L = 19{,}3\ A\quad P = 7260\ Wt$

6.17-Masala. To'la qarshiliklari: $Z_{ab} = 1\ om,\ Z_{ca} = Z_{bc} = 2\ om$ uchburchak shaklda ulangan bo'lib, liniya simlar qarshiliklari: $Z_a = Z_b = Z_c = 0{,}1\ om$ bo'lib, zanjir $U_F = 120\ V$ ga ulangan. Faza va liniya toklari topilsin.



Javob:
$\dot{I}_A = 219 + j36\ A,$
$\dot{I}_B = -141 - j172\ A,$
$\dot{I}_C = -78 + j136\ A,$
$\dot{I}_{AB} = 144 + j83{,}2\ A,$
$\dot{I}_{BC} = 3 - j88{,}8\ A,$
$\dot{I}_{CA} = -75 + j47{,}2\ A$

Nazorat savollari

1. Uch fazali sinusoidal o‘zgaruvchan tok deb nimaga aytiladi?
2. Uch fazali tok sistemalarining bir fazali sinusoidal o‘zgaruvchan tokga nisbatan qanday afzalliklari bor?
3. Uch fazali tok qanday hosil qilinadi va manbai nima? Sinxron generatorning tuzilishi va ishlash prinsipini bilasizmi?
4. Uch fazali generator statoriga joylashtirilgan chulg‘am o‘qlari qanday burchakda joylashtiriladi va qutblar soni nimaga teng?
5. Uch fazali tok chastotasi $f = 50\ Gs$, qutblar soni $p = 6$ ga teng bo‘lganda, magnit maydon aylanish tezligi n_0 nimaga teng?
6. Uch fazali tok grafigi va vektor ifodasini chizing. Analitik, kompleks ifodalarni yozing.
7. Uch fazali tok sistemalarining ulanish sxemalarini bilasizmi?
8. Ulanish sxemalariga qarab liniya, fazalardagi kuchlanish va tokning nisbiy bog‘lanish tenglamasini yozing.
9. Agar yulduzcha shaklida ulangan iste’molchining simmetrik fazalari uchburchak shaklida ulansa, liniya va fazadagi tok qanday o‘zgaradi?
10. 4 simli, uch fazali elektr zanjirda neytral simning vazifasi nimadan iborat?
11. Uch fazali tok sistemasi qaysi holatlarda nosimmetrik bo‘ladi?
12. Uch fazali tokda aktiv, reaktiv va to‘la quvvat ifodalarini yozing.
13. Uch fazali simmetrik va nosimmetrik elektr zanjirlarda aktiv quvvat o‘lchash sxemasini chizing.
14. Neytral simli yulduzcha shaklda ulangan uch fazali tok iste’molchi qarshiliklari, aktiv, induktiv va sig‘imdan iborat bo‘lgan holat uchun vektor ifodasini tuzing.
15. Neytral simsiz yulduzcha shaklda ulangan elektr zanjirning faza simi uzilgan yoki qisqa tutashtirilgan holatda liniya va fazada tok qanday o‘zgaradi?
16. Uch fazali tok vektorlarini operator «a» orqali «to‘g‘ri» va «teskari» ketma-ketlik ifodalanish tenglamasini yozing. Fazalar ketma-ketligini izohlab bering.
17. Nosimmetrik uch fazali elektr zanjirlarni simmetrik tashkil etuvchilarga ajratib hisoblash usulini izohlab bering. «To‘g‘ri», «teskari» va «nol» ketma-ketliklar bir-biridan qanday farq qiladi?

18. Nima uchun simmetrik tashkil etuvchilarga ajratib hisoblash usuli faqatgina chiziqli elektr zanjirni hisoblashda ishlatiladi?
19. Uch fazali tok hosil qiluvchi fazaviy aylanuvchi magnit maydon hosil bo‘lishini tushuntirib bering.
20. Uch fazali tok asinxron dvigatelining tuzilishi va ishlash prinsipini bilasizmi?
21. Yulduzcha shaklda biriktirilgan uch fazali tok iste’molchilarda qaysi holatda neytral nuqtali siljish yuzaga keladi va aksincha?
22. Simmetrik uch fazada tok aktiv quvvatini ikkita vattmetr yordamida o‘lchanganda, tok bilan kuchlanish orasida burchakning qanday qiymatida bir xilda ko‘rsatadi?
23. Neytral simsiz yulduzcha shaklda ulangan uch fazali elektr zanjir neytral tugun orasidagi $U_{00'}$ kuchlanish qanday ifodalanadi.
24. Quvvat koeffitsienti 0.8, umumiy quvvat $5.4\ kVt$ bo‘lgan elektro-dvigatel $220\ V$ kuchlanishga ulangan bo‘lsa, tok qiymati qancha bo‘ladi?
25. Neytral simli yulduzcha shaklida ulangan zanjir faza kuchlanishi $U_\Phi = 220V$ bo‘lib, har bir fazaga $150\ Vt$ li 90 ta lampochka ulangan. Liniyadagi tok va sarf bo‘ladigan quvvatni aniqlang.

7. NOSINUSOIDAL ELEKTR ZANJIR

7.1. Asosiy nazariy tushunchalar

1. Davriy o‘zgaruvchan funksiyalarni garmonik (Furye) qatorga yoyish.

Matematika kursidan ma’lumki, Dirixle shartini qanoatlantiruvchi har qanday uzluksiz davriy funksiya $f(t)$ ni Furye qatoriga yoyish mumkin:

$f(t) = A_0 + A_1 \sin(\omega t + \varphi_1) + A_2 \sin(2\omega t + \varphi_2) + \ldots + A_k \sin(k\omega t + \varphi_k)$

A_0 – o‘zgarmas tashkil etuvchi.

$A_1 \sin(\omega t + \varphi_1)$– asosiy yoki birinchi garmonika.

$A_k \sin(k\omega t + \varphi_k)$ – «k» tartibli yuqori garmonika.

A_k va φ_k – yuqori garmonika amplituda va boshlang‘ich fazasi.

Amalda elektrotexnika, elektronika, elektromagnit zanjirda uchraydigan nosinusoidal signallar miqdori (funksiyalar) Dirixle shartini qanoatlantiradi.

Furye qatorining koeffitsientini aniqlash uchun $f(t)$ funksiyani quyidagicha yozamiz:

$$f(\omega t) = A_0 + B_1 \sin \omega t + B_1 \sin 2\omega t + \ldots + B_k \sin \omega t + \ldots + C_1 \cos \omega t + C_2 \cos 2\omega t + \ldots C_k \cos k\omega t$$

Bu shartning koeffitsientini analitik, grafik usulda hisoblash bilan yoki elektrotexnik o‘lchov asboblari yordamida aniqlanadi.

Analitik usulda quyidagi ifodadan foydalaniladi:

$$A_0 = \frac{1}{T}\int_0^T f(\alpha)d\alpha \qquad B_k = \frac{1}{T}\int_0^T f(\alpha)\,\text{sink}\,\alpha\, d\alpha$$

$$C_k = \frac{1}{T}\int_0^T f(\alpha)\,\text{cosk}\,\alpha\, d\alpha$$

Ushbu koeffitsientning qiymatini aniqlagach, «k» yuqori garmonika amplitudasi va fazasini aniqlash mumkin:

$A_k = \sqrt{B_k^2 + C_k^2}$; $\quad tg\varphi_k = \frac{C_k}{B_k}$; $\quad \varphi_k = arctg\frac{B_k}{C_k}$;

yoki: $B_k = A_k \cos\varphi_k \quad C_k = A_k \sin\varphi_k$.

Agar davriy o‘zgaruvchan nosinusoidal funksiya grafik ko‘rinishda berilgan bo‘lsa, koeffitsientni aniqlashda grafik usuldan (Chebishev usuli) foydalaniladi.

2. Nosinusoidal elektr zanjirni hisoblash.

Chiziqli nosinusoidal elektr zanjirlarni hisoblashda ustma-ustlik (superpozitsiya) usuli tatbiq etilib, har bir garmonikaning zanjir parametriga ta’siri alohida aniqlanadi va ularning oniy qiymatlari yig‘indisi belgilanadi. Masalan, kuchlanish ifodasi:

$u = u_0 + u_1 + u_2 + \cdots + u_k$ bunda: $u_k = U_{km}\sin(k\omega t + \varphi_k)$

tok: $i = I_0 + i_1 + i_2 + \cdots + i_k$ $i_k = I_{km}\sin(k\omega t + \varphi_{ik} - \varphi_{uk})$ Ketma-ket ulangan oddiy R, L, C zanjir uchun «k» garmonika tok amplitudasi:

$$I_{km} = \frac{U_{km}}{\sqrt{R^2 - (k\omega L - \frac{1}{k\omega C})^2}}$$

«k» garmonika faza burchagi:

$$tg\varphi_k = \frac{k\omega L - \frac{1}{k\omega C}}{R}$$

Murakkab nosinusoidal elektr tok zanjirni hisoblashda mavjud bo‘lgan elektr zanjirni hisoblash usullari (kompleks usuldan tashqari) tatbiq etilib, har bir garmonika qiymati alohida hisoblanib topiladi. Shuni takidlash kerak: k yuqori garmonika induktiv qarshiligi «k» martaga katta ($X_L = k\omega L$), sig‘im qarshiligi «k» marta kamayadi ($X_C = 1/k\omega C$). Aktiv qarshilik chastotaga bog‘liq emas va o‘zgarmas bo‘ladi (Zanjir chastotasi juda ham yuqori bo‘lganda inobatga olinadi).

3. Nosinusoidal tok, kuchlanish va quvvatning haqiqiy yoki effektiv qiymati.

Nosinusoidal funksiya f(ωt) effektiv qiymati:

$$A = \sqrt{\frac{1}{T}\int_0^T f^2(\omega t)dt}$$

Tokning effektiv qiymati: $I = \sqrt{I_0^2 + I_1^2 + I_2^2 + \cdots + I_k^2}$

Kuchlanish effektiv qiymati: $U = \sqrt{U_0^2 + U_1^2 + U_2^2 + \cdots + U_k^2}$

EYK effektiv qiymati: $E = \sqrt{E_0^2 + E_1^2 + E_2^2 + \cdots + E_k^2}$

Nosinusoidal tok quvvati har bir yuqori garmonika uchun aniqlangan o‘rtacha quvvatlar yig‘indisiga teng. Nosinusoidal tok aktiv quvvati (o‘rtacha quvvat).

$P = P_0 + P_1 + \ldots\ldots + P_k = U_0I_0 + U_1I_1\cos\varphi_1 + U_2I_2\cos\varphi_2 + \ldots\ldots + U_kI_k\cos\varphi_k$

Reaktiv quvvat:

$Q = Q_1 + Q_2 + ... + Q_k = U_1 I_1 \sin\varphi_1 + U_2 I_2 \sin\varphi_2 + ... + U_k I_k \sin\varphi_k$

To‘la quvvat:

$S = UI = S_0 + S_1 + S_2 + ... + S_k$

Nosinusoidal tok aktiv quvvatning to‘la quvvatga nisbati quvvat koeffitsienti deyiladi:

$$\alpha = \frac{P}{S} = \frac{P_0 + P_1 + P_2 + \cdots P_k}{\sqrt{U_0^2 + U_1^2 + U_2^2 + \cdots + U_k^2} \cdot \sqrt{I_0^2 + I_1^2 + I_2^2 + \cdots + I_k^2}} = \frac{\sum_{k=0}^{n} P_k}{\sqrt{U_k^2} \cdot \sqrt{I_k^2}}$$

Nosinusoidal funksiya formasini aniqlashda alohida garmonikalarga nisbatan koeffitsientlari: $k_a = \frac{E_m}{E}$ – amplituda koeffitsienti; $k_\Phi = \frac{E_m}{E_{o‘rt}}$ – forma koeffitsienti. $k_i = \frac{E_1}{E}$ – siljish koeffitsienti; $k_g = \frac{E_k}{E}$ – garmonik koeffitsient

Nosinusoidal elektr zanjirda quvvat koeffitsienti $a = \frac{P}{IU} < 1$.

4. O‘zgaruvchan tok kuchlanish formalarining zanjir parametrga bog‘liqligi.

Yuqori garmonika formasi silliqlanish yoki buzilish $\frac{A_k}{A_1}$ nisbati bilan xarakterlanib, bu nisbat qancha katta bo‘lsa, shunchalik nosinusoidal funksiya sinusoidal formadan farqli bo‘ladi.

O‘zgaruvchan elektr zanjirga kiruvchi yuqori garmonikali nosinusoidal tok nisbatini quyidagi ko‘rinishda ifodalash mumkin:

$$\frac{I_{km}}{I_{1m}} = \frac{Z_1}{Z_k} \cdot \frac{U_{km}}{U_{1m}}$$

a) agar elektr tok zanjiri aktiv qarshilikga ega bo‘lsa: $Z_k = Z_1 = R$

$$\frac{I_{km}}{I_{1m}} = \frac{U_{km}}{U_{1m}}$$

tok va kuchlanish nosinusoidal formalari o‘xshash bo‘ladi.

b) agar elektr zanjir induktiv qarshilikga ega bo‘lsa:

$$Z_k = k\omega L; \quad Z_1 = \omega L;$$

Bunda:

$$\frac{I_{km}}{I_{1m}} \frac{1}{k} \frac{U_{km}}{U_{1m}}$$

Tok garmonikasi kuchlanish garmonikasi amplutudaga nisbatan past bo‘lib, induktivlik yuqori garmonikalarni **so‘ndiradi** va tok formasini **tekislaydi (silliqlaydi)**.

d) agar elektr zanjir sig‘im qarshiligiga ega bo‘lsa:

$$Z_k = 1 / k\omega C; \quad Z_1 = 1 / \omega C$$

Bunda:

$$\frac{I_{km}}{I_{1m}} = k \frac{U_{km}}{U_{1m}}$$

Tok garmonikalari kuchlanish garmonikalariga nisbatan katta bo‘lib, sig‘im tok garmonikalari **buziladi,** kuchlanish garmonikalari tekislanadi.

Reaktiv elementlarning bu xususiyati elektrotexnikada nosinusoidal formadagi tok va kuchlanishni filtrlash yoki **silliqlashda** keng foydalaniladi.

Reaktiv elementlardan tarkib topgan murakkab elektr zanjirning tarmoq yoki konturida ma’lum bir «k» garmonikali chastotada rezonans holat yuzaga kelishi mumkin.

5. Uch fazali elektr zanjirda yuqori garmonik tashkil etuvchilar.

Uch fazali elektr zanjir EYK va kuchlanishi nosinusoidal va bir xil formaga ega bo‘lganda yuqori garmonikalar fazalar ketma-ketligi hosil bo‘lib, 3n + 1, (butun son yoki nol) uch fazali tok sistemasida faza to‘g‘ri, ketma-ketligi (1, 7, 13... garmonikalar). 3n-1 bo‘lganda uch fazali tok sistemasida fazalar teskari ketma-ketligi (5, 11, 17... garmonikalar) va n=0 bo‘lganda «nol» fazalar ketma-ketligi (3, 9, 15...garmonikalar) ni hosil qiladi.

Uch fazali elektr zanjirda yuqori garmonikalarning bunday xususiyatlarini inobatga olgan holda:

a) generator chulg‘amlari uchburchak shaklda ulangan bo‘lsa:

$$I_\Delta = \sqrt{I_3^2 + I_9^2 + I_{15}^2 + \cdots}$$

Bunda: I_3, I_9, I_{15} yuqori 3, 9, 15 garmonikali tok bo‘lib, generator chulg‘amlari hosil qiluvchi konturdagi tok $I_3 = \frac{E_3}{z_3}$; $I_9 = \frac{E_9}{z_9}$ ga teng.

b) generator chulg‘amlari yulduzcha va uchburchak shaklda ulanganda, liniyadagi kuchlanish:

$$U_{JJ} = \sqrt{U_{J1}^2 + U_{J15}^2 + U_{J17}^2 + U_{J11}^2} < \sqrt{3} U_\phi$$

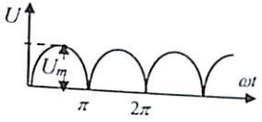
d) neytral simsiz simmetrik uch fazali tok sistemalarining EYK simmetrik bo‘lganda 0 va 0′ nuqta potensial kuchlanishi $U_{00'} \neq 0$ bo‘lib:

$$U_{00'} = \sqrt{E_3^2 + E_9^2 + E_{15}^2 + \cdots}$$

e) neytral simli iste’molchilar qarshiligi teng bo‘lganda ham: $I_0 \neq 0$ teng bo‘lmasdan: $I_0 = 3\sqrt{I_3^2 + I_9^2 + I_{15}^2}$ yuqori garmonika toklar hosil bo’ladi.

7.2. Masalalar yechish va uslubiy ko‘rsatmalar

7.1-Masala. Amplituda kuchlanishi $U_m = 100\ V$ bo‘lgan to‘g‘rilagich (viprya-mitel) hosil qiladigan $f = (\omega t)$ funksiyasini $U = 100\ V$ Furye qatoriga yoyish bilan o‘zgarmas, birinchi va ikkinchi yuqori garmonika tarkibi aniqlansin.



Yechish.

Kuchlanish funksiyasining ifodasi: $U_{\omega t}=U_m(sin\omega t)=100(sin\omega t)$

Furye qatoriga yoyishda berilgan nosinusoidal funksiyaning ordinata o‘qiga simmetrik ekanligini inobatga olamiz. Bunda kuchlanish o‘rtacha qiymati:

$$U_0=\frac{1}{T}\int_0^T U_m(sin\omega t)d\omega t=\frac{1}{\pi}\int_0^T U_m sin\omega t=\frac{2U_m}{\pi}$$

yoki $U_0=\frac{2\cdot100}{3{,}14}=63{,}6\ V$

Birinchi garmonika koeffitsienti:

$u_1=\frac{1}{\pi}\int_0^T U_m(sin\omega t)cos\omega t d\omega t=0$ – ya’ni, yarim davrdagi integrali nolga teng.

Ikkinchi garmonika koeffitsienti:

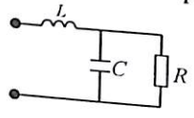
$u_2\frac{1}{\pi}\int_0^{2\pi} U_m(sin\omega t)cos2\omega t d\omega t=\frac{U_m}{\pi}\left[\int_0^{\pi} sin\omega t cos2\omega t d\omega t - \int_{\pi}^{2\pi} sin\omega t cos\omega t d\omega t\right]=\frac{U_m}{\pi}[(-\frac{1}{3}\cos 3\omega t+\cos\omega t)\Big|_0^{\pi}-(-[(-\frac{1}{3}\cos 3\omega t+\cos\omega t)\Big|_{\pi}^{2\pi}]=\frac{U_m}{\pi}\left[\left(\frac{1}{3}-\frac{1}{3}-1-1\right)-\left(-\frac{1}{3}-\frac{1}{3}+1+1\right)\right]=-\frac{4U_m}{3\pi}\ (V)$

yoki: $U_2=\frac{4\cdot100}{3\cdot3{,}14}=-42.4\ V$

Kuchlanish oniy qiymati:

$$u_{(\omega t)}=\frac{2U_m}{\pi}-\frac{4U_m}{3\pi}cos2\omega t=63{,}6-42{,}4cos2\omega t$$

7.2-Masala. Sxemada keltirilgan elektr zanjirlar parametri: $L=0{,}5\ Gn, C=4\ mkf,\ R=300\ Om$ ga teng, hamda chastotasi $f=100Gs$ bo‘lib, $u=100\ sin^3\omega t$ nosinusoidal kuchlanishga ulangan. Tarmoq toklari oniy qiymati aniqlanib, buzilish koeffitsienti aniqlansin.



Yechish. Kuchlanish ifodasini Furye qatoriga yoyamiz:

$sin^3\omega t=sin\omega t\cdot\frac{1-cos2\omega t}{2}=\frac{1}{2}(sin\omega t-sin\omega t\ cos2\omega t)=\frac{3}{4}sin\omega t-\frac{1}{4}sin3\omega t$

Bunda zanjir kuchlanishining oniy qiymati:

$$u=75sin\omega t-25sin3\omega t=75sin\omega t+25sin(3\omega t+\pi)$$

Birinchi garmonika uchun zanjir qarshiligi:

$\underline{Z}_{L_1}=j\omega L_1=j628\cdot0{,}05=j3{,}14\ Om;\ \underline{Z}_{C_1}=\frac{1}{j\omega C}=-j398\ Om$

Bunda: $\omega=2\pi f=628\ \frac{1}{sek}$

Zanjirning kompleks to‘la qarshiligi:

$$\underline{Z}_1=\underline{Z}_{L_1}+\frac{R\cdot\underline{Z}_{C_1}}{R+\underline{Z}_{C_1}}=j31{,}4+\frac{300(-j398)}{300-j398}=192-j112{,}6=220e^{-j30^\circ}$$

Tarmoqdagi tok kompleks ifodasi:

$\dot{I}_{L_1}=\frac{75}{\sqrt{2}\cdot220e^{-j30^\circ}}=0{,}24e^{j30^\circ};\ \dot{I}_{C_1}=\frac{\dot{I}_{L_1}R}{R+\underline{Z}_{C_1}}=\frac{0{,}24e^{j30^\circ}\cdot300}{300-j398}=0{,}145e^{j83^\circ}$

$\dot{I}_{R_1}=\frac{\dot{I}_{L_1}\underline{Z}_{C_1}}{R+\underline{Z}_{C_1}}=\frac{0{,}24e^{j30^\circ}\cdot300e^{-j90^\circ}}{300+j398}=0{,}19e^{-j6^\circ40'}$

Tokning oniy qiymati:

$$i_{L_1}=0{,}24\sqrt{2}\sin(\omega t+30^\circ)\ (A)$$
$$i_{C_1}=0{,}145\sqrt{2}\sin(\omega t+83^\circ20')\ (A)$$
$$i_{R_1}=0{,}19\sqrt{2}\sin(\omega t-6^\circ40')\ (A)$$

Uchinchi yuqori garmonika uchun reaktiv qarshilik:

$$\underline{Z}_{L_3}=j3\omega L=j94\ Om\ \ \underline{Z}_{C_3}=-j\frac{10^6}{3\cdot628\cdot4}=-j133\ Om$$

To‘la kompleks qarshilik:

$$\underline{Z}_3=\underline{Z}_{L_3}+\frac{R\cdot\underline{Z}_{C_3}}{R+\underline{Z}_{C_3}}=j94+\frac{300(-j133)}{300-j133}=49{,}6e^{-19^\circ}$$

Uchinchi garmonika tarmoqdagi tok kompleks ifodasi:

$\dot{I}_{L_3}=\frac{25e^{j180^\circ}}{\sqrt{2}\cdot49{,}6e^{-j19^\circ}}=0{,}36e^{j19^\circ}\ \dot{I}_{C_3}=\frac{0{,}356e^{j199^\circ}}{300-j179}=0{,}325e^{j233^\circ}$

$$\dot{I}_{R_3}=\frac{0{,}356e^{j199^\circ}}{300-j179}=0{,}144e^{j133^\circ}$$

Tokning oniy qiymati:

$$i_{L_3}=0{,}356\sqrt{2}sin(3\omega t+19^\circ)\ (A)$$
$$i_{C_3}=0{,}325\sqrt{2}sin(3\omega t+223^\circ)\ (A)$$
$$i_{R_3}=0{,}144\sqrt{2}sin(3\omega t+133^\circ)\ (A)$$

Tarmoqdagi tokning effektiv qiymati:

$I_L=\sqrt{I_{L_1}^2+I_{L_3}^2}=\sqrt{0{,}24^2+0{,}356^2}=0{,}43\ A\ \ I_C=\sqrt{I_{C_1}^2+I_{C_3}^2}=0{,}373\ A$

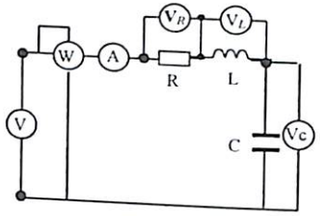
$$I_R=\sqrt{I_{R_1}+I_{R_3}}=0,24\ A$$

Buzilish koeffitsienti:

$$k_L=\frac{I_{L_1}}{I_{L_3}}=0,83\quad k_C=\frac{I_{C_1}}{I_{C_3}}=0,87\quad k_R=\frac{I_{R_1}}{I_{R_3}}=0,33$$

Demak, sig'imdan o'tuvchi tok formasi ko'proq buzilar ekan.

7.3-Masala. Ketma-ket sxemada ulangan elektr zanjir parametri: *R=3 Om, L=636mGn, C=31,8 mkf* bo'lib, 1, 3, 5 yuqori garmonikalardan tarkib topgan nosinusoidal kuchlanish nisbatlari $\frac{U_5}{U_1}=0,2$, $\frac{U_3}{U_1}=0,3$ ga teng. Sxemaga ulangan voltmetr ko'rsatish qiymati *U=128 V*. Barcha elektr o'lchov asboblarining ko'rsatish qiymati aniqlansin.



Yechish.

Elektrodinamik o'lchov asbob tok va kuchlanish effektiv qiymatini ko'rsatadi: $U=\sqrt{U_1^2+U_3^2+U_5^2}=U_1\sqrt{1^2+0,3^2+0,2^2}=U_1\cdot 1,06$

Bundan: $U_1=\frac{128}{1,06}=120\ V$; $U_3=0,3\cdot 120=36,6\ V$; $U_5=0,2\cdot 120=24\ V$

Birinchi garmonikaga nisbatan zanjir reaktiv qarshiligini aniqlaymiz:

$\omega=2\pi 500=3140\ \frac{1}{sek}$ $\quad X_{L_1}=\omega_1 L=3140\cdot 0,636\cdot 10^{-3}=2\ Om$

$X_{C_1}=\frac{1}{\omega_1 C}=\frac{10^6}{3140\cdot 31,8}=10\ Om$ $\quad X_1=X_{L_1}-X_{C_1}=2-10=-8\ Om$

Umumiy qarshiligi: $Z_1=\sqrt{R^2+X_1^2}=\sqrt{9+64}=8,5\ Om$

Yuqori uchini garmonika uchun:

$$X_3=3\omega_1 L-\frac{1}{3\omega_1 C}=3\cdot 2-\frac{10}{2}=2,7\ Om$$

To'la qarshilik: $Z_3=\sqrt{R^2+X_3^2}=4\ Om$

Beshinchi yuqori garmonika uchun:

$$X_5=5\omega_1 L-\frac{1}{5\omega_1 C}=10-2=8\ Om$$

To'la qarshilik: $Z_5=\sqrt{R+X_5}=8,5\ Om$

Har bir garmonika tok effektiv qiymati:

$$I_1=\frac{U_1}{Z_1}=14\ A\ ;\ I_3=\frac{U_3}{Z_3}=9\ A\ ;\ I_5=\frac{U_5}{Z_5}=2,8\ A$$

yoki $I=\sqrt{I_1^2+I_3^2+I_5^2}=17\ A$

Vattmetr ko'rsatgan quvvat: $P=RI^2=3\cdot 17^2=867\ Vt$

Induktivlik va sig'im qarshiliklarida har bir yuqori garmonikalar hosil qiladigan kuchlanishlar qiymati :

$U_{L_1}=\omega_1 L I_1=14\cdot 2=28\ V$; $\quad U_{L_3}=3\omega_1 L I_3=9\cdot\frac{10}{3}=30\ V$;

$U_{L_5}=5\omega_1 L I_5=28\ V$; $\quad U_{C_1}=\frac{1}{\omega_1 C}I_1=14\cdot 10=140\ V$;

$U_{C_3}=\frac{1}{3\omega_1 C}I_3=9\cdot\frac{10}{3}=30\ V$; $\quad U_{C_5}=\frac{1}{5\omega_1 C}I_5=5,6\ V$.

Demak, induktivlikga ulangan voltmetr ko'rsatishi:

$$U_L=\sqrt{U_{L_1}^2+U_{L_3}^2+U_{L_5}^2}=U_1\sqrt{28^2+30^2+28^2}=676\ V$$

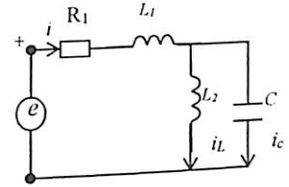
Sig'imga ulangan voltmetr ko'rsatishi:

$$U_C=\sqrt{U_{C_1}^2+U_{C_3}^2+U_{C_5}^2}=144\ V\ V$$

Aktiv qarshilikka ulangan voltmetr ko'rsatishi:

$$U_R=R\cdot I=17\cdot 3=51\ V$$

7.4-Masala. Nosinusoidal elektr zanjirning parametri *R=300 Om, L_1=0.25 Gn, L_2=0.1 Gn, C=3,3 mkf* va chastota *ω=1000 rad/sek* bo'lib, *e=60+250sinωt+100sin3ωt* garmonikalardan tarkib topgan manbaga ulangan. Birinchi tarmoqdagi tokning oniy, effektiv qiymati va aktiv quvvati aniqlansin.



Yechish. O'zgarmas tok kondensatordan oqib o'tmasligi *(I_C=0)* va induktiv qarshilik nolga tengligini *(L=0)* hisobga olsak:

$$I_0=\frac{E_0}{R_1}=\frac{60}{300}=0,2\ A$$

Masalani kompleks usul bilan yechamiz. Bunda birinchi garmonika uchun kompleks tok amplitudasi:

$$\dot{I}_{m_1}=\frac{\dot{E}_{m_1}e^{j0^\circ}}{\underline{Z}_1}$$

Reaktiv qarshiliklarni aniqlaymiz:

$$X_1=\omega L_1=1000\cdot0,25=250\ Om$$
$$X_2=\omega L_2=1000\cdot0,1=100\ Om$$

Sig'imdagi qarshilik: $X_C=\frac{1}{\omega C}=\frac{1}{1000\cdot3,3\cdot10^{-6}}=300\ Om$

Birinchi garmonikadagi kompleks to'la qarshilik:

$$\underline{Z}_1=R_1+j\omega L_1+\frac{j\omega L_2(-j\frac{1}{\omega C})}{j\omega L_2-j\frac{1}{\omega C}}=300+j400=500e^{j53^\circ}$$

Tok amplituda qiymati:

$$\dot{I}_{m_1}=\frac{250e^{j0^\circ}}{500\cdot e^{j53^\circ}}=0,5e^{-j53^\circ}\ (A)$$

Tok oniy qiymati:

$$i_1=0,5\sin(\omega t-53^\circ)\ (A)$$

Uchinchi garmonikadagi tokni aniqlaymiz. Manba kuchlanishi:

$$e_3=100\sin\omega t=E_{m_3}\cdot100e^{j0^\circ}$$

Uchinchi garmonika uchun reaktiv qarshilik:

$$X_{L_1}=3\omega L_1=250\ Om,\ X_{L_2}=3\omega L_2=300\ Om,\ X_C=\frac{1}{3\omega C_3}=100\ Om$$

Umumiy kompleks qarshilik:

$$\underline{Z}_{(3)}=R_1+jX_{L_1}+\frac{jX_{L_2}(-j\frac{1}{\omega C})}{jX_{L_2}-\frac{1}{jX_C}}=300+750+\frac{j300(-j100)}{j300-j100}=$$
$$=300+j600=675e^{j63^\circ}\ Om$$

Uchinchi garmonika tok amplitudasining kompleks ifodasi:

$$\dot{I}_{m_3}=\frac{\dot{E}_{m_3}}{\underline{Z}_{(3)}}=\frac{100}{671e^{j63^\circ}}=0,15e^{-j63^\circ}$$

Tok oniy qiymati:

$$i_3=0,15\sin(3\omega t-63^\circ)$$

Zanjirga kiruvchi tok oniy qiymati :

$$i_1=0,2+0,5\sin(\omega t-53^\circ)+0,15\sin(3\omega t-63^\circ)\ A$$

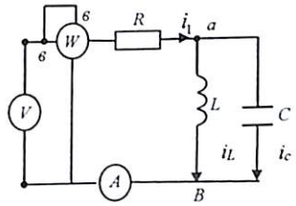
Tok effektiv qiymati:

$$I=\sqrt{0,2^2+(\frac{0,5}{\sqrt{2}})^2+(\frac{0,15}{\sqrt{2}})^2}=0,42\ A$$

Zanjir aktiv quvvati har bir garmonika tok va kuchlanish oniy qiymati ifodasidan:

$$P=P_0+P_1+P_3=60\cdot0,2+\frac{250}{\sqrt{2}}\cdot\frac{0,5}{\sqrt{2}}cos53^\circ+\frac{100}{\sqrt{2}}\cdot\frac{0,15}{\sqrt{2}}cos63^\circ=52,8\ Vt$$

7.5- Masala. Berilgan elektr zanjirning induktivlikdagi nosinusoidal tok $i_L=4+8\sin\omega t+6\sin(2\omega t+90^\circ)$ bo'lib, qarshilik parametri $R=\omega L=5\ Om$, $\frac{1}{\omega C}=20\ Om$ ga teng. Elektr o'lchov asboblari – ampermetr, voltmetr va vattmetrning ko'rsatish qiymati aniqlansin.



Yechish. Induktivlikdagi tok ma'lum bo'lganligi sababli har bir garmonika uchun parallel ulangan tarmoq kuchlanishini aniqlaymiz.

$$U_{Lm_1}=I_{Lm_1}\cdot X_{L_1}=8\cdot5=40\ V$$
$$U_{Lm_2}=I_{Lm_2}\cdot X_{L_2}=6\cdot10=60\ V$$

Sig'im va induktivlikdagi kuchlanish oniy qiymati:

$$u_C=u_L=40\sin(\omega t+90^\circ)+60\sin(2\omega t+180^\circ)=$$
$$=40\sin(\omega t+90^\circ)-60\sin2\omega t$$

Birinchi garmonika uchun parallel ulangan L,C kompleks reaktiv qarshilik:

$$\underline{Z}_{ab_1}=X_{ab_1}=\frac{jX_{L_1}\cdot jX_{C_1}}{jX_{L_1}+jX_{C_1}}=-j\frac{20\cdot5}{5-20}=-j6,67\ Om$$

Birinchi garmonika tok amplitudasi: $I_{m_1}=\frac{U_{Lm_1}}{Z_{ab_1}}=\frac{40}{6,67}=6\ A$

Ikkinchi garmonika uchun: $\underline{Z}_{ab_1}=\frac{j2\omega L\cdot\frac{1}{j2\omega C}}{j\left(2\omega L-\frac{1}{2\omega C}\right)}=\infty$

Demak parallel ulangan reaktiv elementlarda tok rezonansi yuzaga kelib, birinchi tarmoqda ikkinchi garmonika tok ($I_{2m}=0$) nolga teng. Tok oniy qiymati:

$$i=I_0+I_{m_1}\sin(\omega t+\varphi_u-\varphi)=4+6\sin(\omega t+90^\circ-$$
$$90^\circ)=4+6\sin\omega t$$

Ampermetrdagi tok: $I=\sqrt{4^2+\left(\frac{6}{\sqrt{2}}\right)^2}=5,8\ A$

Har bir yuqori garmonika uchun zanjirning umumiy qarshiligini aniqlaymiz. Nolinchi va birinchi garmonika uchun aktiv qarshilik: $R_0=R=5\ Om$

Birinchi garmonika to‘la qarshiligi:

$$Z_1 = \sqrt{R^2 + \left(X_{ab_1}\right)^2} = \sqrt{5^2 + (6{,}7)^2} = 8{,}3\ Om$$

Ikkinchi garmonikada $Z_2=\infty$

Nar bir garmonika uchun kuchlanishni topamiz:

$$U_0 = I_0 R_0 = 4 \cdot 5 = 20V \quad U_{m_1} = I_{m_1} \cdot Z_1 = 6 \cdot 8{,}3 = 50V$$

$$U_{m_2} = U_{Lm_1} = 60\ V$$

Faza burchagi $\varphi_1 = arctg = \frac{X_{ab_1}}{R} = \frac{6{,}67}{5} = 53°$

Zanjirning umumiy kuchlanish oniy qiymati:

$$U = U_0 + U_1 + U_2 = U_0 + Um_1 \sin(\omega t+\varphi_1) + Um_2 \sin 2\omega t =$$
$$=20+ 50 \sin(\omega t+53^0) - 60\sin 2\omega t$$

Voltmetr ko‘rsatishi bo‘yicha:

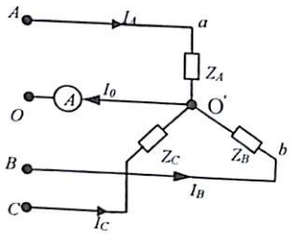
$$U = \sqrt{U_0^2 + U_1^2 + U_1^2} = \sqrt{20^2 + \left(\frac{50}{\sqrt{2}}\right)^2 + \left(\frac{60}{\sqrt{2}}\right)^2} = 58{,}6V$$

O‘rtacha quvvat yoki voltmetr ko‘rsatishi:

$$P = U_0 I_0 + U_1 I_1 \cos\varphi_1 + U_2 I_2 \cos\varphi_2 = 170\ Vt.$$

7.6-Masala. Yulduzcha shaklda ulangan tok zanjirining iste’molchi kompleks qarshiligi:

$\underline{Z_1} = \underline{Z_2} = \underline{Z_3} = (3 + j6)\ Om$ $U_\phi = 141 \sin \omega t + 42{,}5 \sin 3\omega t + 5 \sin 5\omega tB$ bo‘lib, faza kuchlanishi generatorga ulangan. Neytral sim toki I_0 faza-dagi tokning oniy qiymati va uch fazali tok quvvati aniqlansin.



Yechish. Birinchi garmonika uchun iste’molchi faza kuchlanishlari

$\dot{U}_1 = 100\ V;\ \dot{U}_2 = 100\ e^{-j120°};\ \dot{U}_3 = 100\ e^{j120°}$

Tokining effektiv qiymati:

$$I_{\phi_1} = \frac{U}{\underline{Z}} = \frac{100}{\sqrt{3^2 + 6^2}} = 15\ A$$

Faza burchagi: $\varphi = arctg = \frac{X_L}{R} = 63°30'$

Neytral simda birinchi garmonika bo‘lmaydi. ($I_0=0$)

Uchinchi garmonika fazadagi kuchlanish:

$\dot{U}_1 = 30\ V;\ \dot{U}_2 = 30\ e^{-j3\cdot120°} = 30\ V;\ \dot{U}_3 = 30\ e^{j3\cdot120°} = 30V$

Kuchlanish effektiv qiymati: $U=30\ V$

Faza tok effektiv qiymati: $I_{\phi_3} = \frac{U}{Z} = \frac{30}{\sqrt{3^2+18^2}} = 16{,}5\ A$

Faza farqi: $\varphi_3 = arctg\frac{X_{L_3}}{R} = \frac{3\omega L}{R} = 80°30'$

Neytral simda uchinchi garmonikadagi tok fazadagi tokdan uch barobar katta: $I_0 = I_{\phi_3} = 3\cdot1{,}65 = 5\ A$

Liniya kuchlanishlari tarkibida uchinchi garmonika yo‘q. ($U_{l(3)}=0$).

Beshinchi garmonika uchun fazadagi kuchlanish:

$\dot{U}_1 = 3{,}54\ V;\ \dot{U}_2 = 3{,}54\ e^{-j5(120°)};\ \dot{U}_3 = 3{,}54\ e^{j5(120°)} = 3{,}54\ e^{j120°}$

Kuchlanish effektiv qiymati: $U=3{,}54\ V$

Fazadagi tok: $I_{\phi_5} = \frac{U}{\sqrt{R^2+(5\omega L)^2}} = \frac{3{,}54}{\sqrt{3^2+30^2}} = 0{,}117\ A$

Faza farqi: $\varphi_3 = arctg\frac{5\omega L}{R} = 84°$

Neytral simda beshinchi garmonikadagi tok nolga teng. ($I_{0(5)}=0$)

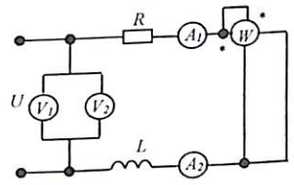
Birinchi fazadagi tok oniy qiymati:

$$i_1 = i_f = 15\sqrt{2}\sin(\omega t-63°30') + 1{,}65\sqrt{2}\sin(3\omega t-80°30') +$$
$$+0{,}117\sqrt{2}\sin(5\omega t-84°)$$

Iste’molchilarda sarf bo‘ladigan uch fazali tok o‘rtacha quvvati:

$$P = 3(U_1 I_1 \cos\varphi_1 + U_3 I_3 \cos\varphi_3 + U_5 I_5 \cos\varphi_5) \approx 9980\ Vt$$

7.7-Masala. Sxemada berilgan induktiv g‘altak kuchlanishi $u=U_0+U_1\sin\omega t\ (V)$ bo‘lib, zanjirga ulangan elektr o‘lchov asboblari: A_1 va V_1–magnitoelektrik, A_2,V_2 va W – elektrodinamik. Bu o‘lchov asboblari ko‘rsatishi: $I_1=4A$, $I_2=5A$, $U_1=30V$, $U_2=90V$, $P=190Vt$ bo‘lganda, quvvat koeffitsienti g‘altak parametrlari va aktiv qarshilikning o‘zgarmas tokga nisbatan qiymati aniqlansin.



Yechish. Magnitoelektrik sistemali elektr o‘lchov asboblari o‘zgarmas tok yoki kuchlanish qiymatini o‘lchaydi. (I_0 , U_0)

Elektrodinamik sistemali elektr o‘lchov asboblari esa tok va kuchlanishning effektiv qiymatini ko‘rsatadi. (I_1 , U_1)

Shunga asosan: $U_1=\sqrt{U_2^2-U_1^2}=\sqrt{90^2-30^2}=85\ V$

$I_1=\sqrt{I_2^2-I_0^2}=\sqrt{5^2-4^2}=3\ A$

Nol garmonika quvvati: $P_0=U_1I_1=30\cdot4=120\ Vt$

Birinchi garmonika quvvati: $P_1=P_2-P_0=190-120=70\ Vt$

Sinusoidal o'zgaruvchan birinchi garmonikadagi to'la qarshilik:

$$Z_{(1)}=\frac{U_1}{I_1}=\frac{80}{3}=26,6\ Om$$

Aktiv qarshilik: $R_{(1)}=\frac{P_1}{I_1^2}=\frac{70}{9}=7,78\ Om$

Induktiv qarshilik: $X_L=\sqrt{Z_1^2-R_1^2}=25,5\ Om$

O'zgarmas tokga nisbatan aktiv qarshilik: $R_0=\frac{U_1}{I_1}=\frac{30}{4}=7,5\ Om$

Siljish koeffitsienti: $k=\frac{R_{(1)}}{R_0}=\frac{7,78}{7,5}=1,036$

7.8-Masala. Ikki qutbli nosinusoidal zanjir kuchlanishi: $u=100+50\sin\omega t-20\sin(3\omega t+\frac{\pi}{6})+10\sin(5\omega t-\frac{\pi}{3})$; $i=2+10\sin(3\omega t-\frac{\pi}{3})+4\sin5\omega t$ tokga ulangan. Kuchlanish va tok haqiqiy qiymati, aktiv, reaktiv, to'la quvvat, siljish va quvvat koeffitsenti aniqlansin.

Yechish. Kuchlanish va tok haqiqiy qiymati:

$$U=\sqrt{U_0^2+\frac{U_{1m}^2}{2}+\frac{U_{3m}^2}{2}+\frac{U_{5m}^2}{2}}=\sqrt{1000+\frac{2500}{2}+\frac{400}{2}+\frac{100}{2}}=$$

$$=\sqrt{11500}=107,2\ V$$

$$I=\sqrt{4+\frac{100}{2}+\frac{16}{2}}=\sqrt{62}=7,87\ A$$

Aktiv quvvat yuqori garmonika algebraik yig'indisidan iborat bo'lib:

$$P=U_0I+U_3\dot{I}_3\cos\varphi_3+U_5\dot{I}_5\cos\varphi_5=100\cdot2+\frac{20}{\sqrt{2}}\cos\varphi_3+U_5\dot{I}_5\cos\varphi_5=$$

$$=100\cdot2+\frac{20}{\sqrt{2}}\cdot\frac{10}{\sqrt{2}}\cos(-90°)+\frac{4}{\sqrt{2}}\cdot\frac{10}{\sqrt{2}}\cos(-90°)=-173,3\ VAR$$

Bu yerda: $(\varphi_3=\varphi_{u3}-\varphi_{i3}=\frac{\pi}{6}-\pi+\frac{\pi}{3}=\frac{\pi}{2})$ $\varphi_5=\varphi_{u5}-\varphi_{i5}=-\frac{\pi}{3}$

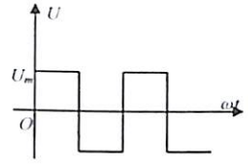
Reaktiv quvvat:

$$Q=\bar{U}_3\bar{I}_3\sin\varphi_3+U_5I_5\sin\varphi_5=\frac{20}{\sqrt{3}}\cdot\frac{10}{\sqrt{3}}\sin(-90°)+\frac{4}{\sqrt{2}}\cdot\frac{10}{\sqrt{2}}\sin(-60°)=-173,3\ VAR$$

To'la quvvat: $S=UI=107,2\cdot7,87=855\ VA$.

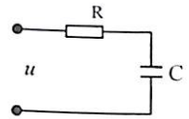
7.3. Mustaqil yechish uchun masalalar

7.1-Masala. Kuchlanish amplituda qiymati $U_m=100\ B$ bo'lgan funksiyani Furye qatoriga yoyish bilan 1,2,3 garmonikalar ifodasi yoki kuchlanish oniy qiymati aniqlansin .



Javob: $u=127,3\sin\omega t+42,4\sin3\omega t+25,5\sin\omega t\ (V)$

7.2-Masala. Ketma-ket ulangan zanjirda qarshiliklar parametrlari $R_1=10$ Om, $X_C=\frac{1}{\omega C}=27$ Om bo'lib, nosinusoidal kuchlanish $u=100+200\sin\omega t+30\sin(3\omega t-90°)+50\sin(5\omega t+45°)$ ga ulangan. Tokning oniy qiymati, kuchlanishi va quvvati aniqlansin.

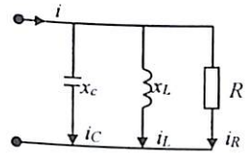


Javob:

$i=0,74\sin(\omega t+88°)+0,33\sin(3\omega t-6°30')+0,97\sin(5\omega t+124°30')$

$U=178\ V,\ I=0,863\ A,\ P=7,47\ Vt$

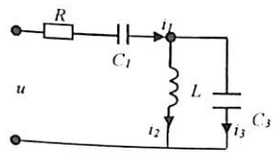
7.3-Masala. Berilgan sxema parametri: $R=\frac{1}{\omega C}=\omega L=10\ Om$ bo'lib, $u=(200\sin\omega t+60\sin3\omega t+30\sin5\omega t)$ (V) kuchlanishga ulangan. Tokning oniy qiymati, effektiv qiymat va quvvati P aniqlansin.



Javob: $i=20\sin\omega t+17,4\sin(3\omega t+67°)+14,7\sin(5\omega t+178°)$

$I=32\ A,\ P=4450Vt$

7.4-Masala. Berilgan sxemaning qarshilik parametri: $R_1=100Om, X_{L_1}=100\ Om, X_{C_1}=X_{C_3}=200\ Om$ bo'lib, nosinusoidal manba kuchlanishi $u=100+500\sin\omega t+200\sin\omega t$ ga ulangan. Tarmoqlardagi tok oniy qiymati aniqlansin.



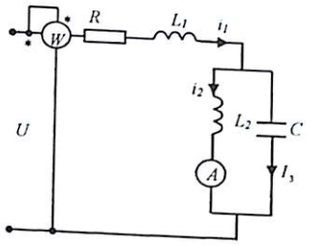
Javob:

$i_1=3,54\sin(\omega t-45°)+0,743\sin(2\omega t+68°)\ A$

$i_2=7,08\sin(\omega t-45°)+0,743\sin(2\omega t+12°)\ A$

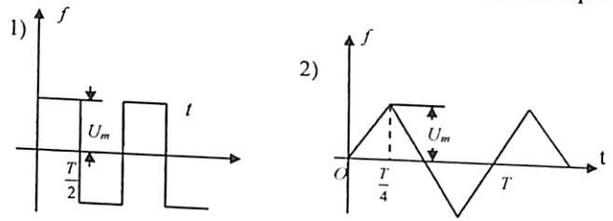
$i_3=3,54\sin(\omega t+135°)+1,5\sin(2\omega t+68°)\ A$

7.5-Masala. Berilgan sxema bo'yicha parametrlar R=20 Om, L_1=20 mGn, L_2=60 mGn, C=16.6 mkf, ω=1000 rad/sek bo'lib, nosinusoidal kuchlanishga $U = 40 + 120\sin\omega t + 60\sin 2\omega t$ ulangan. Birinchi tarmoqdagi tok i_1 va elektr o'lchov asbobining ko'rsatish qiymatini aniqlang.



Javob: i_1=2+1,06sin(ωt+45°)
I_2=2,47 A, P=102,5 Vt

7.6-Masala. Grafikda keltirilgan kuchlanish funksiyasi uchun amplituda k_a, forma k_f va siljish k_{sil} koeffitsienti aniqlansin.



Javob: *1)* k_a=k_ϕ=1; $k_{cuz}=\frac{2\sqrt{2}}{\pi^2}$ *2)* $k_a=\sqrt{3}$; $k_\phi=\frac{2}{\sqrt{3}}$; $k_{cuz}=\frac{4\sqrt{6}}{\pi^2}$

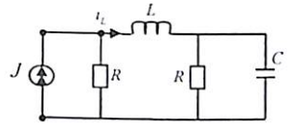
7.7-Masala. (7.3) masaladagi parallel zanjir parametri $\omega = 1000\frac{1}{sek}$ $C = 10\,mkf$, $L = 0{,}1gn$, $g = \frac{1}{R} = 0{,}01sim$ bo'lib, nosinusoidal $u = 100\sin(\omega t + 30°) + 30\sin 3\omega t + 10\sin(5\omega t - 135°)$ kuchlanishga ulangan. Tarmoq toklari oniy $i_{R(t)}$, $i_{L(t)}$, $i_{c(t)}$ va kuchlanish effektiv qiymati aniqlanib, vaqtga nisbatan o'zgaruvchan diagrammasi chizilsin.

Javob: $U = 70\,V$, $I_R = 0{,}71A$, $I_L = 0{,}74A$, $I_c = 1{,}02A$.

7.8-Masala. 7.5 masaladagi aralash sxemada ulangan nosinusoidal elektr zanjir parametri: $L_1 = 2{,}5\,mgn$, $L_2 = 20\,mgn$ $C = 50\,mkf$, $R = 50\,Om$ bo'lib, $u = 50 + 60\sqrt{2}\sin 1000t + +200\sqrt{2}\sin 3000\,t$ kuchlanishga ulangan. Tarmoqlarga ulangan *elek-trodinamik turdagi ampermetr ko'rsatish* tok qiymatini aniqlang:

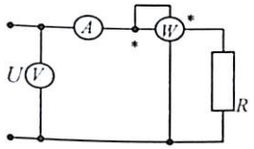
Javob: $I_1 = 4{,}12\,A$, $I_2 = 3{,}24$, $I_3 = 5{,}4\,A$.

7.9-Masala. Nosinusoidal elektr zanjir parametri: $R = 1\,Om$, $X_C = 1\,Om$, $X_L = 0{,}5\,Om$. $i = 10 + 30\sqrt{2}\sin\omega t + +15\sqrt{2}\sin 2\omega t$ tok manbaiga ulangan. Induktivlikdagi tok oniy va haqiqiy qiymati aniqlansin.



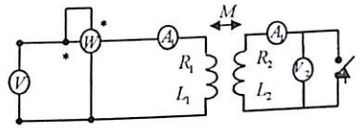
Javob: $i_L = 5 + 28{,}2\sin\omega t + 15{,}8\sin(2\omega t - 26^\circ)$;
$I_L = 23{,}4\,A$

7.10-Masala. Elektr zanjir $u = 220 + 180\sin 314t$ nosinusoidal kuchlanishga ulangan bo'lib, $R = 10\,Om$ qarshiligiga ega. Elektromagnit o'lchov asboblari: ampermetr, voltmetr va vatt-metr ko'rsatish qiymatini aniqlang.



Javob: $U = 254\,V$, $I = 25{,}4\,A$, $P = 6450\,VT$.

7.11-Masala. Havo transformatori (o'zaksiz) $u_1 = 60 + 113\sin 2000\,t$ kuchlanishga ulangan bo'lib parametri: R_1=R_2=6 Om, L_1=L_2=4 mgn, $M = 1\,mgn$. Qisqa tutashuv holat *elektromagnit turdagi o'lchov asboblar* qiymatini aniqlang.



Javob: $I_1 = 12{,}8\,A$; $I_2 = 1{,}6\,A$; $U_1 = 100\,V$; $U_2 = 0$.

Nazorat savollari

1. Nosinusoidal o‘zgaruvchan tok va kuchlanishlarni izohlab bering.
2. Elektr zanjirda nosinusoidal tok, kuchlanish va EYK qanday hosil bo‘ladi?
3. Nosinusoidal o‘zgaruvchan funksiyalarni Furye qatoriga yoyish manosini tushuntiring.
4. Nosinusoidal tok funksiyasining trigonometrik qatoriga yoyilgandagi umumiy ifodasini yozing.
5. Nosinusoidal funksiyaning asosiy garmonikasi yoki yuqori garmo-nikasi deganda nimani tushunasiz?
6. Obsitsa, ordinata va koordinata boshiga simmetrik bo‘lgan sinusoidal funksiya grafigini chizib ko‘rsating.
7. Trapetsiadal ko‘rinishdagi nosinusoidal funksiyani analitik usulda trigonometrik qatorga yoying.
8. Nosinusoidal funksiyaning grafo-analitik usulda hisoblash qanday bajariladi?
9. Nosinusoidal funksiyaning koeffitsienti va boshlang‘ich fazalarini aniqlash formulasini yozing.
10. Nosinusoidal tok kuchlanish va EYKning haqiqiy o‘rtacha qiymatini ifodalovchi formulasini yozing.
11. Nosinusoidal tok quvvatini ifodalovchi tenglamani yozing.
12. Nosinusoidal funksiya amplituda, forma siljish koeffitsienti qanday ifodalanadi?
13. Nosinusoidal elektr zanjirni hisoblashda ustma-ustlik usulidan qanday foydalaniladi?
14. Induktivlik yoki sig‘im parametri yuqori garmonika tok, kuchlanishlarning birinchi garmonikaga nisbatan ifodalanuvchi tenglamasini yozing.
15. Nima sababdan iste’molchi induktiv xarakterga ega bo‘lganda nosinusoidal tok formasi silliqlanib, kuchlanish buziladi?
16. Nima sababdan iste’molchi sig‘im xarakterga ega bo‘lganda nosinusoidal kuchlanish formasi tekislanib, tok formasi buziladi?
17. Uch fazali sistema uchun asosiy va yuqori garmonikali kuchlanish ifodalovchi formulasini yozing.
18. Uch fazali tok sistemalarida qaysi garmonikalar «to‘g‘ri», «teskari» va «nol» ketma-ketlikni hosil qiladi?

19. Nima sababdan simmetrik uch fazali tok sistemasida nosinusoidal kuchlanish ulanganda neytral simdagi tok nolga teng emas?
20. Nima sababdan generator chulg‘amlari uchburchak shaklda ulanganda liniya va faza kuchlanishlarida uch karrali garmonikalar yo‘qoladi?
21. R, L, C parametrning nosinusoidal tok va kuchlanish formulalariga qanday ta’sir ko‘rsatishini tushuntiring.
22. Elektr filtri nima va qanday maqsadda foydalaniladi?
23. Nosinusoidal elektr zanjirda rezonansli filtrlarning xususiyatlarini izohlab bering.
24. Uch fazali generator liniyalarida yuqori garmonika hosil bo‘lishi sababi nimada va qanday xususiyatga ega?
25. $i = 5 + 3\sin(\omega_1 t + 30°) + \sin(3\omega_1 t - 45°) + 4\sin(5\omega_1 t - 30°)$ (A) tok haqiqiy (effektiv) qiymatini toping.
26. Ketma-ket R, L, C zanjir nosinusoidal $U = U_0 + U_{1m}\sin(\omega_1 t + \varphi_{U_1}) + U_{5m}\sin(5\omega_1 t + \varphi_{U_5})$ kuchlanishga ulanganda, tok qiymati ifodasini yozing.
27. Pulsatsiya, modulatsiyalangan tebranish amplitudaviy modulatsiya qanday hosil bo‘ladi?
28. Nosinusoidal elektr zanjiriga ulangan ampermetr, voltmetr, vattmetr ko‘rsatishiga yuqori chastotali garmonikalar ta’sir o‘tkazadimi yoki yo‘qmi?
29. Magnitoelektrik elektr o‘lchov asbobi nosinusoidal tok va kuchlanishning qaysi qiymatini o‘lchaydi?
30. Induksion, elektromagnit, elektrodinamik issiqlik elektr o‘lchov asboblari nosinusoidal tok va kuchlanishlarning qanday qiymatlarini o‘lchaydi?
31. Vattmetr nosinusoidal quvvatning qaysi qiymatini o‘lchaydi?
32. Zanjirga ketma-ket uchta ampermetr: elektromagnit, induksion va issiqlik turdagi tok o‘lchov asbobi ulangan. Agar magnitoelektrik asbob ko‘rsatishi $I_1 = 6A$, induksion ampermetr $I_2 = 8A$ bo‘lsa, issiqlik ampermetr I_3 qiymati nimaga teng?

8 TO‘RT QUTBLI ZANJIR

8.1. Asosiy nazariy tushunchalar

Ikkita kirish (1-1') va ikkita chiqish (2-2') qutblari bo‘lgan har qanday elektr zanjirga **to‘rt qutbli zanjir deyiladi**. Odatda kirish qismi manbaga U_1, chiqish qismiga esa iste’molchi qarshiligi Z_2 ulanadi.

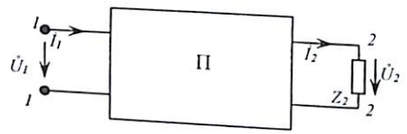
To‘rt qutbli (ko‘p qutbli) ko‘rinishdagi murakkab elektr zanjirni o‘rganishdan asosiy maqsad, to‘rt qutbli ichki tuzilishidan qati nazar, zanjirning kirish va chiqish qismidagi funksional bog‘lanish aniqlanadi. Ya’ni, to‘rt qutbli kirish qismidagi tok I_1va kuchlanish U_1 ma’lum bo‘lsa, chiqishdagi U_2 va I_2 ni aniqlash qonuniyati va bog‘lanishini topish kerak.

To‘rt qutbli ichki parametr tavsiyalariga ko‘ra, kirish va chiqish qismlarini bog‘lovchi tenglama **chiziqli** yoki **nochiziqli** bo‘lishi mumkin.

Ichki tarmoqlarida EYK va tok manbai bo‘lmasa to‘rt qutbli **passiv** bo‘ladi (liniya simlari, transformator, to‘g‘rilash sxemasi, to‘g‘rilagich filtr va hokazolar)

Agarda to‘rt qutbli ichida juda bo‘lmaganda bitta energiya manbai bo‘lsa, u ***aktiv*** bo‘ladi.

1. Chiziqli passiv to‘rt qutbli asosiy xususiyatini tahlil qilish.



Passiv to‘rt qutbli kirish $\dot{I}_1$, $\dot{U}_1$ va chiqish qismlaridagi $\dot{I}_2$, $\dot{U}_2$ tok va kuchlanish chiziqli bo‘lgan ikkita tenglama bilan ifodalanadi:

$$\left.\begin{aligned}\dot{U}_1 &= A\dot{U}_2 + D\dot{I}_2\\ \dot{I}_1 &= C\dot{U}_2 + D\dot{I}_2\end{aligned}\right\} \qquad (8.1)$$

A, B, C, D – to‘rt qutbli doimiy koeffitsientga ega bo‘lib, bularning bog‘lanishi:

$$AD - BC = 1 \qquad (8.2)$$

Agarda to‘rt qutbli kirish qismi chiqish qismi bilan almashtirilsa (8.1) tenglamadan A va D koeffitsientining o‘rni almashadi:

$$\left.\begin{aligned}\dot{U}_1 &= D\dot{U}_2 + B\dot{I}_2\\ \dot{I}_1 &+ C\dot{U}_2 + A\dot{I}_2\end{aligned}\right\} \qquad (8.3)$$

To‘rt qutbli koeffitsientlari: A=D (8. 4) simmetrik bo‘lsa, to‘rt qutblilar doimiy koeffitsient zanjir parametr bilan bog‘langan bo‘lib, quyidagicha ifodalanadi:

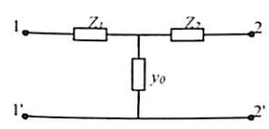
$$A = \frac{\Delta_{2,2}}{\Delta_{1,2}}; \qquad B = \frac{\Delta}{\Delta_{1,2}}(om);$$

$$C = \frac{\Delta_{1,1}\cdot\Delta_{2,2} - \Delta_{1,2}^2}{\Delta\cdot\Delta_{1,2}}\left(\frac{1}{om}\right); \quad D = \frac{\Delta_{1,1}}{\Delta_{1,2}} \qquad (8.5)$$

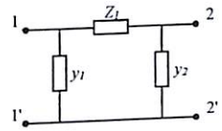
Bunda Δ - kontur uchun tuzilgan tenglama sistemasi asosiy xususiy qarshilik determinanti.

$\Delta_{1,1}$, $\Delta_{1,2}$ va $\Delta_{2,2}$ - algebraik to‘ldiruvchi tenglama tizimi determinanti.

2. Passiv to‘rt qutbli almashinish sxemasi bo‘yicha parametrini aniqlash.



T – sxema



П – схема

T – sxemasi parametri $\underline{Z}_1 = \frac{A-1}{C}$; $\underline{Z}_2 = \frac{D-1}{C}$; $\underline{y}_0 = C$ (8. 6)

Doimiy koeffitsient parametr orqali:

$$\left.\begin{aligned}A &= 1 + \underline{z}\underline{y}_0;\\ B &= \underline{z}_1 + \underline{z}_2 + \underline{z}_1\underline{z}_2\underline{y}_0;\\ C &= \underline{y}_0;\\ D &= 1 + \underline{z}_2\underline{y}_0;\end{aligned}\right\} \qquad (8.7)$$

П – sxema parametri: $\underline{z}_0 = B$; $\underline{Y}_1 = \frac{D-1}{B}$; $\underline{Y}_1 = \frac{A-1}{B}$ (8. 8)

yoki koeffitsient parametri orqali:

$$\left.\begin{aligned}A &= 1 + \underline{y}_2\underline{z}_0;\\ B &= \underline{z}_0;\\ C &= \underline{y}_1 + \underline{y}_2 + \underline{y}_1\underline{y}_2\underline{z}_0;\\ D &= 1 + \underline{y}_1\underline{z}_0;\end{aligned}\right\} \qquad (8.9)$$

3. To‘rt qutbli zanjir parametrni tajriba asosida aniqlash.

Tajriba asosida to‘rt qutbli zanjir parametrlari va doimiy koeffitsientni aniqlashda kirish va chiqish qismidan salt va qisqa tutashuv tajribasi o‘tkaziladi. Natijada chiqish qismida qisqa tutashuv bo‘lganda (8.1) tenglamadan:

$$\underline{Z}_{1k} = \frac{A}{B}; \qquad (8.\ 10)$$

chiqish qismida salt holat tajribasiga asosan:

$$\underline{Y}_{1,0} = \frac{C}{A}; \qquad (8.\ 11)$$

Endi to‘rt qutbli kirish va chiqish qismlari o‘rni almashtirilib, tajriba o‘tkazilganda:

$$\underline{Z}_{2k} = \frac{A}{B}; \underline{Y}_{2,0} = \frac{C}{D}; \qquad (8.\ 12)$$

To‘rt qutbli parametri o‘xshashligidan:

$$\underline{Z}_{1k}\underline{Y}_{1,0} = \underline{Z}_{2k}\underline{Y}_{2,0} \qquad (8.13)$$

$$A = \sqrt{\underline{Z}_{1k} \cdot \underline{Z}_{10}/\underline{Z}_{1k}(\underline{Z}_{20} - \underline{Z}_{2k})} \text{ yoki } A = \sqrt{\frac{Z_{10}}{Z_{20} - Z_{2k}}} \qquad (8.13a)$$

4. Simmetrik to‘rt qutbli uzatuvchanlik funksiya va tavsifiy (operator) qarshiligi.

Tavsifiy qarshilik:

$$\underline{Z}_C = \frac{\dot{U}_2}{\dot{I}_2} = \frac{\dot{U}_1}{\dot{I}_1} = \sqrt{\frac{B}{C}}; \qquad (8.14)$$

Bunda uzatish koeffitsienti:

$$\left.\begin{aligned} \bar{g} = \bar{a} + j\bar{b} = In\frac{\dot{I}_1}{\dot{I}_2} = In\left(A + \sqrt{A^2 + 1}\right) = In\left(A + \sqrt{BC}\right) \\ So'nish\ koeffitsienti: \bar{a} + Reg = In\frac{\dot{U}_1}{\dot{U}_2} = In\frac{\dot{I}_1}{\dot{I}_2} \\ Faza\ koeffitsienti: \bar{b} = lng = \bar{\varphi}_1 - \bar{\varphi}_2 = \bar{\varphi}_1' - \bar{\varphi}_2'(rad/sek) \end{aligned}\right\} \qquad (8.15)$$

Bu tenglamalardan to‘rt qutbli kirish qismidagi tok va kuchlanish:

$$\dot{U}_1 = \dot{U}_1 e^{j\varphi}; \dot{I}_1 = \dot{I}_1 e^{j\bar{\varphi}_1'} \qquad (8.\ 16)$$

Chiqish qismidagi tok va kuchlanish ifodalari (Z_2 – qarshilik ulanganda):

$$\dot{U}_2 = \dot{U}_2 e^{j\varphi}; \dot{I}_2 = \dot{I}_2 e^{j\bar{\varphi}_1'} \qquad (8.\ 17)$$

Tavsifiy qarshilik (Z_c) bilan to‘rt qutbli koeffitsient bog‘lanish tenglamasi:

$$A = D = chg; \ A = \underline{Z}_2 shg; \ A = \frac{1}{\underline{Z}_2} shg \qquad (8.\ 18)$$

Aniqlangan qiymatni (8.1) tenglamaga qo‘yamiz:

$$\left.\begin{aligned} \dot{U}_1 = \dot{U}_2 chg + Z_c \dot{I}_2 shg; \\ \dot{I}_1 = \dot{U}_2 \frac{shg}{Z_c} + \dot{I}_2 chg \end{aligned}\right\} \qquad (8.\ 19)$$

8.19 tenglamadan tavsifiy qarshilik va uzatish koeffitsienti tajriba asosida salt holatda:

$I_2 = 0$; $Z_0 = \frac{\dot{U}_{10}}{thg}$ yoki qisqa tutashuvga asosan: $\dot{Z}_q = \frac{\dot{U}_{1q}}{\dot{I}_{1q}} = \dot{Z}_c thg$

Bundan: $Z_C = \sqrt{Z_0 Z_q}$; $\quad thg = \sqrt{\frac{Z_q}{Z_0}}$

5. To‘rt qutbli har xil turda ifodalash tenglamalari.

To‘rt qutbli ulanish sxemasiga qarab turli xil ko‘rinishdagi tenglamalardan foydalanish mumkin:

Ifoda [z]
$$\left.\begin{aligned} \dot{U}_1 = \underline{z}_{11}\dot{I}_1 + \underline{z}_{12}\dot{I}_2 \\ \dot{U}_2 = \underline{z}_{21}\dot{I}_1 + \underline{z}_{22}\dot{I}_2 \end{aligned}\right\} \qquad (8.\ 20)$$

Ifoda [y]
$$\left.\begin{aligned} \dot{I}_1 = \underline{y}_{11}\dot{U}_1 + \underline{y}_{12}\dot{U}_2 \\ \dot{I}_2 = \underline{y}_{21}\dot{U}_1 + \underline{y}_{22}\dot{U}_2 \end{aligned}\right\} \qquad (8.\ 21)$$

Ifoda [g]
$$\left.\begin{aligned} \dot{I}_1 = \underline{g}_{11}\dot{U}_1 + \underline{g}_{12}\dot{I}_2 \\ \dot{U}_2 = \underline{g}_{21}\dot{U}_1 + \underline{g}_{22}\dot{I}_2 \end{aligned}\right\} \qquad (8.22)$$

Ifoda [h]
$$\left.\begin{aligned} \dot{U}_1 = \underline{h}_{11}\dot{I}_1 + \underline{h}_{12}\dot{U}_2 \\ \dot{I}_2 = \underline{h}_{21}\dot{I}_1 + \underline{h}_{22}\dot{U}_2 \end{aligned}\right\} \qquad (8.\ 23)$$

8.2. Masala yechish va uslubiy ko‘rsatmalar

8.1-Masala. Simmetrik to‘rt qutbli zanjirning doimiy koeffitsienti: $A = 2 + j3$ va $B = (1 + j)$ Om ga teng bo‘lganda, C – koeffitsienti aniqlansin.

Yechish. (8. 2) va (8. 4) tenglamadan

$$C = \frac{A^2 - 1}{B} = \frac{\left(2 + j3\right)^2 - 1}{(1 + j)} = 3 + j9\ \frac{1}{Om}$$

Masala 8.2. To`rtqutbli zanjir parametrlari: $Z_1$=4 Om; $Z_2$=5 Om; $Y_0$=0,5$\left(\frac{1}{Om}\right)$ bo`lganda, “T” va “П” - shakldagi sxemalar uchun A, B, C, D koeffisientlari aniqlansin.

Yechish: “T” shakldagi sxemaning parametrlari koeffisientlari orqali bog`lanish tenglamasiga (8-7) asosan:

A=1+Z_1Y_0=1+$\frac{4}{2}$=3; B=1+ Z_1+ Z_2+ $Z_1Z_2Y_0$=4+5+$\frac{20}{2}$ =19 Om

C=Y_0=$\frac{1}{2}$ ($\frac{1}{Om}$) D=1+Y_0Z_2=1+$\frac{1}{2}$.5=$\frac{7}{2}$=3.5

(8-2) tenglamaga asosan tekshiramiz:

AD-BC=$3\frac{7}{2}$ -$19\frac{1}{2}$ = $\frac{21}{2}$-$\frac{19}{2}$=10.5-9.5=1

"П"- shakldagi sxemaning parametrlari koeffisientlari orqali bog`lanish tenglamasiga (8-9) asosan:

Yechish:

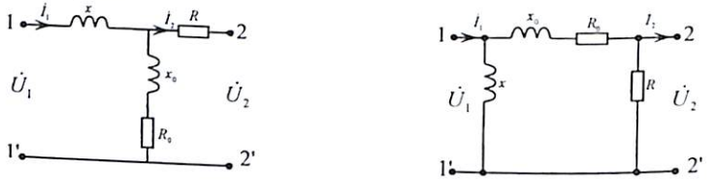
A=1+$Y_2 Z_0$=1+0.2·2=1.4 D=1+ $Y_1 Z_0$=1+0.25·2=1,5

B= Z_0=2 Om C=Y_1+ Y_2+ Y_1 Y_2 Z_0=0.25+0.2+0.25·0,2·2=0,55

(8-2) tenglamaga asosan tekshiramiz:

AD-BC=1,4·1,5-2·0,55=2,1-1,1=1

8.3-Masala. Parametri $R = 10\ (Om), x = 10\ (Om)$, x_0=5 *(Om)*, R_0=5 *(Om)* bo'lgan, T va П shaklda ulangan to'rt qutbli doimiy A, B, C, D koeffitsienti aniqlansin:



Yechish. (8. 7) tenglamaga asosan T - sxema uchun:

$$A = 1 + \underline{z}_1\underline{y}_0 = 1 + \frac{\underline{x}}{R_0+\underline{x}_0} = 1 + \frac{j10}{5+\underline{j}5} = 1 + \frac{j10^{j90^\circ}}{5\sqrt{2}e^{j45^\circ}} = 1 + \sqrt{2}e^{j45^\circ} = 1 + 1 + \underline{j} = 2 + \underline{j}$$

$$B = \underline{z}_1\underline{z}_2 + \underline{z}_1\underline{z}_2\underline{y}_0 = \underline{x} + R + \frac{\underline{x}R}{R_0+\underline{x}_0} = \underline{j}10 + 10 + \frac{\underline{j}10\cdot 10}{5+\underline{j}5} = \underline{j}10 + 10 + 10\sqrt{2}e^{j45^\circ} = \underline{j}10 + 10 + j10 = 20 + \underline{j} = 20 + \underline{j}20\ Om$$

$$C = \underline{y}_0 = \frac{1}{R_0+\underline{x}_0} = \frac{j10}{5\sqrt{2}e^{j45^\circ}} = \frac{\sqrt{2}e^{-j45^\circ}}{10} = \frac{\sqrt{2}e^{j45^\circ}}{10} = 0,1 + \underline{j}0,1\ \left(\frac{1}{Om}\right);$$

$$D = 1 + \underline{z}_2\underline{y}_0 = 1 + \frac{10}{5\sqrt{2}e^{j45^\circ}} = 1 + \sqrt{2}e^{-j45^\circ} = 1 + 1 - \underline{j} = 2 - \underline{j};$$

(8. 9) tenglamaga asosan П - sxema uchun:

$$A = 1 + \underline{z}_0\underline{y}_2 = 1 + \frac{\underline{x}_0+\underline{z}_0}{R_3} = 1 + \frac{5\sqrt{2}e^{j45^\circ}}{10} = 1 + 0,5 + \underline{j}0,5 = 1,5 + \underline{j}0,5;$$

$$B = \underline{z}_0 = x_0 + R_0 = 5 + \underline{j}5\ Om;$$

$$C = \underline{y}_1 + \underline{y}_2 + \underline{y}_1\underline{y}_2\underline{z}_0 = -\underline{j}0,1 + 0,1 + \frac{5\sqrt{2}e^{j45^\circ}}{10\cdot 10e^{j90^\circ}} = -\underline{j}0,1 + 0,1 + 0,05 = 1,5 + \underline{j}0,5\sqrt{2}e^{j45^\circ} = -\underline{j}0,1 + 0,1 + 0,05 - j0,05 = 0,15 - j0,15\ \left(\frac{1}{Om}\right)$$

$$D = 1 + \underline{z}_0\underline{y}_1 = 1 + \frac{R_0+\underline{x}_0}{\underline{x}} = 1 + \frac{5\sqrt{2}e^{j45^\circ}}{10e^{j90^\circ}} = 1 + 0,5 - \underline{j}0,5 = 1,5 + \underline{j}0,5;$$

8.4-Masala. To'rt qutbli qisqa tutashuv va salt holat tajribalari o'tkazilib tok va kuchlanishning quyidagi qiymati aniqlangan.

a) qisqa tutashuv: $\dot{U}_2 = 0;\ \dot{I}_{2k} = 0,05e^{j93^\circ}\ (A);$

$\dot{U}_{1k} = 100(V);\ \dot{I}_{1k} = 0,04e^{j87^\circ}\ (A);$

b) salt holatda: $\dot{I}_{20} = 0;\quad \dot{U}_{20} = 180e^{j15^\circ};$ (V);

$\dot{U}_{10} = 100(V);\ \dot{I}_{10} = 0,055e^{-j57^\circ}\ (A);$

To'rt qutbli doimiy koeffitsienti hisoblab topilsin.

Yechish. (8. 1) tenglamaga asosan qisqa tutashganda $(\dot{U}_2 = 0)$:

$\dot{U}_{1k} = B\dot{I}_{2k};\ \ \dot{I}_{1k} = D\dot{I}_{2k};$

Bundan: $B = \frac{\dot{U}_{1k}}{\dot{I}_{2k}} = 2000e^{-j93^\circ}\ (Om);\ D = \frac{\dot{I}_{1k}}{\dot{I}_{2k}} = 0,8e^{-j16^\circ};$

Salt holatda: $\dot{I}_2 = 0$ bo'lib (8. 1) dan: $\dot{U}_{10} = A\dot{U}_{20};\quad \dot{I}_{10} = C\dot{U}_{20};$

Bundan: $A = \frac{\dot{U}_{10}}{\dot{U}_{20}} = 0,555e^{-j15^\circ};\ C = \frac{\dot{I}_{10}}{\dot{U}_{20}} = 3,06\cdot 10^{-4}e^{j72^\circ}\left(\frac{1}{Om}\right);$

Tekshiramiz:

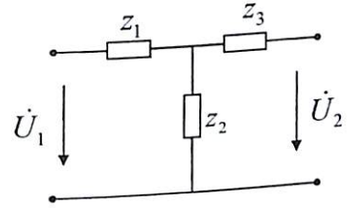
$AD - BC = 0,555e^{-j15^\circ}\cdot 0,8e^{-j16^\circ} - 2000e^{-j93^\circ}\cdot 3,06\cdot 10^{-4}e^{j72^\circ} \approx 1$

8.5-Masala. To'rt qutbli doimiy koeffitsienti: $A = 1 - \underline{j}3,\ B = -3 - j30,\ C = -j0,1\ \ D = -1$ bo'lib, ekvivalent T va П - shakldagi sxema tuzilsin.

Yechish. (8. 6) tenglamaga asosan T - sxema tuzish uchun parametr aniqlanadi.

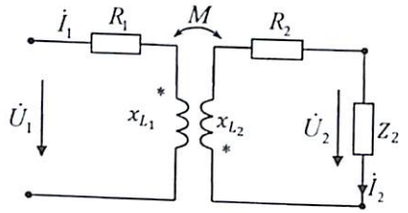
$$\underline{z}_1 = \frac{A-1}{C} = \frac{1-\underline{j}-3}{-\underline{j}0,1} = 30(Om);\quad \underline{z}_2 = \frac{1}{C} = \frac{1-\underline{j}-3}{-\underline{j}0,1} = \underline{j}10(Om);$$

$$\underline{z}_3 = \frac{D-1}{C} = \frac{-1-1}{-\underline{j}0,1} = \underline{j}20(Om);$$



(8.8) Tenglamaga asosan П - sxema tuzish uchun parametr aniqlanadi: $\underline{z}_0 = B = -3 - \underline{j}30$ teng П – shakldagi sxemani tuzish mumkin emas, sababi aktiv qarshilik qiymati "minus" ishora bilan berilgan.

8.6-Masala. Transformatorning ikkilamchi chulg'amidagi tok $\dot{I}_2 = 1\ A$, kuchlanishi $\dot{U}_2 = 20\ V$ bo'lib, aktiv qarshilik ulangan. Transformatorning parametr qarshiligi $R_1 = R_2 = 1\ Om$, $X_{L_1} = X_{L_2} = 25\ Om$ o'zaro induktiv qarshiligi $x_M = \omega M = 20\ Om$ bo'lganda, kirish qismidagi birlamchi chulg'amdagi tok $\dot{I}_1$ va kuchlanish $\dot{U}_1$ aniqlansin.



Yechish. Transformator ekvivalent sxemasi T sxemaga mos keladi, shuning uchun T sxema parametrini aniqlaymiz.

$$\underline{Z}_1 = \underline{Z}_2 = R + j\omega(L_1) - j\omega M = 1 + j25 - j20 = 1 + \underline{j}5\ Om;$$

$$\underline{y}_0 = \frac{1}{j\omega M} = \frac{1}{j20} = -j0{,}05\left(\frac{1}{Om}\right)$$

(8.7) tenglamaga asosan to'rt qutbli doimiy koeffitsientni aniqlaymiz. Bunda $\underline{z}_1 = \underline{z}_2$ bo'lganligi uchun: $A = D$

$$A = D = 1 + \underline{z}_1\underline{y}_0 = 1 + (1 + j5)\cdot\left(-\underline{j}0{,}05\right) = 1{,}25 - \underline{j}0{,}05;$$

$$B = \underline{z}_1 + \underline{z}_2 + \underline{z}_1\underline{z}_2\underline{y}_0 = 2\left(1 + \underline{j}5\right) + \left(1 + \underline{j}5\right)\cdot\left(-\underline{j}0{,}05\right) = 2{,}5 + j11{,}2\ Om$$

$$C = \underline{y}_0 = -\underline{j}0{,}05\left(\frac{1}{Om}\right)$$

Transformator ulangan iste'molchi qarshiligi aktiv bo'lganligi uchun: $\dot{U}_2 = U_2 = 20\ (V)$; tok $\dot{I}_2 = I_2 = 1\ (A)$teng ushbu qiymatlarini (8. 1) tenglamaga qo'yamiz:

$\dot{U}_1 = A\dot{U}_2 + B\dot{I}_2 = (1{,}25 - j0{,}05)\cdot 20 + (2{,}5 + j11{,}2)\cdot 1 = (27{,}1 + j10{,}2)$

$\dot{I}_1 = C\dot{U}_2 + D\dot{I}_2 = (-j0{,}05)\cdot 20 + (1{,}25 - j0{,}05)\cdot 1 = (1{,}25 - j1{,}05)$

Demak: $U_1 = \sqrt{27{,}5^2 + 10{,}2^2} = 28{,}5V$; $I_1 = \sqrt{1{,}25^2 + 1{,}05^2} = 1{,}6V$

8.7-Masala. To'rt qutbli zanjir simmetrik bo'lib, koeffitsienti: $A = 1 + \underline{j}2$ va $B = -80 + \underline{j}240$ ga teng. Qisqa tutashuv va salt holat to'la kompleks qarshilikni hisoblang.

Yechish. To'rt qutbli simmetrik bo'lganligi uchun: $A = D = 1 + \underline{j}2$;

(8.2) tenglamadan C koeffitsientni topamiz: $C = \frac{AD - A^2}{B} = \frac{A^2 - 1}{B}$; (8.1) tenglamadan to'rt qutbli salt holati uchun: $\dot{U}_{10} = A\dot{U}_2$; $\dot{I}_{10} = C\dot{U}_2$

Yoki: $\frac{\dot{U}_{10}}{\dot{I}_{10}} = \frac{A}{C}$

Bunda: $\underline{Z}_{10} = \frac{AB}{A^2 - 1} = \frac{(1+J2)\cdot(-80+J240)}{(1+J2)^2} = 80 + J60 = 100e^{j36°45'}$

Qisqa tutashuv holatdagi tenglama: $\dot{U}_{1k} = B\dot{I}_2$; $\dot{I}_{1k} = D\dot{I}_2$;

yoki $\frac{\dot{U}_{1k}}{\dot{I}_{1k}} = \frac{A}{D}$;

$$\underline{Z}_{1k} = \frac{-80 + J240}{1 + J2} = \frac{253e^{j108°}}{2{,}24e^{j63°}} = 112^{j45°} = 78 + j80{,}7\ Om;$$

8.8-Masala. To'rt qutbli zanjr kirish qismida qisqa tutashuv va salt holat, chiqish qismida salt holat tajribasi o'tkazilib o'lchov asbobi yordamida quyidagi qiymatlar aniqlangan:

$\dot{U}_{10} = 158\ B$; $\dot{I}_{10} = 10\ A$; $P_{10} = 500\ Vt$; $\varphi_{10} > 0$;
$\dot{U}_{1k} = 12{,}5\ B$; $\dot{I}_{1k} = 10\ A$; $P_{1k} = 400\ Vt$; $\varphi_{1k} > 0$;
$\dot{U}_{20} = 158\ B$; $\dot{I}_{20} = 10\ A$; $P_1 = 500\ Vt$; $\varphi_{20} > 0$;

To'rt qutbli zanjir doimiy koeffitsienti aniqlansin.

Yechish. Elektr o'lchov asboblari ko'rsatish qiymatiga asosan to'rt qutbli salt holat uchun kirish qismidagi to'la qarshilik:

$$\underline{Z}_{10} = \frac{\dot{U}_{10}}{\dot{I}_{10}} = \frac{158}{10} = 15{,}8\ Om$$

Quvvat koeffitsienti:

$$\cos\varphi_{10} = \frac{P_{10}}{\dot{U}_{10}\cdot\dot{I}_{10}} = \frac{500}{158\cdot 10} = 0{,}316;\ \varphi_{10} = 71°30'$$

yoki: $\underline{Z}_{10} = 15{,}8e^{j71°30'} = 5 + \underline{j}15$

Qisqa tutashuv holatda to'la qarshilik: $\underline{Z}_{1k} = \frac{\dot{U}_{1k}}{\dot{I}_{1k}} = \frac{126{,}5}{10} = 12{,}65\ Om$;

Quvvat koeffitsienti:

$$\cos\varphi_{1k} = \frac{P_{1k}}{\dot{U}_{1k}\cdot\dot{I}_{1k}} = \frac{400}{12{,}5\cdot 10} = 0{,}31;\ \varphi_{1k} = 71°30';$$

yoki: $\underline{z}_{1k} = 12{,}65e^{j71°30'} = 12{,}6 + j4{,}3$

To'rt qutbli chiqish qismidagi salt holat to'la qarshiligi:

$$\underline{z}_{20} = \frac{\dot{U}_{20}}{\dot{I}_{20}} = 15{,}81\ (Om);$$

Quvvat koeffitsienti: $\cos\varphi_{20} = \frac{P_{20}}{\dot{U}_{20}\cdot\dot{I}_{20}} = \frac{1500}{158\cdot10} = \frac{1500}{1580}0{,}94$; $\varphi_{10} = 19°$;

yoki: $\underline{Z}_{20} = 15{,}8e^{j19°} = 15 + j5$

To‘rt qutbli (8.10), (8.11), (8.12) tenglamasiga asosan koeffitsientni aniqlaymiz:

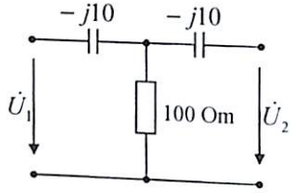
$$A = \frac{\underline{Z}_{10}}{\sqrt{\underline{Z}_{20}\cdot\underline{Z}_{10}\cdot\underline{Z}_{1k}}} = \frac{5+j15}{\sqrt{(15+j5)\cdot(5+j15)\cdot(12{,}6+j4{,}3)}} = 1{,}023e^{j26°}$$

$$C = \frac{1}{\underline{Z}_{10}} = \frac{1}{5+j5} = 0{,}064e^{-j45°};$$

$$D = C\cdot\underline{Z}_{10} = 0{,}064e^{-j45°}\cdot 15{,}8e^{j71°30'} = 1{,}02e^{j25°30'};$$

$$B = D\cdot\underline{Z}_{1k} = 1{,}02e^{j25°30'}\cdot 12{,}65e^{j71°30'} = 13e^{j96°30'};$$

8.9-Masala. Simmetrik T sxema parametri $\underline{x}_1 = -\underline{j}10\ Om$; $\underline{x}_2 = -\underline{j}10\ Om$; $R = 100\ Om$; ga teng bo‘lganda, xarakteristik qarshiligi $(\underline{Z}_C)$ va uzatish koeffitsientilarini (g) topilsin.



Yechish. To‘rt qutbli zanjir koeffitsientlarini aniqlaymiz:

$$A = D = 1 + \underline{Z}_1\underline{Y}_0 = 1 + \frac{-\underline{j}10}{100} = 1 - \underline{j}0{,}1 = 1e^{j5°30'};$$

$$C = \underline{Y}_0 = \frac{1}{100} = 0{,}01\left(\frac{1}{Om}\right)$$

$$B = \frac{1}{C}(A^2 - 1) = -1 - \underline{j}20 = 20e^{-j93°};$$

(8.14) tenglamaga asosan to‘rt qutbli xarakteristik qarshiligi:

$$\underline{Z}_C = \sqrt{\frac{B}{C}} = 44{,}7e^{-j46°30'};$$

Uzatish koeffitsienti (8. 15) tenglamadan:

$$g = ln\left(\sqrt{A^2} + \sqrt{BC}\right) = ln\left(A + \sqrt{BC}\right)$$

Bundan: $A + \sqrt{BC} = 1{,}31 - \underline{j}0{,}42 = 1{,}38e^{j18°20'}$

$$g = ln1{,}38e^{j18°20'} = ln1{,}38 - \underline{j}18°20' = 0{,}322 - \underline{j}0{,}32$$

So‘nish koeffitsienti: $a = 0{,}322$ nep.

Faza koeffitsienti: $b = -0{,}32\ rad/sek.$

8.10-Masala. To‘rt qutbli zanjir doimiy koeffitsient qiymati $A = 0{,}56e^{-j15°}$, $B = 20006e^{-j93°}(Om)$, $C = 3{,}06\cdot10^{-4}e^{j72°}$, $D = 0{,}8e^{-j6°}$ bo‘lib, $[z]$ forma tenglamasi koeffitsientlari aniqlasin.

Yechish. To‘rt qutbli $[A]$ forma tenglamasi (8-1) dan :

$$\left.\begin{aligned}\dot{U}_1 &= A\dot{U}_2 + B\dot{I}_2\\ \dot{I}_1 &= C\dot{U}_2 + D\dot{I}_2\end{aligned}\right\}$$

Bu tenglamada kompleks kuchlanishni chap tomonga o‘tkazamiz:

$$\left.\begin{aligned}\dot{U}_1 - A\dot{U}_2 &= B\dot{I}_2\\ C\dot{U}_2 &= \dot{I}_1 - D\dot{I}_2\end{aligned}\right\}$$

Ikkinchi tenglamadan: $\dot{U}_2 = \frac{1}{C}\dot{I}_1 - \frac{1}{D}\dot{I}_2$ buni $[A]$ tenglamaning birinchi ifodasidagi $\dot{U}_2$ o‘rniga qo‘yamiz:

$$\dot{U}_1 = B\dot{I}_2 + A\left(\frac{1}{C}\dot{I}_1 - \frac{1}{D}\dot{I}_2\right) = \frac{A}{C}\dot{I}_1 - \frac{1}{C}\dot{I}_2;$$

[z] ifodali (8-20) tenglamadan doimiy koeffitsient kompleks qarshiligi:

$$\underline{Z}_{11} = \frac{A}{C} = \frac{0{,}56e^{-j15°}}{3{,}06\cdot10^{-4}e^{j72°}} = 1830e^{j57°}$$

$$\underline{Z}_{12} = -\frac{1}{C} = -\frac{1\cdot10^4}{3{,}06\cdot e^{j72°}} = 3260e^{-j108°}$$

$$\underline{Z}_{21} = \frac{1}{C} = \frac{1\cdot10^4}{3{,}06\cdot e^{j72°}} = 3260e^{-j72°}$$

$$\underline{Z}_{22} = \frac{D}{C} = \frac{0{,}8\cdot e^{-j6°}}{3{,}06\cdot e^{j72°}} = 260e^{-j114°}$$

8.11-Masala. To‘rt qutbli doimiy A, B, C, D koeffitsientlari 8.9-masalada berilgan qiymatlar bo‘yicha $[y]$ forma tenglamadagi doimiy koeffitsient aniqlansin.

Yechish. To‘rt qutbli (8.1) tenglamadagi tok $\dot{I}_1$ va $\dot{I}_2$ ifodalarini chap tomonga o‘tkazamiz:

$$\left.\begin{aligned}B\dot{I}_2 - \dot{U}_1 &= A\dot{U}_2\\ \dot{I}_1 &= D\dot{I}_2 - C\dot{U}_2\end{aligned}\right\}$$

Bundan $\dot{I}_1$ va $\dot{I}_2$ tokni topamiz, ya’ni $\dot{I}_1 = \frac{\Delta_1}{\Delta}$ va $\dot{I}_2 = \frac{\Delta_2}{\Delta}$

$$\Delta = \begin{vmatrix}0 & B\\ 1 & -D\end{vmatrix} = -B;$$

$$\Delta_1 = \begin{vmatrix}\dot{U}_1 - A\dot{U}_2 & B\\ C\dot{U}_2 & -D\end{vmatrix} = -\dot{U}_1 D + AD\dot{U}_2 - BC\dot{U}_2 = -D\dot{U}_1 + \dot{U}_2;$$

$$\Delta_2 = \begin{vmatrix}0 & \dot{U}_1 - A\dot{U}_2\\ 1 & C\dot{U}_2\end{vmatrix} = -\dot{U}_1 + A\dot{U}_2;$$

yoki:
$$\left.\begin{aligned} \dot{I}_1 &= \frac{D}{B}\dot{U}_1 - \frac{1}{B} = \dot{U}_2 \\ \dot{I}_2 &= \frac{D}{B}\dot{U}_1 - \frac{1}{B} = \dot{U}_2 \end{aligned}\right\}$$

Bu toklar tenglamasi $[y]$ formadagi (8.21) tenglamaga o'x-shashligi sababli doimiy koeffitsientini ifodalovchi parametrni topamiz:

$$\underline{y}_{11} = \frac{D}{B};\ \underline{y}_{12} = -\frac{1}{B};\ \underline{y}_{21} = \frac{1}{B};\ \underline{y}_{22} = \frac{A}{B}$$

A, B, C, D koeffitsient qiymatini qo'ysak:

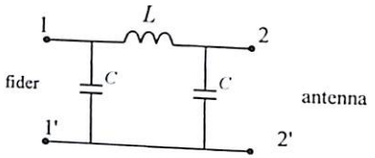
$$\underline{y}_{11} = \frac{0{,}8e^{-j6^\circ}}{2000e^{-j93^\circ}} = 10^{-4}\left(0{,}21 + \underline{j}4\right)\left(\frac{1}{Om}\right);$$

$$\underline{y}_{12} = \frac{1}{2000e^{-j93^\circ}} = 10^{-4}\left(0{,}26 - \underline{j}5\right)\left(\frac{1}{Om}\right)$$

$$\underline{y}_{21} = -\underline{y}_{12} = 10^{-4}\left(0{,}26 + \underline{j}5\right)\left(\frac{1}{Om}\right);$$

$$\underline{y}_{22} = \frac{0{,}5e^{-j15^\circ}}{2000e^{-j93^\circ}} = 10^{-4}\left(-0{,}58 - \underline{j}2{,}74\right)\left(\frac{1}{Om}\right);$$

8.12-Masala. To'lqin qarshilik $\underline{z}_0 = 125\ (Om)$; $\omega_0 = 5\cdot 10^5\left(\frac{1}{sek}\right)$ bo'lgan П - shaklidagi to'rt qutbli fiderga antennani rostlash uchun $R_A = 500\ (Om)$ aktiv qarshilik ulangan. To'rt qutbli parametri L, C ni hisoblab toping.



Yechish. To'rt qutbli [a] tenglamasini (8.1) va (8.4) dan kuchlanish ifodasini tokga bo'lamiz hamda to'rt qutbli kirish qismida fider Z_F to'la qarshilik antenna bilan rostlanishini inobatga olamiz.

Bunda:

$$\underline{Z}_F = \frac{A\dot{U}_2 + B\dot{I}_2}{C\dot{U}_2 + A\dot{I}_2} = \frac{A\underline{Z}_a + B}{C\underline{Z}_a + A};$$

Xuddi shunga o'xshash to'rt qutbli chiqish qismidagi antenna to'la qarshiligi:

$$\underline{Z}_a = \frac{A\cdot\underline{Z}_\phi + B}{C\cdot\underline{Z}_\phi + A}$$

Bu ikkita tenglamaga $\left(\underline{Z}_F, \underline{Z}_a\right)$ to'rt qutbli (8.2) tenglamani qo'shib hisobga olgan holda, uchta noma'lum tenglama sistemasini A, B, C, D koeffitsientga nisbatan yechamiz.

Berilgan qiymat qo'shilganda quyidagicha tenglama hosil bo'ladi:

$$\left.\begin{aligned} 375A + B + 250^2C &= 0 \\ -375A + B - 250^2C &= 0 \\ A^2 - BC &= 1 \end{aligned}\right\}$$

Birinchi tenglamadan ikkinchisini ayirsak:

$$A = 0;\quad \frac{B}{C} = 250^2;\quad BC = -1;$$

Bu qiymatni tenglama sistemasiga qo'yish bilan:

$$BC = j250(Om)$$

$$C = j4\cdot 10^2\left(\frac{1}{Om}\right)$$

П shaklda sxemaning Z va У parametrlarini (8.8) tenglamaga asosan topamiz:

$$\underline{Z}_0 = B = j250\ Om$$

$$\underline{У} = \frac{A-1}{B} = -\frac{1}{B} = -\frac{1}{j250} = 4\cdot 10^{-3}\left(\frac{1}{Om}\right)$$

Bundan induktivlik: $Z = \frac{\underline{Z}_0}{\omega} = \frac{250}{5\cdot 10^5} = 5\cdot 10^{-4}(Gn) = 0{,}5(mGn)$

Sig'im parametri: $Z = \frac{\underline{У}}{\omega} = \frac{4\cdot 10^{-3}}{5\cdot 10^5} = 0{,}8\cdot 10^{-8}(F) = 8(mGn)$

8.13-Masala. To'rt qutbli doimiy koeffitsienti 8.9-masalada berilgan qiymatlar bo'yicha [g] forma tenglamasidagi doimiy koeffitsient qiymati hisoblab topilisin.

Yechish. To'rt qutbli asosiy $[A]$ forma tenglamasidagi (8.3) tok $\dot{I}_1$ va kuchlanish $\dot{U}_2$ga nisbatan yechamiz: $\dot{U}_2 = \frac{1}{A}\left(\dot{U}_1 - B\dot{I}_2\right) = \frac{1}{A}\dot{U}_1 - \frac{B}{A}\dot{I}_2;$

Bu tenglamani (8.3) tenglamadagi $\dot{U}_2$ kuchlanish o'rniga qo'yamiz:

$$\dot{I}_1 = \frac{C}{A}\left(\dot{U}_1 - B\dot{I}_2\right) + D\dot{I}_2 = \frac{C}{A}\dot{U}_1 - \frac{1}{A}\dot{I}_2;$$

Bu ikkala tenglamaning to'rt qutbli $[g]$ formadagi (8.21) o'xshashligidan doimiy koeffitsient parametrini aniqlaymiz:

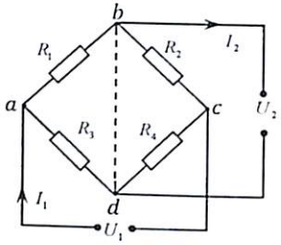
$$\underline{g}_{11} = \frac{C}{A} = \frac{30{,}6\cdot 10^{-4}e^{-j72^\circ}}{0{,}56e^{-j15^\circ}} = 5{,}46\cdot 10^{-4}e^{-j57^\circ}\left(\frac{1}{Om}\right)$$

$$\underline{g}_{12} = \frac{1}{A} = \frac{1}{0{,}56e^{-j15^\circ}} = 1{,}78e^{j15^\circ}\left(\frac{1}{Om}\right)$$

$$\underline{g}_{21} = -\frac{1}{A} = \frac{1}{0{,}56e^{-j15^\circ}} = 1{,}78e^{j15^\circ}\left(\frac{1}{Om}\right)$$

$$\underline{g}_{22} = \frac{B}{A} = \frac{2000e^{-j93^\circ}}{0{,}56e^{-j15^\circ}} = 3570e^{j102^\circ}\left(\frac{1}{Om}\right)$$

8.14-Masala. Ko'prik sxemada ulangan to'rt qutbli elektr zanjir-ning parametri: $R_1 = 1\ Om,\ R_2 = 3\ Om, R_3 = R_4 = 2\ Om$ ga teng. To'rt qutbli elektr zanjir doimiy koeffitsienti A,B,C,D ni aniqlang.



Yechish. To'rt qutbli zanjir doimiy koeffitsientini aniqlash uchun salt ishlash va qisqa tutashuv tajribasidan foydalanamiz:

(8-13a) ifodadan: $A = \sqrt{\frac{R_{10}}{R_{20}-R_{2K}}}$

a) Salt holatda chiqishidagi kuchlanish $U_{20} = 0$ bo'lib:

bundan: $R_{10} = \frac{(R_1+R_2)(R_3+R_4)}{R_1+R_2+R_3+R_4} = \frac{(1+3)(2+2)}{1+3+2+2} = \frac{16}{8} = 2\ Om$

b) Kirishdagi kuchlanish $U_{10} = 0$:

bo'lganda $R_{20} = \frac{(R_1+R_3)(R_2+R_4)}{R_1+R_2+R_3+R_4} = \frac{3\cdot5}{1+3+2+2} = \frac{15}{8}\ Om$

v) Kirishda qisqa tutashuv holatida:

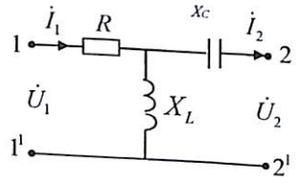
$R_{2K} = \frac{R_1R_3}{R_1+R_3} = \frac{R_2R_4}{R_2+R_4} = \frac{5/2}{3} + \frac{3/6}{5} = \frac{28}{15}\ Om$ demak: $A = \sqrt{\frac{2}{\frac{15}{8}-\frac{7}{4}}}$

(8.10), (8.11), (8.12) tenglamaga asosan:

$C = \frac{A}{R_{10}} = \frac{A}{2} = 2\left(\frac{1}{Om}\right);\quad B = \frac{A}{R_{2X}} = 4\cdot\frac{7}{4}\ (Om)$

Tekshirib ko'ramiz: $AD - BC = 4\cdot3{,}75 - 7\cdot2 = 1$

8.15-Masala. T - sxemada ulangan to'rt qutbli elektr zanjr parametri $R = X_L = 10\ Om,\ X_c = 20\ Om$ ga teng. Salt holat va qisqa tutashuv tajriba va xarakteristik tenglamasi asosida $A, B, C,$ koeffitsienti aniqlansin.



Yechish. a) to'rt qutbli elektr zanjirga $\dot{U}_1$ kuchlanish ulanib, chiqish qismida salt holat bo'lganda (8.1) tenglamadan:

$$A = \frac{\dot{U}_1}{\dot{U}_{20}} = \frac{\dot{U}_1}{\frac{\dot{U}_1}{R+jx_L}} = \frac{R+jx_L}{jx_L} = \frac{10+j10}{j10} = \frac{\sqrt{2}10e^{j45^\circ}}{10e^{j90^\circ}} = \sqrt{2}e^{-j45^\circ}$$

$$C = \frac{I_{10}}{U_{20}} = \frac{\dot{I}_1}{I_{10}\cdot jx_L} = \frac{1}{jx_L} = \frac{1}{j10} = -j0{,}1 = 0{,}1e^{-j90^\circ}\left(\frac{1}{Om}\right)$$

Chiqishda qisqa tutashuv bo'lganda :

$$B = \frac{\dot{U}_1}{I_{2q}} = \frac{\dot{U}_1}{\frac{\dot{U}_1/R}{\left(\frac{1}{R}+\frac{1}{jx_L}-\frac{1}{jx_c}\right)(-jx_c)}} = -jx_cR\left(\frac{1}{R}+\frac{1}{jx_L}-\frac{1}{jx_c}\right) = -j200(0{,}1 - j0{,}1 + j0{,}05) = 22{,}4e^{-j116^\circ}\ Om$$

$$D = \frac{\dot{I}_{1k}}{\dot{I}_{2k}} = \frac{\dot{I}_{1k}}{\frac{\dot{I}_{1k}jx_L}{jx_L-jx_c}} = \frac{j(x_L-x_c)}{jx_L-jx_c} = \frac{-j10}{j10} = -1$$

Masalaning yechimini tekshiramiz:

$$AD - BC = \sqrt{2}e^{-j45^\circ}(-1) - 22{,}4e^{-j116^\circ}\cdot0{,}1e^{j90^\circ} = -(1-j) + j0{,}1(-10+j20) = -1+j-j+2 = 1$$

b) endi xarakteristik tenglama orqali to'rt qutbli koeffitsientni aniqlaymiz.

Salt ishlash tajribasida, kirish qismida xarakteristik qarshiligi:

$$Z_{10} = R + x_L = 10 + j10 = \sqrt{2}\cdot10e^{j45^\circ}\ Om$$

qisqa tutashuvda esa:

$$Z_{1k} = R + \frac{jx_L(-x_c)}{j(X_L-X_c)} = \frac{10+j10(-j20)}{-j10}10 + j20 = 22{,}8e^{j63^\circ}\ Om$$

Kirishda qisqa tutashtirilgan holda, chiqishdagi xarakterstik qarshilik:

$$Z_{2k} = R + \frac{-jx_c+R_jX_L}{R_j+jx_L} = \frac{-j20+10\cdot j10}{\sqrt{2}e^{j45^\circ}} = -j20 + \frac{10}{\sqrt{2}}e^{j45^\circ} = -j20 + 5 + j5 = 5 - j15 = 15{,}8e^{-j71{,}5}\ Om$$

$(8.10 \div 8.13a)$ tenglamaga asosan to'rt qutbli koefitsientni topamiz:

$$A = \sqrt{\frac{(22{,}8e^{j}63^\circ)\cdot\left(10\sqrt{2}e^{j45^\circ}\right)}{(15{,}8e^{-j71{,}5})(10+j10-10+j20)}} = \sqrt{\frac{322e^{j108^\circ}}{15{,}8e^{-j71{,}5}\cdot10e^{-j90^\circ}}} = \sqrt{2\cdot e^{j270^\circ}} = 1{,}41e^{j135^\circ}$$

$$C = \frac{A}{Z_{10}} = \frac{\sqrt{2}e^{-j45^\circ}}{10\sqrt{2}e^{j45^\circ}} = -j0{,}1\left(\frac{1}{Om}\right)$$

$$B = \sqrt{2}e^{-j45^\circ}\cdot15{,}8e^{-j71{,}5} = 22{,}3e^{-j116{,}5^\circ}\ Om$$

$$D = \frac{B}{Z_{1k}} = \frac{22{,}3e^{-j116{,}5^\circ}}{22{,}36e^{j63^\circ}} = -1$$

8.16-Masala: П - sxemadagi to'rt qutbli elektr zanjirga $Z_2 = 5 + j5$ iste'molchi ulangan bo'lib, $\dot{U}_1 = 100$ V kuchlanish qo'yilgan. Tok $\dot{I}_1$ va iste'molchi kuchlanishi $\dot{U}_2$ qiymati aniqlansin.

Yechish. (8.1) tenglamadan iste'molchi kuchlanishini $\dot{U}_2 = Z_2\dot{I}_2$ inobatga olgan holda: $\dot{U}_1 = \left(A + \frac{B}{Z_2}\right)\dot{U}_2$; $\dot{I}_1 = \left(C + \frac{D}{Z_2}\right)\dot{U}_2$;

yoki: $\dot{U}_2 = \dot{U}_1\left(A + \frac{B}{Z_2}\right)^{-1} = 100\left(1 - j + \frac{10}{5\sqrt{2}e^{j45°}}\right)^{-1} =$

$= 100(1 + j + 1 - j)^{-1} = 100(2 - j)^{-2} = \frac{100}{2\sqrt{2}e^{j45°}} = \frac{50}{\sqrt{2}}e^{j45°}\ B.$

$\dot{I}_1 = \dot{U}_2\left(C + \frac{D}{Z_2}\right) = \frac{50e^{j45°}}{\sqrt{2}}\left(0{,}1 + \frac{\sqrt{2}e^{j45°}}{5\sqrt{2}e^{j45°}}\right) = \frac{50}{\sqrt{2}}e^{j45°}(0{,}1 + 0{,}2) = \frac{15}{\sqrt{2}}e^{j45°}\ A.$

8.17-Masala. T - sxema to'rt qutbli parametri $Z_1 = j2\ Om$, $Z_2 = j2\ Om$, $Z_3 = 2\ Om$, bo'lganda, (B) formadagi koeffitsientlarni toping.

Yechish. (B) ko'rinishda ifodalanuvchi to'rt qutbli tenglamaga asosan:

$\dot{I}_1 = 0$ bo'lganda $B_{11} = \frac{\dot{U}_2}{\dot{U}_1} = \frac{Z_2 + Z_3}{Z_3} = 1 - j1$

$\dot{U}_1 = 0$ bo'lganda $B_{12} = \frac{\dot{U}_2}{\dot{I}_1} = Z_1 + Z_2 + \frac{Z_1 Z_2}{Z_3} = 2\ Om$

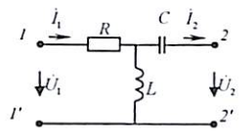
$\dot{I}_1 = 0$ bo'lganda $B_{21} = \frac{\dot{I}_2}{\dot{U}_1} = \frac{1}{Z_3} = 0{,}5\ \frac{1}{Om}$

$\dot{U}_1 = 0$ bo'lganda $B_{22} = \frac{\dot{I}_2}{\dot{I}_1} = \frac{Z_1 + Z_3}{Z_3} = 1 + j1$

Yechimini tekshiramiz: $B_{11} \cdot B_{22} - B_{12} \cdot B_{21} = \frac{Z_3^2}{Z_3^2} = 1$

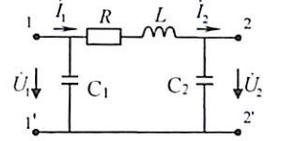
8.3. Mustaqil yechish uchun masalalar

8.1-Masala. T - sxema shaklidagi to'rt qutbli elektr zanjir qarshiligi $R = x_L = x_c = 10\ (Om)$ A, B, C, D doimiy koeffitsientni aniqlang:



Javob: $A = D = \sqrt{2}e^{-j45°}$,
$B = 10e^{-j90°}\ (Om), C = 0{,}1e^{-90°}\ \left(\frac{1}{Om}\right).$

8.2-Masala. П - sxema shaklidagi to'rt qutbli elektr zanjir parametri $\underline{Z} = (10 + j20)\ Om, \underline{Y}_1 = j0{,}1\ \left(\frac{1}{Om}\right), \underline{Y}_2 = j0{,}25\ \left(\frac{1}{Om}\right)$ doimiy A, B, C, D doimiy koeffitsientlari aniqlansin.



Javob: $A = -4 + j2{,}5;\ B = 10(1 + j2)(Om);$
$C = -0{,}05(5 + j3)\left(\frac{1}{Om}\right);\ D = -1 + j$

8.3-Masala. П − sxemadagi to'rt qutbli elektr zanjir doimiy koeffitsienti $A = -4 + j2{,}5;\ B = 10(1 + j2)(Om);\ C = -0{,}05(5 + j3)\left(\frac{1}{Om}\right);\ D = -1 + j$ bo'lganda, parametrini aniqlang.

Javob: $\underline{z}_0 = 10(1 + j2)\ (Om), \underline{Y}_1 = j0{,}1\ \left(\frac{1}{Om}\right), \underline{Y}_2 = j0{,}25\ \left(\frac{1}{Om}\right)$

8.4-Masala. (8. 1) masaladagi T - sxema bo'yicha to'rt qutbli parametri $R = \underline{x}_2 = 10\ (Om)$, $\underline{x}_c = 20\ (Om)$ to'rt qutbli kirish (1 – 1') va chiqish (2 – 2') qismlarida qisqa tutashuv va salt holat tajribalari asosida doimiy koeffitsienti aniqlansin.

Javob: $A = \sqrt{2}e^{-j45°};\ C = 0{,}1e^{-j90°}\ \left(\frac{1}{Om}\right);$
$B = 22{,}4e^{-j116°}\ Om;\ D = -1$

8.5-Masala. T - sxema shaklidagi to'rt qutbli parametri $\underline{Z}_1$=10 *(Om)*, $\underline{Z}_2$=$-j10$ *(Om)*, $\underline{Y}_0 = 0{,}1\ \left(\frac{1}{Om}\right)$ bo'lib, $\underline{Z_{ist}} = 5 - j5$ iste'molchi qarshiligi ulangan to'rt qutbli kirish qismidagi kuchlanish $\dot{U}_1 = 100\ (V)$ ga teng bo'lganda $\dot{I}_1$ va $\dot{I}_C$ tok aniqlansin.

Javob: $\dot{I}_1 = 35\sqrt{2}e^{-j45°}(A);\ , \dot{I}_2 = 5(A)$

8.6-Masala. Doimiy koeffitsienti $A_2 = 2;\ B = j10$ga teng simmetrik to'rt qutbli kirish qismidagi kuchlanish $\dot{U}_1 = 100\ (V)$ bo'lib xarakteristik qarshilikga ulangan. Xarakteristik qarshilik, uzatish koeffitsienti va $\dot{U}_2$ kuchlanishni aniqlang.

Javob: $\dot{U}_2 = 268\ (V);\ g = 1{,}32\ (Np);\ a = 0;\ b = j5{,}77\ (rad);$

8.7-Masala. Xarakteristik qarshiligi $\underline{z}_c = 100\ (Om);\ a = 0;\ b = 0{,}785\ (rad)$ bo'lgan simmetrik to'rt qutblik $\underline{Z}_{ist} = 100 + j100(Om)$ iste'molchi qarshiligiga ulangan. To'rt qutbli kirish qismidagi kuchlanish $\dot{U}_1 = 100\ (V)$ bo'lganda, ekvivalent umumiy qarshilik $\underline{z}_{um1}$va $\dot{I}_2$ tok hisoblab topilsin.

Javob: $\underline{z}_{um1} = 223{,}6e^{-j26^\circ}(Om),\ \dot{I}_2 = 0{,}632e^{-j63^\circ}\ (A)$

8.8-Masala. Simmetrik to'rt qutblida zanjirda qisqa tutashuv va salt holat tajribalari asosida quyidagilar aniqlangan:

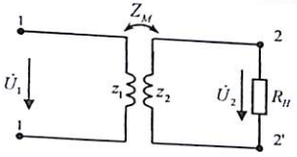
$\dot{U}_{10} = 10\ (V), \dot{I}_{20} = 1\ (A),\ P_{10} = 10\ (Vt),$

$\dot{U}_{1k} = 10\ (V), \dot{I}_{1k} = 0{,}8\ (A), P_{1k} = 8\ (Vt)$

To'tr qutbli doimiy koeffitsient aniqlanib, T - shakldagi sxemasi tuzilsin.

Javob: $A = j2;\ B = 25{,}6e^{j90^\circ}\ Om;\ C = 0{,}2e^{j90^\circ}\left(\frac{1}{Om}\right)$

8.9-Masala. Chiziqli transformator parametrlari $x_1 = x_2 = R_1 = R_2 = 10(Om)$ bo'lib, induktiv bog'lanish koeffitsienti $K = 0{,}5$ ga teng. Kirishdagi kuchlanishi $\dot{U}_1 = 184\ (V)$ bo'lib, ikkilamchi chulg'amiga $R = 10(Om)$ aktiv qarshilikga ulangan. To'rt qutbli zanjir doimiy koeffitsienti $A, B, C, D, \dot{U}_2$ - kuchlanish va kirish qismidagi $\underline{Z}_{um}$ - qarshilik aniqlanib, T - ekvivalent sxemasi tuzilsin.



Javob: $A = 2 - j2;\ B = 40 - j5(Om);$
$C = -0{,}2\left(\frac{1}{Om}\right);\ D = 2 - j2;,$
$Z_{um} = 14{,}6e^{-j14^\circ}(Om);\ \dot{U} = 28{,}4\ (V)$

8.10-Masala. To'rt qutbli transformator $A = \frac{1}{3}(-5 + j);\ B = -\frac{1}{3}(10 + j15)(Om);\ C = \frac{j}{3}\left(\frac{1}{Om}\right)$ teng va $f = 50 \cdot 10^3(Gs)$ bo'lganda transformatorning parametrlari aniqlansin.

Javob: $R_1 = R_2 = 1\ (Om);\ L_1 = L_2 = -10^{-4}(Gn);\ M = 0{,}6 \cdot 10^{-4}(Gn)$

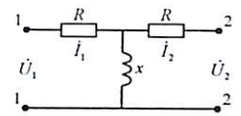
8.11-Masala. To'rt qutblining parametri $R_{12} = x = 1\ (Om)$ bo'lib, salt holat va qisqa tutashuv tajribalari asosida quyidagilar aniqlangan:

1) $\dot{U}_2 = 1\ (V);\ \dot{I}_2 = 2\ (A);\ \cos\varphi_2 = 0{,}8;\ \varphi_2 > 0;$

2) $\dot{U}_2 = 10\ (V); \dot{I}_2 = 10\ (A); \cos\varphi_2 = 0{,}8;\ \varphi_2 < 0;$

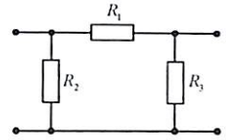
3) $\dot{U}_2 = 5\ (V);\ \dot{I}_2 = 1\ (A);\ \cos\varphi_2 = 1;\ \varphi_2 < 0;$

To'rt qutbli kirish qismidagi tok $\dot{I}_1$ va kuchlanish $\dot{U}_2$ aniqlansin.



Javob: 1) $\dot{U}_1 = 12{,}5\ (V); \dot{I}_1 = 8{,}05\ (A);$
2) $\dot{U}_1 = 32{,}5\ (V); \dot{I}_1 = 18{,}4\ (A);$
3) $\dot{U}_1 = 8{,}05\ (V); \dot{I}_1 = 6{,}08\ (A);$

8.12-Masala. П - sxemada ulangan to'rt qutbli zanjir parametrlari $R_1 = 450\ Om,\ R_2 = 1800\ Om,\ R_3 = 900\ Om$ bo'lganda, doimiy koeffitsienti aniqlansin.



Javob: $A = 1{,}5,\ B = 450\ Om,$
$C = 1{,}95 \cdot 10^{-3}\frac{1}{Om}, D = 1{,}25$

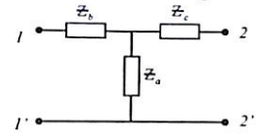
8.13-Masala. Nosimmetrik to'rt qutbli koeffitsientlari $A = 1;\ B = 2{,}83e^{j45^\circ}\ Om,\ C = j0{,}5\ sm,\ D = j1$ ga teng. Xarakteristik qarshiligi va uzatish koeffitsienti aniqlansin.

Javob: $Z_{s_1} = \pm 2{,}38e^{-j67{,}5}Om;\ Z_{s_2} = \pm 2{,}38e^{j22{,}5}Om,$
$g = 0{,}765 + j1{,}0\ (\alpha = 0{,}765\ nep,\ \beta = 1rad)$

8.14–Masala. Simmetrik to'rt qutbli zanjir $\dot{U}_1 = 100\ (V)$ kuchlanishga ulangan. Ikkilamchi parametri $Z_s = 100\ Om;\ a = 0;\ \beta = 0{,}785\ rad$ bo'lib, $Z_s = 100 + j \cdot 100\ Om$ qarshilikga ulanganda, kirish qismidagi qarshilik Z_1 va I_2 tok qiymati aniqlansin:

Javob: $Z_1 = 223{,}6e^{-j26{,}6^\circ};\ \dot{I}_2 = 0{,}632e^{-j63:5^\circ}$

8.15-Masala. T - sxemada ulangan to'rt qutbli elektr zanjir parametri: $Z_a = 30 - j40\ Om;\ Z_b = Z_c = 12 + j16\ Om.$ So'nish koeffitsienti a va faza koeffitsienti b aniqlansin.



Javob: $a = 0{,}562\ nep,\ b = 0{,}703\ rad.$

Nazorat savollari

1. To‘rt qutbli elektr zanjir nima? Asoslab bering.
2. Elektr zanjirni to‘rt qutbli ko‘rinishida ifodalash bilan qanday masalalar yechiladi?
3. To‘rt qutbli elektr zanjir doimiy koeffitsienti nechta?
4. Aktiv va passiv to‘rt qutbli nima? Amalda qanday elektrotexnik uskuna va sxemalar misol bo‘la oladi?
5. Elektr energiyasi uzatish liniyasi to‘rt qutblimi?
6. Passiv to‘rt qutbli kirish $(\dot{I}_1, \dot{U}_1)$ va chiqish $(\dot{I}_1, \dot{U}_1)$ qismidagi tok va kuchlanish bog‘lanishini ifodalovchi tenglamani yozing.
7. To‘rt qutbli A, B, C, D koeffitsientlar bog‘lanish tenglamasini yozing.
8. To‘rt qutbli qanday holatda simmetrik bo‘ladi?
9. To‘rt qutbli almashinish (ekvivalent) sxemasi bo‘yicha parametrini aniqlash tenglamasini yozing.
10. To‘rt qutbli parametri qanday aniqlanadi?
11. To‘rt qutbli qanday sxemada ulanadi va qaysi turdagi (formadagi) tenglamadan foydalaniladi?
12. To‘rt qutbli elektr zanjirning chiqish qismidagi to‘la qarshiligi uzatish va tutashtiruv tajribasiga asosan $(\underline{Z}_{20}, \underline{Z}_{2K})$ doimiy koeffitsientlari bilan bog‘lanish tenglamasini yozing.
13. To‘rt qutbli elelktr zanjirining kirish qismidagi to‘la qarshilik uzilgan va qisqa tutashtirilgan tajribasiga o‘tqazilganda $(\underline{Z}_{10}, \underline{Z}_{1K})$ doimiy koeffitsient bilan ifodalanish tenglamasini yozing.
14. Parametri T, Π, Γ shaklda ulangan to‘rt qutbli sxemani chizing va doimiy koeffitsient bilan bog‘lanish tenglamasini yozing.
15. Simmetrik to‘rt qutblida tajriba o‘tqazish (salt holat, qisqa tutashtirish) natijasida kirish qismidagi kompleks qarshilik: $\underline{Z}_{10}=10e^{-j90}$ *Om*, $\underline{Z}_{1K}=10e^{-j30}$ *Om* bo‘lganda, A – doimiy koeffitsient qiymati nimaga teng?
16. Differensiallovchi yoki integrallovchi to‘rt qutbli sxemani chizing va ta’riflab bering.
17. Chastotaviy elektr filtr nima va qaysi maqsadda foydalaniladi?
18. Aktiv to‘rt qutbli elektr zanjirining kirish qismidagi R_1 aktiv quvvatga nisbatan, chiqish qismidagi R_2 aktiv quvvat katta bo‘lishi mumkinmi?

19. П shaklida ulangan to‘rt qutbli elektr zanjir parametri: R_1=450 *Om*, R_2=1800 *Om*, R_3=900 *Om* ga teng. Doimiy koeffitsient qiymati nimaga teng?
20. П shaklida ulangan to‘rt qutbli elektr zanjir kirish qismidagi kuchlanish $U_1 = 60(V)$ bo‘lib, $R_2 = 1000\,Om$ iste’molchiga ulangan. Chiqish qismidagi U_2 kuchlanish va I_2 tok aniqlansin
21. Simmetrik to‘rt qutbli tavsifiy tenglamasi uzatish koeffitsienti ifodalari ma’nosini tushuntiring.
22. To‘rt qutbli uzatish koeffitsienti qanday ifodalanadi?

9. ELEKTR FILTR

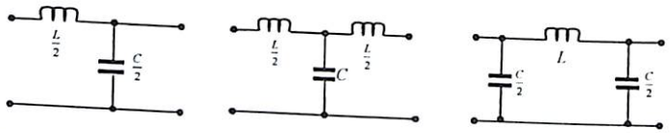
9.1. Asosiy nazariy tushunchalar

Reaktiv elementlardan tarkib topgan to‘rt qutbli zanjirsimon chastota ajratuvchi elektr filtr radiotexnika, aloqa, avtomatika va boshqa sohalarda keng foydalaniladi. Elektr filtrlarining turlicha elektr signallarini kuchaytirish, pasaytirish, tekislash yoki chegaralash xususiyatlariga ega bo‘lishi induktivlikning past chastotaga qarshiligi kichik, sig‘imda esa qarshiligi yuqori yoki aksincha ekanligi sabab bo‘ladi.

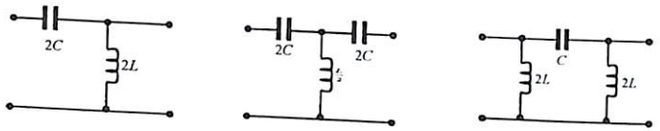
Chastota ajratuvchi filtrlarning ishlash prinsipi L va C qarshilikning (o‘tkazuvchanliklari) signal chastotasi ω ga bog‘liq holda o‘zgarishga asoslangan bo‘lib, turli xildagi – Γ, T, Π sxemalarda ulash bilan signallar maqsadli filtrlanadi.

Shuni ta’kidlash kerakki, chastota ajratuvchi filtrlarning reaktiv elementlar L, C dan tuzilishiga asosiy sabab aktiv energiya isrofi minimal bo‘lishidadir.

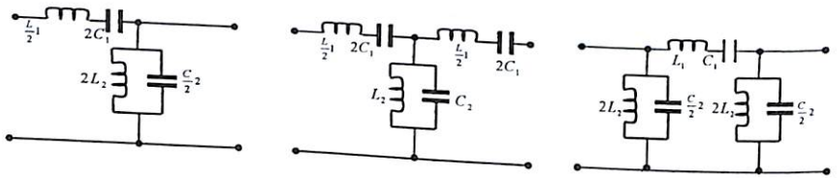
Elektr filtr vazifasi va sxemasining tuzilishi jihatdan quyi chastotali, yuqori chastotali, hududli (chastotalararo) va to‘suvchi filtrlarga bo‘linadi:



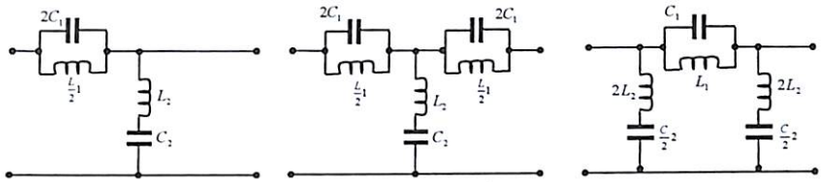
a) quyi chastotali



b) yuqori chastotali



d) hududli



e) to‘suvchi.

Past chastotali filtrlar tok chastotasini

$$0 \div f_0 \text{ gacha } \left(0 \le f \le \frac{1}{\pi\sqrt{(LC)}}\right)$$

Yuqori chastotali filtr $f_0 \div \infty$ gacha $\left(\frac{1}{4\pi\sqrt{LC}} \le f \le 0\right)$ o‘tkazadi.

Hududiy filtrlar esa: f_1 va f_2 gacha $f_{1,2} = \frac{1}{2\pi}\left(\sqrt{\frac{1}{L_2C_2} + \frac{1}{L_1C_1}} \mp \frac{1}{\sqrt{L_1C_2}}\right)$ tok chastotasini oraliqda chegaralaydi.

To‘sib qoluvchi filtr $0 \div f_0$ va $f_0 \div \infty$ gacha

$f_{1,2} = \frac{1}{8\pi}\left(\sqrt{\frac{1}{L_2C_1} + \frac{16}{L_1C_2}} \mp \frac{1}{\sqrt{L_2C_1}}\right)$ bo‘lgan tok chastotasini o‘tkazadi.

Odatda hududiy yoki to‘suvchi elektr filtrda $L_1C_1 = L_2C_2$ shart bajarilishi kerak.

Elektr filtr kaskadli zanjirsimon to‘rt qutbli reaktiv elementlardan tuzilgan sxemalar bo‘lib, chiqish yoki keyingi filtrga kiruvchi tavsifiy qarshilik Z_S ga teng bo‘ladi.

Bunda filtrdan chiquvchi tok va kuchlanish kompleks ifodasi $e^{ng} = e^{na} \cdot e^{jnb}$ bo‘lib, moduli kirishdagi signalga nisbatan e^{na} marta kichik bo‘ladi.

n – zanjirsimon sxemada ulangan filtrlar soni, α – chastotaga bog‘liq to‘rt qutbli **so‘nish koeffitsienti bo‘lib,** (8.18) tenglamaga asosan:

$$A = ch = ch(\alpha + jb) \quad (9.1)$$

$$T \text{ – sxema uchun: } A = 1 + \frac{y_T Z}{2} \quad (9.2)$$

$$\Pi \text{ – sxema uchun: } A = 1 + \frac{y_0 Z}{2} \quad (9.3)$$

(9.2), (9.3) y, z mavhum son bo‘lib, A koeffitsient mavhum son bo‘la olmaydi, shunga asosan:

$$A = ch(\alpha + jb) = cha\cos b + jsha\sin b \quad (9.4)$$

$$\text{ya’ni: } sha\sin b = 0 \quad (9.5)$$

$$cha\cos b = A = 1 + \frac{yZ}{2} \quad (9.6)$$

Bu tenglamadan chastota o‘zgarishi bilan $-y, z$ parametr ikki holatda bo‘ladi.

a) agar $sha = 0$ bo‘lganda, $\alpha = 0$ bo‘lib, $cha = 1$.

Shunga asosan: $\cos b = A + \frac{yZ}{2}$ (9.7)

Tenglamada y, z qiymatlar bir xil mavhum son bo‘lib, chastotaviy chegarasi:

$-1 \le 1 + \frac{yZ}{2} \le +1$, unda chastota o‘tkazish chegaralari:

$$\begin{matrix} -yZ = \{0 \\ -yZ = \{4. \end{matrix} \quad (9.7a)$$

Agarda: $\frac{Z}{2} + \frac{2}{y} = 0$ bo‘lsa, bundan $yz + 4 = 0$ bo‘lib, **filtr rezonans holatda bo‘ladi.**

Tavsifiy qarshilik tenglama ham chastotaga bog‘liq bo‘lib, to‘rt qutbli koeffitsientlar orqali quyidagicha bog‘langan:

T – sxema bo‘lganda: $Z_{ST} = \sqrt{\frac{B}{C}} = \sqrt{\frac{A^2-1}{C^2}}$;

Π – sxema uchun: $Z_{S\Pi} = \sqrt{\frac{B}{C}} = \sqrt{\frac{B^2-1}{A^2-1}}$

yoki: $Z_{sT}\ va\ Z_{s\Pi}$ tavsifiy qarshilikni to‘rt qutbli koeffitsient orqali ifodalash bilan (9.2), (9.3) tenglamaga asosan:

$$Z_{ST} = \sqrt{\frac{A^2-1}{y_T^2}} = \sqrt{\frac{Z}{y}}\sqrt{1 + \frac{yZ}{4}}; \quad (9.8)$$

$$Z_{S\Pi} = \sqrt{\frac{Z_P^2}{A^2-1}} = \sqrt{\frac{Z}{y}}\sqrt{1 + \frac{yZ}{4}}; \quad (9.9)$$

(9.8), (9.9) formuladan chegaraviy hududlari: $0 \le -Zy \le 4$

Chastotaviy chegara T sxema uchun: $0 \div Z_S = \sqrt{\frac{Z}{y}} = \sqrt{\frac{B}{C}}$

Π sxema uchun: $Z_S \div \infty$ gacha bo‘lib $Z_S = R$

Elektr filtr chastotani chegaralashda, chastota o‘zgarishiga nisbatan faza koeffitsienti ham o‘zgaradi. (8.15) tenglamani (8.18) tenglamaga qo‘yish bilan

$$sh = sh(a + jb) = CZ_c = \frac{B}{Z_c}$$

Bunda: $b = 0$: $j \sin b = Cz_c = y_T Z_{ST}$; yoki $j \sin b = \frac{B}{Z_S} = \frac{Z_p}{Z_{cp}}$.

Faza koeffitsienti ishorasi o‘tkazuvchanlik parametri bilan bog‘liq ekan.

b) endi (9.5) tenglamadan $sha \sin b = 0$, $\sin b = 0$, bo‘lganda, $sha \ge 1$ bo‘lib, $\cos b = -1$ Unda (9.6) dan $cha = -A\left(1 + \frac{yZ}{4}\right)$ (9.10)

So‘nish koeffitsienti $b = 0$, signalni filtrlash chegarasi:

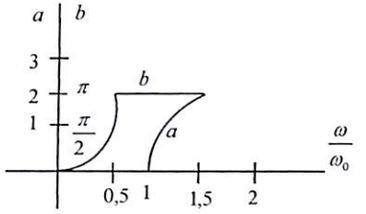
$$\left.\begin{matrix} 1 \le -\left(1 + \frac{yZ}{4}\right) \le \infty \\ yoki \quad -yZ = 4 \\ \quad\quad -yZ = \infty \end{matrix}\right\}$$

Bu esa filtr sxemasining $R = 0$; $y = \infty$ ekanligini belgilaydi.

Bu holda: $A^2 - 1 = ch^2 a - 1 \ge 0$ bo‘lib, (9.8), (9.9) tenglamaga asosan so‘nish chegarasida tavsifiy qarshilik mavhum son bo‘lib, T va Π filtr sxema uchun ishorasi har xil bo‘ladi.

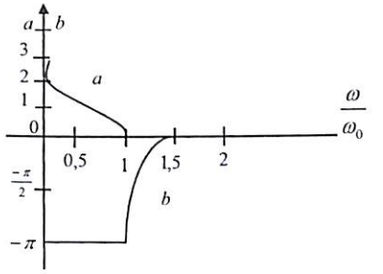
Tahlil qilingan elektr filtr xususiyatlariga asosan:

a) quyi chastotali filtr: T - sxemadan $z = j\omega L$, $y = j\omega c$ bo‘lganda, filtrlash chegarasi (9.7a) asosan $-yZ = \omega^2 LC = \begin{matrix}\{0 \\ 4\end{matrix}$



Demak: $\omega_1 = 0$; $\omega = \frac{2}{\sqrt{LC}} = \omega_0$

b) yuqori chastotali filtr: T - sxema reaktiv qarshilik parametri $Z = \frac{1}{j\omega c}$; $y = \frac{1}{j\omega L}$ bo‘lib, $-YZ = \frac{1}{\omega^2 LC} = \begin{matrix}\{0 \\ 4\end{matrix}$ filtrlash chegarasi $\omega_1 = \frac{1}{2\sqrt{LC}} = \omega_0$ va $\omega_2 = \infty$ gacha bo‘ladi.



d) hududiy filtr: Yuqorida keltirilgan shartga asosan: $L_1C_1 = L_2C_2$ bo‘lib,

$$\omega_0 = \frac{1}{\sqrt{L_1C_1}} = \frac{1}{\sqrt{L_2C_2}}$$

yoki: $Z = j\omega L_1 + \frac{1}{j\omega c_1} = \frac{1}{j\omega c_1}(1 - \omega^2 L_1C_1) = \frac{1}{j\omega c_1}\left(1 - \frac{\omega^2}{\omega_0^2}\right)$

$$y = j\omega L_2 + \frac{1}{j\omega c_2} = \frac{1}{j\omega L_2}\left(1 - \frac{\omega^2}{\omega_0^2}\right)$$

Keltirilgan tenglamalar quyidagi chegarada ifodalanadi

$$-ZY = \frac{\left(1-\frac{\omega^2}{\omega_0^2}\right)^2}{\omega^2 L_2C_1} = \begin{cases}0\\4\end{cases}$$

bundan: $\omega^2 \pm 2\omega\omega_0^2\sqrt{L_2C_1} - \omega_0^2 = 0$

$\omega_1 = \omega_0\left(\sqrt{k^2+1} - k\right); \omega_2 = \omega_0\left(\sqrt{k^2+1} + k\right); k = \omega_0\sqrt{L_2C_1} = \sqrt{\frac{L_2}{L_1}}$

Demak filtr chastotani $\omega_1 \div \omega_2$ oraliqda chegaralaydi. ω_0 esa oraliq chastotani ifodalaydi, ya’ni: $\omega_1\omega_2 = \omega_0^2$

e) to‘suvchi filtr:

Bu filtr sxemasidan yuqoridagi shartlarga asosan:

$$L_1C_1 = L_2C_2 \text{ va } \omega_0 = \frac{1}{\sqrt{L_1C_1}} = \frac{1}{\sqrt{L_2C_2}}.$$

$$Z = \frac{1}{j\omega c_1 + \frac{1}{j\omega L_1}} = \frac{j\omega L_1}{1-\frac{\omega^2}{\omega_0^2}}; y = \frac{1}{j\omega L_2 + \frac{1}{j\omega c_2}} = \frac{j\omega c_2}{1-\frac{\omega^2}{\omega_0^2}}$$

Chastotani to‘sish chegarasi esa:

$$-ZY = \frac{\omega^2 L_1C_1}{\left(1-\frac{\omega^2}{\omega_0^2}\right)^2} = 0 \qquad -YZ = \frac{\omega^2 L_1C_2}{\left(1-\frac{\omega^2}{\omega_0^2}\right)^2} = 4\,.$$

Birinchi tenglama ikkita qiymat beradi: $\omega_1 = 0$; $\omega_4 = \infty$. Ikkinchisi: $\omega_2 = \omega_0\left(\sqrt{k^2+1} - k\right)$; uchinchisi: $\omega_3 = \omega_0\left(\sqrt{k^2+1} + k\right)$

Bunda: $k = \frac{\omega_0\sqrt{L_1C_2}}{4} = \frac{1}{4}\sqrt{\frac{L_1}{L_2}}$

Demak filtr chastotani $0 \div \omega_2$ va $\omega_3 \div \infty$ o‘tkazib, chastotani to‘sish chegarasi: $\omega_2 \div \omega_3$ ga teng yoki: ω_0 – chegara ichida bo‘lib:

$$\omega_0^2 = \omega_2\omega_3.$$

9.2. Masalalar yechish va uslubiy ko‘rsatmalar

9.1-Masala. T sxemadagi filtr parametrlari $L = 20\,mgn$, $C = 20\,mkf$ bo‘lganda chastota o‘tkazish chegaralari aniqlanib, $\omega = 2000\,{}^{rad}/_{sek}$ va tok $I_2 = 0{,}1\,A$ bo‘lganda so‘nish koeffitsient a topilsin.

Yechish. T sxema uchun (9.2) ifodaga asosan:

$$A = 1 + \frac{Z_1}{Z_3} = 1 + j\omega L \cdot j\omega c = 1 - \omega^2 LC$$

Agarda $A = 1$; bo‘lsa $\omega_1 = 0$;

yoki $A = -1$ bo‘lganda; $-1 = 1 - \omega^2 LC$; (1)

Bundan: $\omega_2 = \sqrt{\frac{2}{LC}} = 2235\,{}^{rad}/_{sek}$

Chastotani filtrlash chegarasi: $b = \arccos A = \arccos(1 - \omega^2 LC)$.

Chastota $\omega = 2000\,{}^{rad}/_{sek}$ bo‘lganda, tavsifiy qarshilik:

$$Z_c = \sqrt{\frac{2L}{C} - \omega^2 L^2} = 80\ om.$$

filtr tavsifiy qarshiligi 80 Om bo‘lganda chiqishdagi kuchlanishi:

$$U_2 = I_2 Z_c = 0{,}1 \cdot 80 = 8\,V.$$

So‘nish koeffitsient a chastotaga nisbatan o‘zgarishini topish uchun (9.1) tenglamadan $cha = -A = \omega^2 LC - 1$

Bundan $\omega = 2\omega_2 = 2 \cdot 2235 = 4470\,{}^{rad}/_{sek}$ teng bo‘lganda:

$cha = (4470) \cdot 20 \cdot 10^{-3} \cdot 20 \cdot 10 - 1 = 8, \qquad a = 2{,}8\ nep.$

9.2-Masala. K turdagi quyi chastotali filtr yuqori chegaralash chastotasi $f_0 = 0{,}5\,kgts$ bo‘lib, $R = 500\,Om$ iste’molchi qarshiligiga ulangan.

a) filtr parametri L, C, $f_1 = 1\,kgts$ bo‘lgan so‘nish koeffitsienti a kirish va chiqishdagi kuchlanishga nisbatan qiymatlari $nep, detsb$ o‘lchamlari topilsin; b) ekvivalent sxemasi tuzilsin.

Yechish. K turdagi quyi chastotali filtrlarning yuqori chastota chegarasi quyidagicha ifodalanadi .

$L = \frac{R}{\pi f_0} = 0{,}317\ gn, \quad C_0 = \frac{1}{\pi f_0 R} = 1{,}27\ mkf.$

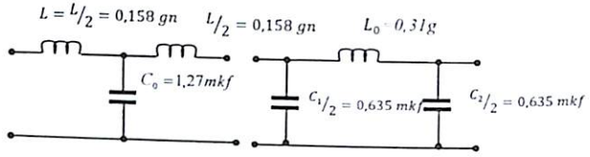
So‘nish koeffitsienti $f_1 = 1\,kgts$ bo‘lganda $ch\mathrm{L} = 2\eta_1^2 - 1$;

Bundan $\eta = \frac{\omega_1}{\omega_0} = \frac{f_1}{f_0} = 2$:

Demak: $ch\alpha = 7, \quad \alpha = 2{,}64$ nep $= 22{,}9$ dtsb.

Bundan: $\alpha = \ell n \frac{U_1}{U_2}$ yoki $\frac{U_1}{U_1} = e^{\alpha} = 14$

Ekvivalent sxema T yoki П ko‘rinishda bo‘ladi:



9.3-Masala. T sxemada filtr parametri $C_3 = 0{,}08\ mkf$ va $L_2 = 0{,}02\ gn$ bo‘lganda, filtrlash chegarasi aniqlanib, iste’molchi qarshilik R_2ning qaysi chastota formasi buzilmasligi va chastotaning $f_1 = 0$; $f_2 = \frac{f_s}{2}$; $f_3 = 0$; $f_4 = 2f_s$ $(f_s - rezonans\ chastota)$ qiymatida tavsifiy qarshiligi Z_C va so‘nish koeffitsienti a aniqlansin.

Yechish. Masalaning shartiga ko‘ra T sxema quyi chastotali filtr bo‘lib, filtrlash oralig‘i tenglamaga asosan: $-1 \le \frac{Z_1}{yZ_2} \le 0$

Bunda: $Z_1 = j\omega L\ va\ Z_2 = \frac{1}{j\omega c.}$

Shunga asosan quyi chegarasi $f_1 = 0$ dan yuqori chegarasi $f_s = \frac{1}{\pi\sqrt{LC}} = 8000\ gs$ oralig‘ida chastota filtrlanadi.

T sxema uchun tavsifiy qarshilik tenglamasi:

$$Z_c = \sqrt{Z_1 Z_2 \left(1 + \frac{Z_1}{yZ_2}\right)} = R_c \sqrt{1 - \left(\frac{f}{f_c}\right)^2}$$

Bunda: $R_C = \sqrt{\frac{L}{C}}$ filtrlarning tavsifiy qarshilik tenglamasi.

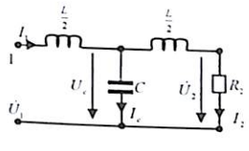
Filtr so‘nishini ifodalovchi tenglama: $ch\frac{a}{2} = \sqrt{\frac{x_1}{4x_2}} = \sqrt{\frac{\omega^2 LC}{4}} = \frac{f}{f_c}$

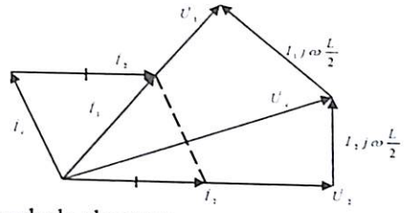
Qiymatlarini jadval asosida keltiramiz.

$f(gs)$	0	$f_s/2$	f_s	$2f_s$
$Z_C\ Om$	500	433	0	$j865$
$a.(nep.)$	0	0	0	2,64

Shuni ta’kidlash kerakki, filtrning $f = 0$ dan $f = f_c$ filtrlash chegaralarida tavsifiy qarshilik qiymati haqiqiy, so‘nish chegarasida esa mavhum son qiymatiga ega. Demak T - shakldagi quyi chastota filtrlash hususiyati xarakteristik tenglamaning $Z_c = R_c$ dan $Z_s = 0$ oralig‘ida bo‘lar ekan.

9.4-Masala. T - sxema shaklidagi quyi chastotali xarakteristik parametri $L = 0{,}02$ gn, $C = 8\ mkf$ bo‘lib, R_2 qarshiligiga $U_2 = 13\ B$ kuchlanish ulangan. Chastota filtrlash chegarasi $\omega_1 = \frac{\omega_0}{2}$, va so‘nish $\omega_2 = 2\omega_0$ bo‘lganda tok va kuchlanish qiymati aniqlanib, vektor ifodasi tuzilsin:





Yechish. Rezonans holatda burchak chastota:

$\omega_0 = \frac{2}{\sqrt{LC}} = \frac{2}{\sqrt{0{,}02 \cdot 8 \cdot 10^{-6}}} = 500\ ^{rad}/_{sek}$

Demak: $\omega_1 = 250\ ^{rad}/_{sek};\quad \omega_2 = 10^4\ ^{rad}/_{sek}$

Salt yoki qisqa tutashuv tajribasiga asosan xarakteristik qarshilikni topamiz:

$$Z_{1x} = j\omega_1 \frac{L}{2} + \frac{1}{j\omega_1 C} = j25 - j50 = -j25\ Om$$

$$Z_{1k} = jx_L \frac{jx_L \cdot jx_c}{j(x_L - jx_c)} = j25 + \frac{j25(-j50)}{j25 - j50} = j75\ Om$$

Tavsifiy qarshiligi: $R_2 = Z_0 = \sqrt{Z_{1x} \cdot Z_{1k}} = 25\sqrt{3}\ Om.$

Tok: $\dot{I}_2 = \frac{\dot{U}_2}{R_2} = \frac{13}{25\sqrt{3}} 0{,}3\ A.$

Filtr sxemasidan: $\dot{U}_c = \dot{U}_2 + j\omega \frac{L}{2} \dot{I}_2 = (13 + j7{,}5)V$

$\dot{I}_c = \frac{\dot{U}_c}{-jx_c} = \frac{13+j7{,}5}{-j50} = (-0{,}15 + j0{,}26)\ A$

Kirish qismidagi tok:

$\dot{I}_1 = \dot{I}_2 + \dot{I}_c = 0{,}3 - 0{,}15 + j0{,}26 = 0{,}15 + j0{,}26 = = 0{,}3e^{j60^\circ} A$

Kuchlanish:

$\dot{U}_1 = U_c + j\omega_1 \frac{L}{2} I_1 = 13 + j7{,}5 + j25(0{,}15 + j0{,}26) = 6{,}5 + j11{,}25$

$= 13e^{j60^\circ} V$

So‘nish chegarasi $\omega_2 = 10^4\ ^{rad}/_{sek}$ bo‘lganda, tok va kuchlanish qiymatini topamiz.

$$\dot{U}_c = \dot{U}_2 + j\omega_2 \frac{L}{2}\dot{I}_2 = 13 + j100 \cdot 0{,}3 = (13 + j30)\ V$$

$$\dot{I}_c = \frac{\dot{U}_c}{jx_c} = \frac{13 + j30}{-j12{,}5} = (-2{,}4 + j1{,}04)\ A$$

$$\dot{I}_1 = \dot{I}_2 + \dot{I}_c = 0{,}3 - 2{,}4 + j1{,}04 = -2{,}1 + j1{,}04 \approx 2{,}34e^{j153^\circ} A$$

$$\dot{U}_1 = \dot{U}_c + j\omega_2 \frac{L}{2}\dot{I}_1 = 13 + j30 - j210 - 104 = -91 - j180$$

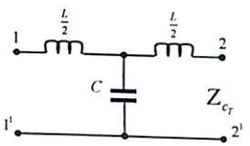
$$\approx 202, e^{j117^\circ} \text{V}$$

9.5-Masala. Quyi chastotali (K turdagi) T va П sxemadan iborat bo'lgan elektr filtr burchak chastotasi $\omega_0 = 3{,}14 \cdot 10^{-3}\ \frac{1}{sek}$ bo'lib, $R_c = R_2 = 0{,}5 \cdot 10^{-3}\ Om$ tavsifiy aktiv qarshilikga ulangan.

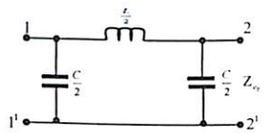
a) elektr filtr parametrlari L, C.

b) chastotani filtrlash chegarasi $\omega = 0{,}5 \cdot \omega_0$ bo'lganda, tavsifiy qarshiligi Z_{st}, Z_{sp} faza koeffitsienti $b/2$.

d) $\omega = 1{,}5\omega_0$ bo'lganda (chastotani to'sishda) so'nish koeffitsienti $b/2$ qiymati aniqlansin.



a)



b)

Yechish.

a) quyi chastotali T - shakldagi elektr filtr parametri yuqori chegarasini aniqlaymiz:

$$L = \frac{2R}{\omega_0} = \frac{2 \cdot 0{,}5 \cdot 10^3}{3{,}14 \cdot 10^3} = 0{,}318 gn, C = \frac{2}{\omega_{0R}} = \frac{2}{3{,}14 \cdot 10^3 \cdot 0{,}5 \cdot 10^3}$$
$$= 1{,}274 \cdot 10^{-6}\ f$$

b) K turdagi elektr filtr tavsifiy qarshiligi:

$$K = Z_c = \sqrt{\frac{L}{C}} = \sqrt{\frac{0{,}318}{1{,}27 \cdot 10^{-6}}} = 0{,}5 \cdot 10^3\ Om.$$

d) filtr chastotasi $\omega = 0{,}5\omega_0 = 1{,}57 \cdot 10^3\ \frac{1}{sek}$ bo'lganda, filtr reaktiv qarshiligini aniqlaymiz:

$$X_L = \omega\left(\frac{L}{2}\right) = 1{,}57 \cdot 10^3 \cdot \frac{0{,}318}{2} = 250\ Om;$$

$$X_c = \frac{1}{\omega\left(\frac{C}{2}\right)} = \frac{0{,}318}{1{,}57 \cdot 10^3 \cdot \frac{1}{2} 1{,}27 \cdot 10^{-6}} = 1000\ Om;$$

e) endi $\omega = 0{,}5\omega_0$ bo'lganda quyi chastotani filtrlar tenglamasiga asosan T, П sxema tavsifiy qarshiligini aniqlaymiz:

$$Z_{CT} = K\sqrt{1 - \left(\frac{\omega}{\omega_0}\right)^2} = 0{,}5 \cdot 10^3 \cdot \sqrt{1 - \left(\frac{0{,}5 \cdot \omega_0}{\omega_0}\right)^2} = 0{,}433 \cdot 10^3\ Om;$$

$$Z_{C\Pi} = \frac{K}{\sqrt{\left(\frac{\omega}{\omega_0}\right)^2}} = \frac{0{,}5 \cdot 10^3}{\sqrt{1 - \left(\frac{0{,}5 \cdot \omega_0}{\omega_0}\right)^2}} = 0{,}577 \cdot 10^3\ Om.$$

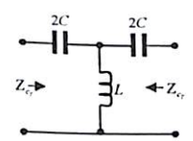
f) chastota o'tkazish chegarasi $\omega = 0{,}5\ \omega_0\ \frac{1}{sek}$ bo'lganda, so'nish koeffitsienti $\frac{a}{2} = 0$ bo'lib, faza koeffitsienti:

$$\frac{b}{2} = arc\sin\frac{\omega}{\omega_0} = arc\sin 0{,}5 = 30^\circ$$

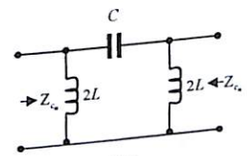
g) $\omega = 1{,}5\ \omega_0 = 4{,}77 \cdot 10^3\ \frac{1}{sek}$, chastotani to'sish chegarasida, so'nish koeffitsienti: $\frac{a}{2} = arcch\frac{\omega}{\omega_0} = arcch1{,}5 = 0{,}963\ NP =$ 8,345 Db. ($1\ NP = 8{,}686\ Db$)

Faza koeffitsienti: $\frac{b}{2} = 90°$

9.6-Masala. K - turdagi yuqori chastotali filtr burchak chastotasi $\omega = 3{,}14 \cdot 10^3\ \frac{1}{sek}$ bo'lib, $R = Z_c = 2 \cdot 10^3\ Om$, $\left(R = K = \sqrt{\frac{L}{C}}\right)$ tavsifiy qarshiligi ulangan. Filtr o'tkazish chegarasi $\omega = 1{,}5\ \omega_0$ bo'lganda, tavsifiy qarshilik qiymati $Z_{CT}, Z_{C\Pi}$ va faza koeffitsienti $b/2$ hamda to'sish chegarasi va $\omega = 0{,}5\ \omega_0$ bo'lganda so'nish koeffitsienti $a/2$ qiymati aniqlansin.



a)



b)

Yechish.

a) yuqori chastotali filtr parametrini (9.10) ifodaga asosan:

$$L = \frac{R}{2\omega_0} = \frac{2 \cdot 10^3}{2 \cdot 3{,}14 \cdot 10^3} = 0{,}318\ gn;$$

$$C = \frac{1}{2\omega_0 R} = \frac{1}{2 \cdot 3{,}14 \cdot 10^3 \cdot 2 \cdot 10^3} = 0{,}0795 \cdot 10^{-6}\, f$$

b) K - turdagi yuqori chastotali filtr tavsifiy qarshiligi:

$$K = Z_c \sqrt{\frac{L}{C}} = \sqrt{\frac{0{,}318}{0{,}08 \cdot 10^{-6}}} = 2 \cdot 10^3\ Om.$$

d) $\omega = 1{,}5\omega_0 = 1{,}5 \cdot 3{,}14 \cdot 10^3 = 4{,}7 \cdot 10^3 \frac{1}{sek}$ bo‘lganda filtr reaktiv qarshiliklarini topamiz:

$$X_c = \frac{1}{\omega(2c)} = \frac{1}{4{,}7 \cdot 10^3 \cdot 2 \cdot 0{,}08 \cdot 10^{-6}} = 1335\ Om;$$

$$X_L = \omega(2c) = 4{,}7 \cdot 10^3 \cdot 2 \cdot 0{,}3 = 3000\ Om.$$

e) П sxemadagi filtr chastota o‘tkazish chegarasidagi tavsifiy qarshilik qiymatini ($\omega = 1{,}5\omega_0$) aniqlaymiz:

$$Z_{CT} = K \cdot \sqrt{1 - \left(\frac{\omega_0}{\omega}\right)^2} = 2 \cdot 10^3 \sqrt{1 - \frac{\omega_0}{1{,}5\omega_0}} = 1{,}5 \cdot 10^3\ Om.$$

$$Z_{C\Pi} = \frac{K}{\sqrt{1-\left(\frac{\omega_0}{\omega}\right)^2}} = \frac{2 \cdot 10^3}{\sqrt{\left(1-\frac{\omega_0}{1{,}5\omega_0}\right)}} = 2{,}7 \cdot 10^3\ Om.$$

f) chastota o‘tkazish chegarasi:

$\omega = 1{,}5\omega_0 = 4{,}7 \cdot 10^3 \frac{1}{sek}$ bo‘lganda, so‘nish koeffitsienti $a/2 = 0$ faza koeffitsienti:

$$b/2 = arc\sin\left(-\frac{\omega_0}{\omega}\right) = arc\sin\left(\frac{1}{1{,}5}\right) = -42°$$

Chastotani to‘sish chegarasi: $\omega = 0{,}5\omega_S = 1{,}57 \cdot 10^3 \frac{1}{sek}$

g) so‘nish koeffitsienti:

$$\frac{a}{2} = arch\frac{\omega_c}{\omega} = arch\frac{1}{0{,}5} = Arch = 2 = 1{,}32NP = 11{,}45Db;$$

Faza koeffitsienti: $b = -90°$

9.7-Masala. K - turdagi hududiy filtr burchak chastotasi $\omega_{01} = 62{,}8 \cdot 10^3 \frac{1}{sek}$; $\omega_{02} = 75{,}4 \cdot 10^3 \frac{1}{sek}$ bo‘lib, tavsifiy qarshiligi

$$R = R_c = 10 \cdot 10^3 Om \left(R_{yuk} = K = \sqrt{\frac{L_1}{C_2}} = \sqrt{\frac{L_2}{C_1}}\right)$$

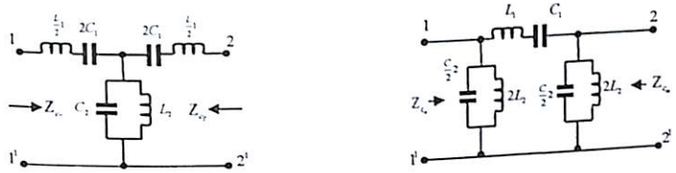
a) filtr parametrlari: L_1, C_1, L_2, C_2.

b) $\omega = 0{,}5 \cdot (\omega_{01} + \omega_{02})$ chastota o‘tkazish chegarasida Z_{st}, Z_{sp} tavsifiy qarshiligi va faza koeffitsienti $b/2$

d) filtr chap tomonida to‘sish chastotasi $\omega = 0{,}5\omega_{01}$ bo‘lganda, so‘nish koeffitsienti $a/2$ qiymatni aniqlansin.

Yechish.

a) hududiy filtr signallarini o‘tkazish ifodasiga yoki chegaralanish ifodasiga asosan:



$$L_1 = \frac{2R}{\omega_{02} - \omega_{01}} = \frac{2 \cdot 10 \cdot 10^3}{75{,}4 \cdot 10^3 - 62{,}8 \cdot 10^3} = 1{,}59gn$$

$$C_1 = \frac{\omega_{02} - \omega_{01}}{2R\omega_{02} \cdot \omega_{01}} = \frac{75{,}4 \cdot 10^3 - 62{,}8 \cdot 10^3}{2 \cdot 10 \cdot 10^3 75{,}4 \cdot 10^3 - 62{,}8 \cdot 10^3} = 0{,}133 \cdot 10^{-9} = 0{,}133nf$$

$$L_2 = \frac{R(\omega_{02} - \omega_{01})}{2\omega_{02} \cdot \omega_{01}} = \frac{10 \cdot 10^9 (75{,}4 \cdot 10^3 - 62{,}8 \cdot 10^3)}{2 \cdot 75{,}4 \cdot 10^3 - 62{,}8 \cdot 10^3} = 0{,}0133gn$$

$$C_2 = \frac{2}{R(\omega_{02} - \omega_{01})} = \frac{2}{10 \cdot 10^3 (75{,}4 \cdot 10^3 - 62{,}8 \cdot 10^3)} = 15{,}88 \cdot 10^{-9} f = 15{,}9nf$$

b) K turdagi hududiy filtr tavsifiy qarshiligi:

$$Z_C = K = \sqrt{\frac{L_1}{C_2}} = \sqrt{\frac{1{,}59}{15{,}9 \cdot 10^{-9}}} = 10 \cdot 10^3 Om$$

$$Z_c = K = \sqrt{\frac{L_2}{C_1}} = \sqrt{\frac{0{,}0133}{0{,}133 \cdot 10^{-9}}} = 10 \cdot 10^3 f$$

d) filtrning ketma-ket yoki parallel ulangan konturlardagi rezonans chastotasini topamiz:

$$\omega_0 = \frac{1}{\sqrt{\frac{L_1}{2} \cdot 2C_1}} = \frac{1}{\sqrt{15{,}9 \cdot 0{,}133 \cdot 10^{-9}}} = 68{,}8 \cdot 10^3 \frac{1}{sek}$$

yoki: $\omega_0 = \frac{1}{\sqrt{2L_2\frac{L_1}{2}}} = \frac{1}{\sqrt{0{,}0133\cdot 15{,}9\cdot 10^{-9}}} = 68{,}8\cdot 10^3 \frac{1}{sek}$

Filtrning chastota o'tkazish chegaralanish qiymatini aniqlaymiz:

$$\omega = 0{,}5(\omega_{01}+\omega_{02}) = 0{,}5(62{,}8\cdot 10^3 + 75{,}4\cdot 10^3)69{,}1\cdot 10^3 \frac{1}{sek}$$

Chap tomondagi to'sish chastotasi:

$$\omega = 0{,}5\omega_{01} = 0{,}5\cdot 62{,}8\cdot 10^3 = 31{,}4\cdot 10^3 \frac{1}{sek}$$

e) T,Π shakldagi hududiy filtrning $\omega = 0{,}5(\omega_{01}+\omega_{02}) = 69{,}1\cdot 10^3 \frac{1}{sek}$ qiymatidagi tavsifiy qarshiligini topamiz:

$$Z_{CT} = K = \sqrt{1-\left[\frac{\omega^2-\omega_2^2}{\omega_0(\omega_{01}+\omega_{02})}\right]^2} = 10\cdot$$

$$10^3\sqrt{1-\left[\frac{(69\cdot 10^3)^2-(68{,}8\cdot 10^3)^2}{69\cdot 10^3(75{,}4\cdot 10^3-62{,}8\cdot 10^3)}\right]^2} = 9{,}99\cdot 10^3 Om$$

$$Z_{C\Pi} = \frac{K}{\sqrt{1-\left[\frac{\omega^2-\omega_2^2}{\omega_0(\omega_{01}+\omega_{02})}\right]^2}} = \frac{10\cdot 10^3}{\sqrt{1-\left[\frac{(69\cdot 10^3)^2-(68{,}8\cdot 10^3)^2}{69\cdot 10^3(75{,}4\cdot 10^3-62{,}8\cdot 10^3)}\right]^2}} = 10\cdot 10^3$$

Chastotaning filtrlash chegarasi:

f) $\omega = 0{,}5\cdot(\omega_{01}+\omega_{02}) = 69\cdot 10^3\frac{1}{sek}$ bo'lganda so'nish koeffitsienti $a/2$ va faza koeffitsienti $b/2$ qiymatlarini aniqlaymiz:

So'nishi: $a/2 = 0$; faza koeffitsienti

$$b/2 = arc\ \sin\frac{\omega^2-\omega_0^2}{\omega(\omega_{02}-\omega_{01})} = arc\sin 0{,}0382 = 2°11^1$$

g) chap tomon filtr to'sish chastotasi: $\omega = 0{,}5\cdot\omega_{01} = 31{,}4\cdot 10^3\frac{1}{sek}$ bo'lganda, so'nish va faza koeffitsienti:

$$a/2 = Arch\left[\frac{\omega^2-\omega_0^2}{\omega(\omega_{02}-\omega_{01})}\right] arch 9{,}45 = 2{,}934NP = 25{,}5Db$$

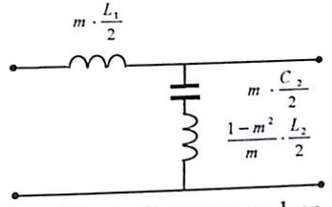
$b/2 = -90°$«minus» ishora filtr chap tomon to'sish chegarasini ifodalaydi.

9.8-Masala. m - turkumidagi quyi chastotali G shaklidagi differensiallovchi filtr burchak chastotasi $\omega_0 = 6{,}28\cdot 10^3\frac{1}{sek}$; $m = 0{,}6$ bo'lib, $R = Z_c = 0{,}5\cdot 10^3\ Om$ aktiv tavsifiy qarshilik yuklangan.

a) Γ - shakldagi quyi chastotali filtr, K turkumidagi o'xshashligiga asoslanib L, C parametri;

b) T - turdagi differensial filtr L_1, C_2, L_2 parametri;

d) $\omega_0 = \infty$ bo'lgandagi (ketma-ket ulangan rezonansli kontur) so'nish chastota qiymati hisoblab topilsin.



Yechish. Avval K turkumidagi Γ sxema uchun L, C parametrlarni topamiz:

$$L = \frac{2R}{\omega_0} = \frac{2\cdot 0{,}5\cdot 10^3}{6{,}28\cdot 10^3} = 0{,}16gn; C = \frac{2}{\omega_0 R_n} = \frac{2}{6{,}28\cdot 10^3\cdot 0{,}5\cdot 10^3}$$
$$= 0{,}637\cdot 10^{-6}\ f.$$

Endi Γ shakldagi m turkumli quyi chastotali filtr doimiy koeffitsienti $m = 0{,}6$ bo'lganda parametrini aniqlaymiz:

$$L_1 = m\frac{L}{2} = 0{,}6\cdot\frac{0{,}16}{2} = 0{,}0477\ gn = 47{,}7mgn.$$

$$C_1 = m\frac{c}{2} = 0{,}6\cdot\frac{0{,}637\cdot 10^{-6}}{2} = 0{,}19\cdot 10^{-6}\ f = 0{,}191mkf$$

$$L_2 = \frac{1-m^2}{m}\cdot\frac{L}{2} = \frac{1-0{,}6^2}{0{,}6}\cdot\frac{0{,}16}{2} = 0{,}085\ gn = 85\ mgn$$

m - turkumidagi differensiallovchi quyi chastotali filtr: $\omega_\infty = \omega_0$ da so'nish chastotasi:

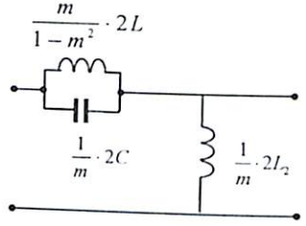
$$\omega_\infty = \omega_0\cdot\frac{1}{\sqrt{1-m^2}} = 6{,}28\cdot 10^3\cdot\frac{1}{\sqrt{1-0{,}6^2}} 7{,}85\cdot\frac{1}{sek}$$

Masala 9.9. Γ shakldagi m turkum yuqori chastotali filtr burchak chastotasi $\omega_0 = 31{,}4\cdot\frac{1}{sek}$; m = 0,6 bo'lib, $R = Z_c = 25\cdot 10^3\ Om$ aktiv tavsifiy qarshilik ulangan $\left(R = K = \sqrt{\frac{L}{C}}\right)$

a) K - turdagi yuqori chastotali filtr parametri;

b) m - turkumidagi Γ shakldagi differensiallovchi filtr parametri L_1, C_1, L_2;

d) parallel sxemadagi rezonansli kontur xususiyatiga asosan $m-$ turkumdagi differensiallovchi filtr $\omega=\infty$ so'nish chastota qiymati hisoblab topilsin.



Yechish.

a) R aktiv qarshilikga yuklangan K turkumda filtr parametrini aniqlaymiz:

$$L=\frac{R}{2\omega_0}=\frac{25\cdot 10^3}{2\cdot 31{,}4\cdot 10^3}=0{,}4gn;$$

$$C=\frac{1}{2\omega_0 R}=\frac{25\cdot 10^3}{2\cdot 31{,}4\cdot 10^3\cdot 25\cdot 10^3}=0{,}637\cdot 10^{-9}\,f=0{,}637nf.$$

b) endi $m=0{,}6$ ga teng bo'lgandagi differensiallovchi yuqori chastotali filtr parametrini topamiz:

$$L_1=\frac{m}{1-m^2}2L=\frac{0{,}6}{1-0{,}6^2}\cdot 2\cdot 0{,}4=0{,}747\ gn.$$

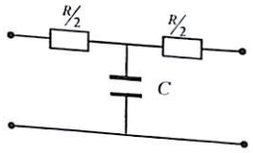
$$C_1=\frac{1}{m}2C=\frac{1}{0{,}6}\cdot 2\cdot 0{,}637\cdot 10^{-9}=0{,}764\cdot 10^{-9}\,f=0{,}764nf.$$

$$L_2=\frac{1}{m}2L=\frac{1}{0{,}6}\cdot 2\cdot 0{,}4=0{,}478\ gn$$

d) cheksiz so'nish chastota qiymati:

$$\omega_\infty=\omega_0\sqrt{1-m^2}=31{,}4\cdot 10^3\sqrt{1-0{,}6^2}=25{,}1\cdot 10^3\frac{1}{sek}$$

Masala 9.10. T sxemadagi induktivsiz quyi chastotali R, C parametri: $R=2\cdot 10^3 Om;\ C=0{,}5\cdot 10^{-9}\,f=0{,}5nf$ bo'lganda, chastota o'tkazish chegarasi aniqlanib, filtr tavsifiy qarshiligi hisoblab topilsin.



Yechish. a) quyi chastotali R, C filtr, chastota o'tkazish chegarasi chap va o'ng tarmoq aktiv qarshilik bilan ularni bog'lovchi tarmoqdagi sig'im reaktiv qarshilik tomon tengligidan topamiz:

$\frac{R}{2}=\frac{1}{\omega_0\frac{C}{2}}$ bundan: $\omega_0=\frac{4}{RC}=\frac{4}{2\cdot 10^3\cdot 0{,}5\cdot 10^{-9}}=0{,}4\cdot 10^6\frac{1}{sek}$

yoki: $f_0=637\cdot 10^3\ gts$

b) $\omega=\omega_0$ shart uchun tavsifiy qarshilik Z_c ni salt yoki qisqa tutashuv tajriba asosida aniqlaymiz. Filtr chiqish qismida salt holatda bo'lganda:

$$Z_0=\frac{R}{2}-j\frac{1}{\omega_0 c}=\frac{2\cdot 10^3}{2}-j\frac{1}{4\cdot 10^6\cdot 0{,}5\cdot 10^{-9}}$$
$$=1{,}11\cdot 10^3 e^{-j26°34^1}Om$$

$\omega=\omega_0$ shartga asosan chiqishda qisqa tutashtirish bilan:

$$Z_k=\frac{R}{2}+\frac{\frac{R}{2}\left(-j\frac{1}{\omega_0 c}\right)}{\frac{R}{2}-j\frac{1}{\omega_0 c}}=\frac{2\cdot 10^3}{2}+\frac{\frac{2\cdot 10^3}{2}\left(-j\frac{1}{4\cdot 10^6\cdot 0{,}5\cdot 10^{-9}}\right)}{\frac{2\cdot 10^3}{2}-j\frac{1}{4\cdot 10^6\cdot 0{,}5\cdot 10^{-9}}}=1{,}26\cdot$$
$$10^3 e^{-j18°}(Om)$$

T shakldagi filtr chastotani o'tkazishda chegaralanish tavsifiy qarshiligi $(\omega=\omega_0)$

$Z_c=\sqrt{Z_0\cdot Z_k}=\sqrt{1{,}11\cdot 10^3 e^{-j26°34'}\cdot 1{,}26\cdot 10^3 e^{-j18°}}=1{,}2\cdot$
$e^{-j22°30'}\ (Om)$

9.3. Mustaqil yechish uchun masalalar

9.1-Masala. Parametri $L_1 = 0{,}02\ gn$, $C = 0{,}08\ mkf$ bo'lgan T sxemadagi filtrning salt, qisqa tutashuv va tavsifiy qarshiligi hamda chastota filtrlash chegarasi aniqlansin.

Javob: $Z_0 = j(0{,}01\omega - 125 \cdot 10^5)\ Om;$

$$Z_q = j\left(0{,}01\omega + \frac{125 \cdot 10^3}{125 \cdot 10^5 - 0{,}01\omega^2}\right) Om.$$

$$Z_c = \sqrt{Z_0 Z_k} = \sqrt{2{,}5 \cdot 10^5 - 10^{-4}\omega^2}\ Om.$$

Bundan $0 \le \omega \le 5 \cdot 10^4$

9.2–Masala. Π sxemadagi filtr parametri $C = 0{,}08\ mkf, L = 0{,}02\ gn$ bo'lganda, chastota o'tkazish chegarasi aniqlanib, xarakteristik qarshilik va faza koeffitsienti topilsin.

Javob: Chastota $12{,}5 \cdot 10^3 \le \omega \le \infty$ oraliqda chegaralaydi.

$$Z_{sn} = \sqrt{\frac{Z_1 Z_2}{1 + \frac{Z_1}{4Z_2}}} = \frac{500}{\sqrt{1 - \frac{156 \cdot 10^6}{\omega^2}}} om.\ 500 \le Z_s \le \infty. -\pi \le b \le 0;\ 500 \div \infty$$

9.3-Masala. 9.1-masalada T sxema krish chastotasi $\omega_c = 10^{-4}\frac{1}{sek}$ va tavsifiy qarshiligi $R = 60\ Om$ bo'lib, chastotasi $\omega = 0{,}5\omega_c$ ga teng bo'lganda filtr parametrlari L, C qiymatlari aniqlansin:

Javob: $L = 69{,}3mgn, C = 0{,}289mkf$

9.4-Masala. T sxemada filtr parametri $L_1 = 100\ mgn,\ L_2 = 100\ mgn,\ C = 0{,}005\ mkf$ bo'lganda, chastota o'tkazish chegarasi aniqlansin.

Javob: $2 \cdot 10^4 \frac{1}{sek} \le \omega \le 4{,}47 \cdot 10^4 \frac{1}{sek}$

9.5-Masala. K tartibli quyi chastotali filtr chastota chegarasi $f_0 = 8\ kgs$ bo'lganda, so'nish koeffitsienti $f_1 = 12kgts,\ f_2 = 4kgs$ ga teng. Faza koeffitsientini aniqlang.

Javob: $\alpha = 1{,}93nep,\ \beta = \frac{\pi}{3}$

9.6-Masala. Quyi chastotali filtr chastota chegarasi $f_0 = 8\ kgs$ bo'lganda, chastotaning qanday qiymatida faza koeffitsienti 60° ga teng bo'ladi.

Javob: $f_0 = 7{,}12\ kgs.$

9.7-Masala. K - turdagi yuqori chastotali filtr chastota chegarasi $f = 250gs \div \infty$ ga teng bo'lganda: 1) so'nish koeffitsienti α: faza koeffitsienti β chastotalarning $f_1 = 125gs\ da,\ f_2 = 200gs,$ va $f_3 = 500gs$ qiymatida aniqlansin.

Javob: 1) $\alpha = 2{,}64nep,\ \beta_2 = \pi;\ \beta_3 = -\frac{\pi}{3}$

9.8-Masala. Quyi chastotali filtr chastotalar chegarasi $f = 1000gs$ xarakteristik qarshiligi $Z_s = 100om(f_0 = 0)$ga teng, filtr parametri aniqlansin.

Javob: $L = 31{,}8\ mgn,\ \ C = 3{,}18\ mkf.$

9.9-Masala. T - shakldagi sxema parametri $L = 0{,}4\ gn, C = 0{,}1\ mkf$ bo'lib, $R = 1000\ Om$ qarshilikga ulangan. ω chastotaning qanday qiymatida kirishdagi to'la qarshilik $Z_1 = \frac{\dot{U}_1}{\dot{I}_1}$ haqiqiy qiymatga erishadi va Z_2 qiymati nimaga teng.

Javob:

$\omega_1 = 5000\frac{1}{sek};\ \omega_2 = 6620\frac{1}{sek}; z = 4000\ Om;\ Z_2 = 1000\ Om.$

$$u_{C(0^+)} = u_{C(0^-)}, \left[q_{(0^+)} = q_{(0^-)}\right]$$

Chiziqli elektr zanjiridagi o'tkinchi jarayonni tahlil qilish uchun klassik usul, operator usuli, Dyuamel integrali (formulalarini ustma-ustlash usuli) va Furye integralidan (chastotali usul) foydalaniladi.

1. Klassik usulga asosan elektr zanjir uchun tuzilgan chiziqli differensial tenglamani yechish bilan bajariladi:

Masalan: Koeffitsienti o'zgarmas chiziqli differensial tenglama:

$$A_0\frac{d^n i_K}{dt^n} + A_1\frac{d^{n-1} i_K}{dt^{n-1}} + \ldots\ldots + A_{n-1}\frac{di_K}{dt} + A_n i_K = F_K$$

Bunday differensial tenglama yechimi yoki integrali xususiy va umumiy yechimdan iborat bo'lib:

$$i_{K(t)} = i'_{K(t)} + i''_{K(t)} \qquad (10.1)$$

$i'_{K(t)}$ - differensial tenglamaning xususiy yechimi bo'lib, elektr zanjirining kommutatsiyadan keyingi **turg'un** holatini ifodalaydi.

$i''_{K(t)}$ - differensial tenglamaning umumiy yechimi bo'lib, **o'tkinchi jarayon** vaqtidagi erkin holatdagi tok va kuchlanishni ifodalaydi:

$$A_0\frac{d^n i''_{K(t)}}{dt^n} + A_1\frac{d^{n-1} i''_{K(t)}}{dt^{n-1}} + \ldots\ldots + A_{n-1}\frac{di''_K}{dt} + A_n i''_K = 0$$

Ya'ni, fizik manoda kommutatsiyadan keyin reaktiv elementlarda to'plangan elektromagnit maydon energiyasi erkin kamayishi va ko'payishini ifodalaydi va vaqtga nisbatan so'nuvchan yoki kamayuvchan bo'ladi:

Ya'ni:

$$i''_K = A_1 e^{a_1 t} + A_2 e^{a_2 t} + \ldots\ldots + A_n e^{a_n t} = \sum_{K=1}^{n} A_K e^{a_k t}$$

(10.1) tenglamadan:

$$i_{K(t)} = i'_{K(t)} + \sum_{K=1}^{n} A_K e^{a_k t} \qquad (10.2)$$

Bunda A doimiy integrallash koeffitsienti bo'lib, boshlang'ich shartdan yoki kommutatsiya qonuniga asosan topiladi.

α_K differensial tenglama ildizi bo'lib, xarakteristik tenglamadan topiladi.

a) ***R, L* zanjirida o'tkinchi jarayon:**

Bunday zanjir tenglamasi birinchi tartibli differensial tenglama bilan ifodalanadi: $L = \frac{di}{dt} + iR = U$ (10.3)

Xarakteristik tenglamasi: $LP + R = 0$; Bundan: $P = -\frac{R}{L} = \frac{1}{\tau}\left(\frac{1}{sek}\right)$

yoki: $\tau = \frac{L}{R}\ (sek)$ – o'tkinchi jarayon vaqti.

O'tkinchi jarayondagi tok $i_{(t)} = i' + Ae^{-\frac{1}{\tau}}$ (10.4)

b) ***R, C* zanjirida o'tkinchi jarayon:**

Bunday zanjirning differensial tenglamasi:

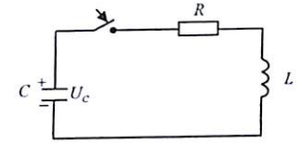
$$RC\frac{dU_C}{dt} + U_C = U \qquad (10.5)$$

Yechimi quyidagicha bo'ladi:

$$U_{C(t)} = U'_C + Ae^{-\frac{t}{\tau}} \quad \text{yoki:} \quad \tau = RC(sek) \qquad (10.6)$$

A - doimiy integrallash koef-fitsienti boshlang'ich shartdan, ya'ni kommutatsiya qonuniga asosan aniqlanadi.

d) **R, L, C zanjirning razryadlanishi:**



Bu zanjirning differensial tenglamasi:

$$\left.\begin{aligned} L\frac{di}{dt} + Ri + \frac{q}{C} = 0 \\ L\frac{d^2 i}{dt^2} + R + \frac{di}{dt} + \frac{1}{C}i = 0 \end{aligned}\right\} \qquad (10.7)$$

Ushbu tenglamaning yechimi:

$$i_{(t)} = i' + i'' = A_1 e^{P_1 t} + A_2 e^{P_2 t} \qquad (10.8)$$

P_1 va P_2 - ildiz koeffitsienti xarakteristik tenglamadan aniqlanadi:

$$LP^2 + RP + \frac{1}{C} = 0 \qquad (10.9)$$

Bundan: $P_{1,2} = -\delta \pm \sqrt{\delta^2 - \omega_0^2}$ yoki: $\delta = \frac{R}{2L}$; $\omega_0^2 = \frac{1}{LC}$ (10.10)

A_1 va A_2 – koeffitsient boshlang'ich shart, ya'ni kommutatsiya qonuniga asosan aniqlanadi.

Ushbu R, L, C zanjirda uch xil holat yuzaga kelishi mumkin:

a) aperiodik zaryadsizlanish: $\delta^2 > \omega_0^2$; $R > 2\sqrt{\frac{L}{C}}$

Bunda $i_{(t)}$tok o‘zgarishi: $i_{(t)} = \frac{U_0}{2L\gamma}(e^{a_2 t} - e^{a_1 t})$
yoki: $\gamma = (P_1 - P_2)$

b) tebranuvchan zaryadsizlanish: $\delta^2 < \omega_0^2$; $R < 2\sqrt{\frac{L}{C}}$

Bunda $i_{(t)}$tok: $i_{(t)} = -I_0 e^{-\delta t}\sin\omega t = -\frac{U_0}{\omega L}e^{-\delta t}\sin\omega t$
U_0 – kondensatordagi boshlang‘ich kuchlanish

d) kritik holat: $\delta^2 = \omega_0^2$; $R = 2\sqrt{\frac{L}{C}}$. Bunda: $i_{(t)} = \frac{U_0}{L}te^{-\delta t}$.

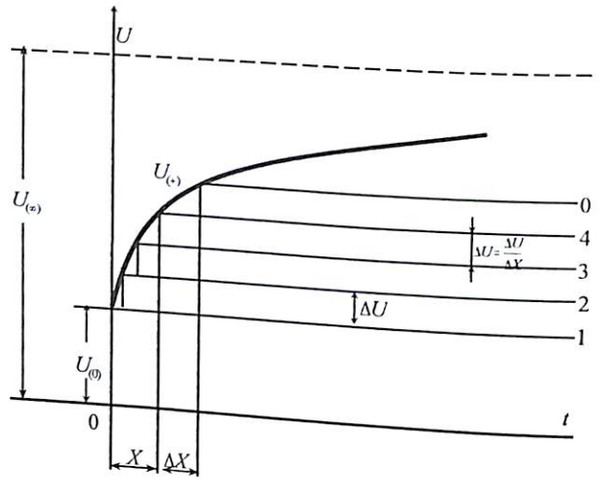
Ixtiyoriy shakldagi kuchlanish ta’sir etgan zanjirdagi o‘tkinchi jarayonni hisoblash (Dyuamel integrali)

Strukturasi ma’lum bo‘lgan passiv zanjirga kuchlanishi vaqtga nisbatan ixtiyoriy qonunga (funksiyaga) asosan o‘zgaruvchan bo‘lsa, o‘tkinchi jarayon masalasi quyidagicha hal qilinadi.

Masalan: Elektr zanjir $t = 0$ vaqtda qandaydir o‘zgarmas U_0 kuchlanishga ulangan deb faraz qilaylik. Zanjir iste’mol qiladigan o‘tkinchi tok shu kuchlanishning o‘tkinchi o‘tkazuvchanligi deb ataladigan $y_{(t)}$ga ko‘paytmasini ifodalovchi funksiya bo‘ladi.

$$i_{(t)} = y_{(t)}U_0 \qquad (10.11)$$

Funksiya $y_{(t)}$ faqat zanjirning strukturasiga bog‘liq bo‘lib, berilgan kuchlanish U_0 ning miqdoriga bog‘liq emas.



Masalan, ketma-ket ulangan R, L zanjirida:

$$i_{(t)} = U_0 y_{(t)} = \frac{U_0}{R}\left(1 - e^{-\frac{t}{\tau}}\right) \qquad (10.12)$$

bo‘lib, tok $i_{(t)}$ning o‘zgarish qonuni ushbu zanjir o‘tkinchi jarayon o‘tkazuvchanligining o‘zgarish qonuni $y_{(t)} = \frac{1}{R}\left(1 - e^{-\frac{t}{\tau}}\right)$ da aks ettirilgan.

Shunga o‘xshash berilgan egri chiziqli kuchlanish funksiyasini ΔU bo‘lakchalarga bo‘lib, har birining ta’siridan aniqlangan tokning yig‘indisi o‘tkinchi jarayon tokni ifodalaydi. Bunga Dyuamel integrali deyilib, oltita formula ko‘rinishida ifodalanadi:

$$\left.\begin{aligned}
&1.\quad i_{(t)} = U_{(0)}y_{(t)} + \int_{x=0}^{x=t} y(y-x)U'_{(t)}\,dx\\
&2.\quad i_{(t)} = U_{(0)}y_{(t)} + \int_{x=0}^{x=t} y(t)U'_{(t-x)}\,d\\
&3.\quad i_{(t)} = U_{(t)}y_{(0)} + \int_{x=0}^{x=t} U(x)\frac{d}{dx}y(y-x)\,dx\\
&4.\quad i_{(t)} = U_{(t)}y_{(0)} + \frac{d}{dx}\int_{x=0}^{x=t} y(x)U_{(t-x)}\,dx\\
&5.\quad i_{(t)} = \frac{d}{dt}\int_{x=0}^{x=t} y(t-x)U_{(t)}\,dx\\
&6.\quad i_{(t)} = \frac{d}{dt}\int_{x=0}^{x=t} y(x)U_{(t-x)}\,dx
\end{aligned}\right\} \qquad (10.13)$$

3. Operator usuli.

Original deb ataluvchi har qanday vaqt funksiyasi $f_{(t)}$ ni unga ekvivalent bo‘lgan kompleks o‘zgaruvchan $p = \delta + j\omega$ argumentli $F_{(p)}$ funksiyasi bilan almashtirish mumkin.

Matematik ko‘rinishda: $f_{(x)} \doteqdot F_{(p)}$ yoki $F_{(p)} = f_{(t)}$ (10.14)

Berilgan funksiya $f_{(t)}$tasviri $F_{(p)}$ «Laplas almashtirishi» deb ataladigan formulaga asosan:

$$F_{(p)} = \int_0^\infty e^{-Pt} f_{(t)}dt \qquad (10.15)$$

Bu integral birmuncha chegaralangan bo‘lganligi uchun, original $f_{(t)}$ dan uning tasviri $F_{(p)}$ ga o‘tish uchun «Karson-Xevidsayd almashtirishi» deb ataluvchi formuladan foydalaniladi:

$$F_{(p)} = p\int_0^\infty e^{-Pt} f_{(t)}dt$$

Bu formula operator P ga ko'paytirish bilan farq qiladi. Funksiya hosilasi va integralining Laplas bo'yicha tasviri:

$$f'_{(t)} \doteqdot p[F_{(p)} - f_{(0)}] \qquad (10.16)$$

Bunda, $f_{(0)}$ funksiyasining $t=0$ bo'lgandagi qiymati.

Integrali:

$$\int_0^t f_{(t)}\,dt \doteqdot \frac{1}{p}F(p) \qquad (10.17)$$

Om qonuni operator ifodasi:

$$I_{(p)} = \frac{U_{(p)}}{Z_{(p)}} \qquad (10.18)$$

Kirxgof qonuni operator ifodasi:

$$\sum E_{K(P)} = \sum[I_{K(P)}Z_{K(P)} - PL_K i_{K(0)} + U_{CK(0)}] \qquad (10.19)$$

Bunda: $i_{K(0)} - t = 0$ da L_K – induktivlikdagi tok:

$U_{CK(0)} - t = 0$ da C_K – sig'imdagi kuchlanish:

$PL_K i_{K(0)}$ va $U_{CK(0)}$ – boshlang'ich shartga asosan hosil bo'ladigan tok va kuchlanishni ichki manba bilan almashtirilgan ifodasi.

O'tkinchi jarayon boshlang'ich shartlarini ichki manba bilan almashtirish natijasida ustma-ustlash usuliga asosan masalani yechish mumkin, natijada operator formada tok tenglamasini quyidagicha ifodalaymiz:

$$I_{(p)} = P\frac{G_{(p)}}{H_{(p)}} \qquad (10.20)$$

$G_{(p)}$ va $H_{(p)}$ ko'rsatkichli funksiya butun sonlar m va n polinomlari bunda $(m \leq n)$

Keltirilgan tenglamadagi (yoyish teoremasi) $H_{(p)} = 0$ deyilib ildiz operatori $P_1, P_2, P_3, \ldots\ldots P_n$ topiladi.

Barcha ildizlar R_K aniqlangandan keyin tok funksiyasi $i_{(t)}$ (original) quyidagicha ifodalanadi:

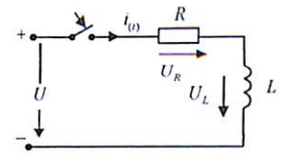
$$i_{(t)} = \sum_{K=1}^{n} \frac{G_{(p)}}{H'_{(p)}} e^{p_{kt}} \qquad (10.21)$$

Bunda $H', \frac{dH}{dP}$ - olingan hosila. Agarda elektr zanjir sinusoidal o'zgaruvchan kuchlanishga ulangan bo'lsa, $U = U_m \sin(\omega t + \varphi)$ kompleks ifodasiga o'tilib, keyin operator ko'rinishida yoziladi:

$$\dot{U}_m e^{j\omega t} \doteqdot \frac{\dot{U}_m P}{P - j\omega} \qquad (10.22)$$

10.2. Masalalar yechish va uslubiy ko'rsatmalar (klassik usul)

10.1-Masala. Ketma-ket ulangan elektr zanjirning aktiv va induktiv parametri $R = 10\ Om, L = 40\ MGn$ bo'lib, o'zgarmas kuchlanishga $U = 100\ V$ ulanganda o'tkinchi tok $i_{(t)}$ aniqlanib, grafigi chizilsin.



Yechish. Kalit zanjirga ulangan paytda induktivlikda o'zinduksiya hodisasiga asosan elektr yurituvchi kuch induksiyalanadi $e_L = -L\frac{di}{dt}$

Kirxgof 2-qonuniga asosan differensial tenglamasi:

$$U = iR + L\frac{di}{dt}$$

Bu birinchi tartibli differensial tenglama bo'lib, o'tkinchi tok quyidagicha ifodalanadi:

$$i_{(t)} = i' + i'' + Ae^{Pt}$$

$i_{(t)}$– o'tkinchi jarayondagi tok.

i'– differensial tenglamaning xususiy yechimi bo'lib, kommutatsiyadan keyingi turg'un holatdagi tok.

i''– differensial tenglamaning umumiy yechimini ifodalovchi (kommutatsiya vaqtidagi) erkin tok. Kommutatsiya birinchi qonuniga asosan aniqlanadi.

A – doimiy integrallash koeffitsienti boshlang'ich shart yoki kommutatsiya qonuniga asosan aniqlanadi.

P – xarakteristik tenglama ildizi.

Kommutatsiyadan keyin zanjirdan o'tuvchi turg'un tok.

$$i' = \frac{U}{R} = \frac{100}{10} = 10A$$

Erkin holatdagi tok i''topish uchun tenglamani quyidagicha ifodalaymiz:

$$L\frac{di''}{dt} + Ri'' = 0$$

Bu differensial tenglamaning yechimi: $i'' = Ae^{Pt}$

Xarakteristik tenglamadan ildizni topamiz: $LP + R = 0$

Bunda: $P = -\frac{R}{L} = \frac{10}{40 \cdot 10^{-3}} = -0{,}25 \cdot 10^{-3} = 250 \quad \left(\frac{1}{sek}\right)$

Zanjirdagi o‘tkinchi tok ifodasi:

$$i_{(t)} = 10 + Ae^{-250t}$$

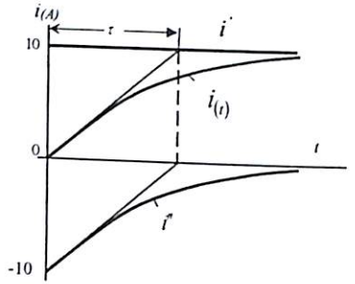
A – integrallash koeffitsienti kommutatsiya birinchi qonuniga asosan $t = 0$ bo‘lganda:

$$i_{(0)} = i_{(0^-)} = 10 + A = 0; \text{ yoki } A = -10$$

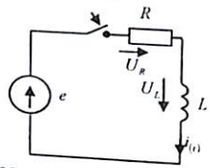
Demak, o‘tkinchi jarayon tok ifodasi:

$$i_{(t)} = 10 - 10e^{-250t} = 10(1 - e^{-250t}) \qquad (A)$$

Bunda: $P = -\frac{1}{\tau}$ yoki $\tau = 40 \cdot 10^{-3}$ sek - o‘tkinchi jarayon vaqti yoki R, L janjir uchun: $\tau = \frac{L}{R}$ (sek)



10.2-Masala. Induktiv g‘altakning aktiv qarshiligi $R = 10\ Om$, induktivligi $L = 0{,}01$ Гн bo‘lib, $e = 100\sqrt{2}\sin(1000t + 15°)$ B kuchlanishga ulanganda o‘tkinchi jarayon tok $i_{(t)}$ aniqlansin.



Yechish. Zanjirning differensial tenglamasi :

$$L = \frac{di}{dt} + Ri = e_{(t)}$$

Tenglamaning yechimi:

$$i_{(t)} = i' + i'' = i' + Ae^{Pt}$$

Xarakteristik tenglamadan: $LP + R = 0$

$$P = -\frac{R}{L} = -\frac{10}{0{,}01} = -10^3 \left(\frac{1}{sek}\right)$$

Bunda kommutatsiyagacha bo‘lgan tok nolga teng $\left(i_{(0^-)} = 0\right)$.

Kommutatsiyadan keyingi turg‘un holatdagi tokni topamiz.

$$\dot{I}'_m = \frac{\dot{E}}{\underline{Z}} = \frac{100\sqrt{2}e^{j15°}}{10 + j10} = 10e^{-j30°} = 10\sin(\omega t - 30°)$$

Kommutatsiya vaqtida $t = 0$;

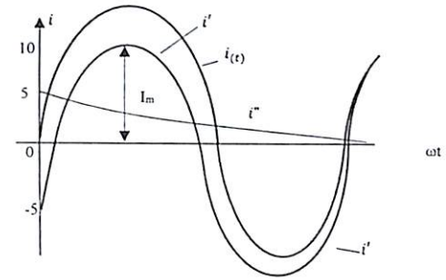
$$i'_{(0)} = 10\sin(30°) = 5$$

Kommutatsiya qonuniga asosan $i_{L(0^-)} = i_{L(0^+)}$

O‘tkinchi jarayondagi tok t=0 bo‘lganda:

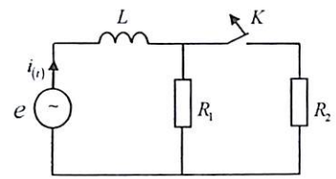
$i''_{(0)} = i_{(0^-)} - i'_{np} = 0 + 5 = 5\ A$

Demak: $i_{(t)} = i' + i'' = 10\sin(\omega t - 30°) + 5e^{-10^3 t}$



O’tkinchi jarayon grafigi

10.3-Masala. Elektr zanjiri parametri $R_1 = R_2 = 5\ Om, L = 10mGn$ bo‘lib, chastotasi $f = 50\ Gs, U = 220sin(\omega t + 90°)$ kuchlanishga ulangan. Kalit uzilgan holatidagi $i_{(t)}$ o‘tkinchi jarayondagi tok aniqlansin.



Yechish.

1. Kommutatsiyagacha bo‘lgan tokni topamiz:

$$\dot{I}_{(o-)} = \frac{220\sqrt{2}e^{j90°}}{\underline{Z}} = \frac{220\sqrt{2}e^{j90°}}{j\omega L + \frac{R_1 \cdot R_2}{R_1 + R_2}} = \frac{220\sqrt{2}e^{j90°}}{2{,}5 + j314 \cdot 0{,}01} = \frac{220\sqrt{2}e^{j90°}}{4e^{j51°30'}} =$$

$$77{,}5e^{j38°30'}$$

2. Kommutatsiyadan keyingi turg‘un holatdagi tokni topamiz:

$$\dot{I}' = \frac{220\sqrt{2}e^{j90^\circ}}{\underline{z}} = \frac{220\sqrt{2}e^{j90^\circ}}{5+j3{,}14} = \frac{220\sqrt{2}e^{j90^\circ}}{5{,}89e^{j32^\circ10'}} = 52{,}6e^{j57^\circ50'}\ A$$

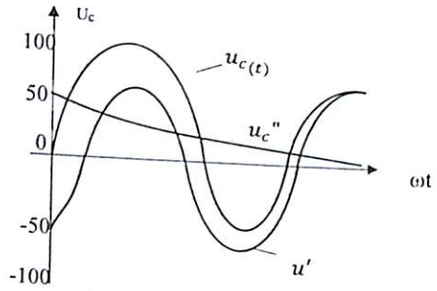
Bunda doimiy vaqt koeffitsienti: $\tau = \frac{L}{R_1} = \frac{0{,}01}{5} = 0{,}002\ sek.$

O‘tkinchi jarayondagi tok: $i_{(t)} = i'_{(+)} + i''_{(+)} = 52{,}6\sin(\omega t + 57^\circ30') + Ae^{-\frac{t}{\tau}}$

bundan $t = 0$ bo‘lgandagi boshlang‘ich shartdan, ya’ni kommutatsiya birinchi qonuniga asosan $\left(i_{L(0^-)} = i_{L(+)}\right)$ A – koeffitsientni aniqlaymiz: $i_{(0)} = 52{,}6\sin(57^\circ30') + A = 77{,}5\sin(38^\circ30')$ yoki: $A = 48{,}3 - 44{,}3 = 4\ A.$

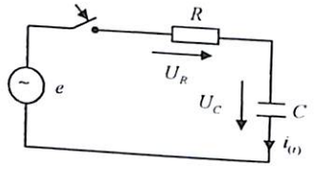
O‘tkinchi jarayon tok ifodasi:

$$i_{(t)} = 52{,}6\sin(\omega t + 57^\circ30') + 4e^{\frac{t}{0{,}002}}$$



O’tkinchi jarayon grafigi

10.4-Masala. Ketma-ket ulangan aktiv qarshiligi $R = 100\ Om$ va sig‘imi $C = 10^{-5}$ Ф bo‘lgan elektr zanjir sinusoidal o‘zgaruvchan EYK $e = 100\sin(10^3t - 90^\circ)\ B$ ulangandan keyingi o‘tkinchi jarayon (sig‘im) $U_{C(t)}$ kuchlanishi va tok $i_{(t)}$ aniqlansin.



Yechish.

1. R, C zanjir uchun differensial tenglamani tuzamiz:

$$e = iR + U_C = RC\frac{dU_C}{dt} + U_C \qquad (1)$$

differensial tenglamaning yechimi quyidagicha ifodalanadi:

$$U_{C(t)} = U'_C + U''_C = U'_C + Ae^{Pt} \qquad (2)$$

2. (1) dan xarakteristik tenglamaga asosan ildizni aniqlaymiz:

$$Z_{(P)} = 0; \qquad RCp + 1 = 0$$

Bundan: $P = -\frac{1}{RC} = \frac{1}{100\cdot10^{-5}} = -10^3\left(\frac{1}{sek}\right)$

O‘tkinchi jarayon vaqti: $\tau = \frac{1}{P} = RC = 10^{-3}\ (sek)$

3. Ushbu zanjirda kommutatsiyagacha bo‘lgan tok $i_{(0^-)} = 0$ $U_{C(0^-)} = 0$ bo‘lib, kommutatsiya ikkinchi qonuniga asosan:

$$u_{C(0^-)} = u_{C(0^+)} = 0$$

4. Kommutatsiyadan keyingi sig‘im turg‘un holat kuchlanishini aniqlaymiz:

$$\dot{U}'_C = \dot{I}jx_c = U'_C\frac{e^{-j90^\circ}}{\sqrt{2}e^{-j45^\circ}}(-j100) = \frac{100}{\sqrt{2}}e^{-j135^\circ}$$

$$u'_{C(t)} = \frac{100}{\sqrt{2}}\sin(\omega t - 135^\circ)$$

yoki $t = 0$da $u'_{C(t)} = \frac{100}{\sqrt{2}}\sin(-135^\circ) = \frac{100}{\sqrt{2}}\cdot\frac{\sqrt{2}}{2} = -50\ (V)$

(2) tenglamadan $t = 0$ bo‘lganda $U_{C(0)} = U'_{C(0)} + A$

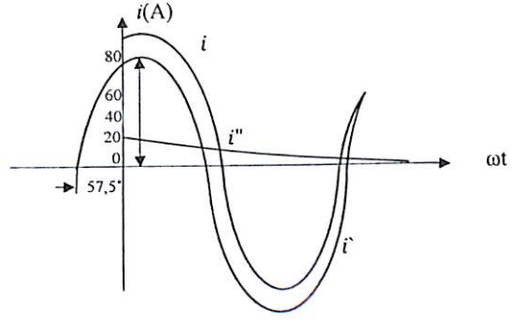
yoki $0 = -50 + A;\ \ A = 50.$ Sinusoidal o‘tkinchi jarayon kuchlanish ifodasi:

$$u_{C(t)} = \frac{100}{\sqrt{2}}\sin(\omega t - 135^\circ) + 50e^{-10^3t}\ \ (V)$$

O‘tkinchi jarayon tok ifodasini aniqlash uchun quyidagi tenglamadan foydalanamiz:

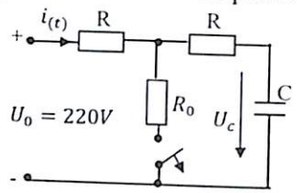
$$i_{C(t)} = C\frac{dU_C}{dt} = \frac{100}{\sqrt{2}}10^{-5}10^3 10^{-5}\cos(\omega t - 135^\circ) +$$

$$5010^{-5}10^3e^{-10^3t} = \frac{1}{\sqrt{2}}\sin(\omega t - 45^\circ) + 0{,}5e^{-10^3t}\ A$$



O’tkinchi jarayon grafigi

10.5-Masala. Elektr zanjiri parametri $R_0 = 2om;\ R = 20om;\ C = 10^{-2}F$ bo'lib, $U_0 = 220V$ kuchlanishga ulangan. Kalit uzilgan holatidagi $u_{c(t)}$ o'tkinchi jarayondagi kuchlanishi aniqlansin.



Yechish

1) komutatsiyagacha bolgan tok va kuchlanish:

$$I_{(0^-)} = \frac{U_0}{R+R_0} = \frac{220}{22} = 10A; \qquad U_{C_{(0^-)}} = I \cdot R_0 = 10 \cdot 2 = 20V$$

2) komutatsiyadan keyingi kuchlanish:

$$U_c' = U_c = U_0 = 220V$$

3) zanjirning difirensial tenglamasi:

$$2RI_{(t)} + U_c = U_0 \quad (I_{(t)} = C\frac{duc}{dt})$$

$$2RC\frac{duc}{dt} + U_c = U_0 \qquad (1)$$

Bu yerda: $2RcP + 1 = 0.$ $\quad P = \frac{-1}{2Rc} = \frac{1}{40*10^{-2}} = \frac{-1}{0,4}t$

(1) tenglamani yechish: $\dot{U}_{(t)} = U' + U'' = U' + Ae^{pt}$ (2)

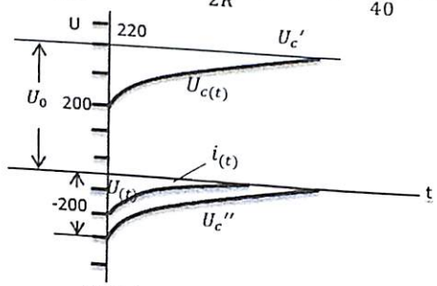
yoki: (t=0) $\quad U_{c_{(0)}} = U_{c_{(0)}} = U_{(0)} = 20V$

(2) tenglamadan: $\quad t = 0 \quad U_{(0)} = 220 + A = 20$

yoki: $A = 20 - 220 = -200$

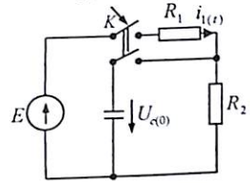
Unda: $U_{(t)} = 220 - 200e^{-\frac{1}{0,4}t} = 20(11 - 10e^{-\frac{1}{0,4}t})$

$$i_{(t)} = C\frac{duc}{dt} = CU_0\frac{1}{2Rc}e^{-\frac{1}{0,4}t} = \frac{-U_0}{2R}e^{-\frac{1}{0,4}t} = \frac{-200}{40} = -5e^{-\frac{1}{0,4}t}$$



O'tkinchi jarayon grafigi

10.6-Masala. Elektr zanjir parametri $R_1 = 40m,\ R_2 = 20m, C = 300(mkF)$ va manba kuchlanishi $E = 12\,V$ bo'lib, kommutatsiyagacha sig'im kuchlanishi $U_{C(0^-)} = 6\,V$ kuchlanishga ega. Kalit ulangandan keyin R_1 qarshilikdan o'tuvchi $i_{1(t)}$o'tkinchi jarayondagi tok aniqlansin.



Yechish.

1) kommutatsiyagacha bo'lgan tok nolga teng $i_{C(0^-)} = 0.$

O'tkinchi jarayondagi tok: $i_{(t)} = i'_{(t)} + i''_{(t)} = i' + Ae^{Pt}$ (1)

2) kommutatsiyadan keyingi turg'un holatdagi tok:

$$i' = \frac{E}{R_1 + R_2} = \frac{12}{6} = 2A$$

O'tkinchi jarayon vaqti: $\tau = \frac{R_1 \cdot R_2}{R_1 + R_2} \cdot C = 4 \cdot 10^{-4}(sek)$

3) Kirxgof qonuniga asosan $t = 0$ bo'lgan holat tenglamasini tuzamiz va kommutatsiya ikkinchi qonuniga asosan $u_{C(0^-)} = u_{C(0^+)}$ ekanligini hisobga olsak: $i_{1(0)}R_1 + U_{C(0)} = E \quad i_{2(0)}R_2 - U_{C(0)} = 0$

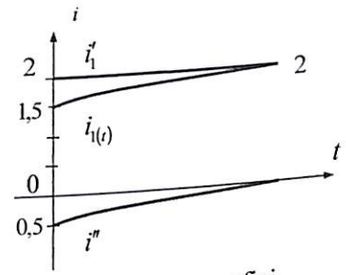
Bundan: $i_{2(0)} = \frac{U_{C(0)}}{R_2} = \frac{6}{2} = 3A \quad i_{2(0)} = \frac{E - U_{C(0)}}{R_1} = \frac{12-6}{4} = 1,5A$

(1) tenglamadan $t = 0$ bo'lganda:

$$i_{(t)} = i'_{1(0)} + i''_{2(0)} = i'_{1(0)} + A$$

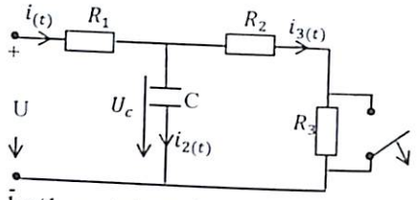
Bundan: $A = i''_{1(0)} - i'_{1(0)} = 1,5 - 2 = -0,5A$

O'tkinchi jarayon toki: $i_{(t)} = 2 - 0,5e^{-2,5\cdot 10^3 t}$



O'tkinchi jarayon grafigi

10.7- Masala. Elektr zanjir parametri $R_1 = 50om;\ R_2 = 30om;\ R_3 = 20om; c = 10MkF = 10 * 10^{-6}F$ bo'lib, $U = 80V$ kuchlanishiga ulangan. Kalit uzilgan holatidagi $u_{c(+)}$ o'tkinchi jarayondagi kuchlanishi aniqlansin.



1) Kommutatsiyagacha bo'lgan tok va kuchlaqnish:

$$\dot{I}_{(0)} = \frac{U}{R_1+R_2} = \frac{80}{80} = 1A; \quad U_{c_{(0)}} = \dot{U}_{(0)} * R_2 = 1 \cdot 30 = 30V$$

2) Kommutatsiyadan keyingi tok va kuchlanish:

$$\dot{I}_{(0)} = \frac{U}{R_1+R_2+R_3} = \frac{80}{100} = 0{,}8A;\ U'_{c_{(0^+)}} = \dot{I}_{(0^+)} \cdot (R_2 + R_3) = 0{,}8 \cdot 50 = 40V$$

3) Z_p=0 shartdan xarakteristik ildiz P-ni topamiz:

$$z_{(p)} = R_1 + \frac{(R_2+R_3)\cdot\frac{1}{Pc}}{(R_2+R_3)+\frac{1}{Pc}} = R_1 + \frac{R_2+R_3}{Pc(R_2+R_3)+1} = \frac{R_1[Pc(R_2+R_3)+1]+R_2+R_3}{Pc(R_2+R_3)+1} = 0$$

$$PR_1C(R_1R_2 + R_1R_3) + R_1 + R_2 + R_3 = 0$$

$$P = \frac{-(R_1+R_2+R_3)}{R_1c(R_2+R_3)} = \frac{-100}{50\cdot10^{-3}} = -\frac{1}{125} = -4 * 10^{-4}$$

4) O'tkinchi jayayon tenglamasidan: $U_{(t)} = U'_c + Ae^{pt}$

$$t = 0\ ;\ U_{(0)} = 40 + A30; \quad A = 30 - 40 = -10$$

Tenglamaga asosan:
$$\left.\begin{aligned} U_{(0)} &= \dot{I}_{(0)}R_1 + U_{c(0)} \\ I_{2(0)}(R_2 + R_3) + U_{(0)} &= 0 \end{aligned}\right]$$

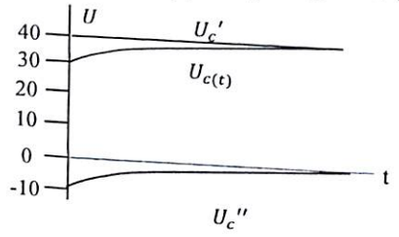
Tarmoqdagi toklari:

$$I_{1(0)} = \frac{U-U_{C(0)}}{R_1} = \frac{80-10}{50} = \frac{90}{50} = 1{,}8om$$

$$I_{2(0)} = \frac{-UC0}{50} = \frac{-10}{50} = -0{,}2A$$

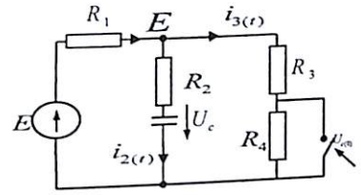
$$I_{3(0)} = I_{1(0)} - I_{2(0)} = 1{,}8 - 0{,}2 = 1{,}6A$$

Kuchlanishdagi o'tkinchi jarayon: $U_{c(t)} = U'_c + Ae^{pt} = 40 - 10e^{-4*10^{-4}}$



10.8-Masala. Parametri: $R_1 = R_2 = R_3 = R_4 = 100m,\ C = 1mkF$ va EYK $E = 60\,V$ ulangan. Elektr zanjirda kalit ulangandan keyingi o'tkinchi jarayondagi $i_{1(t)}$tok aniqlansin.

Yechish.



1. Kommutatsiyagacha bo'lgan tarmoqdagi tokni aniqlaymiz:

$$i_{1(0^-)} = i_{3(0^-)} = \frac{E}{R_1 + R_1 + R_1} = \frac{60}{30} = 2(A)$$

Sig'imdan o'zgarmas tok o'tmasligi sabib: $i_{2(0^-)} = 0$

Sig'imdagi kuchlanish:$u_{C(0^-)} = i_{3(0^-)}(R_3 + R_4) = 2 \cdot 20 = 40(V)$

Kommutatsiya qonuniga asosan: $u_{C(0^-)} = u_{C(0^+)} = 40\ (V)$

2. Kommutatsiyadan keyingi elektr tokni aniqlash uchun Kirxgof qonuniga asosan tenglama tuzamiz: $2i_{(0)}R + Ri_{3(0^+)} = 2E - u_{C(0)}$

$$\begin{cases} i_{1(0^+)}R_1 i_{2(0^+)}R_2 + U_{1(0^+)} = E \\ i_{1(0^+)}R_1 + i_{3(0^+)}R_3 = E \\ i_{1(0^+)} = i_{2(0^+)} + i_{3(0^+)} \end{cases} \quad (1)$$

Tok qiymatini topamiz:

$$i_{2(0^+)} = \frac{E-U_{C(0^+)}-i_{1(0^+)}R}{R_2};\ i_{3(0^+)} = \frac{E-i_{1(0^+)}R_1}{R_3}$$

$$i_{1(0^+)} = \frac{E-U_{C(0^+)}-i_{1(0^+)}R_1+E-i_{1(0^+)}R_1}{R} = \frac{2E-U_{C(0^+)}-2i_{1(0^+)}R_1}{R}$$

Bundan: $i_{1(0^+)} = \frac{2E-U_{C(0^+)}}{3R_1} = \frac{120-40}{30} = 2{,}66A$

3. O'tkinchi jarayondagi tok ifodasi: (2)

$$i_{1(t)} = i'_1 + i''_1 = i'_1 + Ae^{Pt}$$

Turg'un holatdagi tok: $i'_1 = \frac{E}{2R} = \frac{60}{20} = 3(A)$

(2) tenglamadan $t = 0$ bo'lganda:

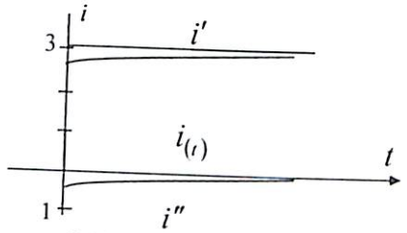
$i''_{1(0)} = i_{1(0^+)} - i'_{1(0)} = 2{,}66 - 3 = 0{,}34(A)$ yoki: $i''_{1(0)} = A = -0{,}34(A)$

4. Zanjirning xarakteristik tenglamasiga asosan ildizni aniqlaymiz ya'ni $Z(p) = 0$

$$Z(p) = R + \frac{R\left(R + \frac{1}{pC}\right)}{R + R + \frac{1}{pC}}$$

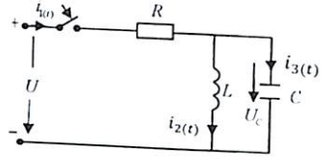
yoki: $3R^2Cp + 2R = 0;\ p = -\frac{2R}{3R^2C} = -\frac{2}{3\cdot10\cdot10^{-6}} = -6{,}66\cdot10^4\left(\frac{1}{sek}\right)$

O‘tkinchi jarayondagi tok: $i_{1(t)} = i_1' + i_1'' = 3 - 0{,}33e^{6{,}66*10^4 t}$.



O’tkinchi jarayon grafigi

10.9-Masala. Tarmoqlangan elektr zanjir parametri R, L, C bo‘lib, o‘zgarmas kuchlanishga ulangandan keyingi o‘tkinchi jarayondagi tok $i_{2(t)}$ va sig‘imdagi kuchlanish $U_{C(t)}$ifodalari aniqlansin.



Yechish.

1. Kirxgof qonuniga asosan differensial tenglama tuzamiz:

$$\begin{cases} U = i_{1(0^+)}R + L\frac{di_{2(t)}}{dt} \\ U_{C(t)} = L\frac{di_{2(t)}}{dt} \\ i_{1(t)} = i_{2(t)} + i_{3(t)} = i_{2(t)} + C\frac{du_{C(t)}}{dt} \end{cases} \quad (1)$$

Ushbu tenglamaning $i_{2(t)}$ nisbatan differensial tenglamasini tuzamiz:

$$\frac{di_{2(t)}}{dt^2} + \frac{1}{RC}\frac{di_{2(t)}}{dt} + \frac{1}{LC}i_{2(t)} = \frac{U_{(t)}}{RLC} \quad (2)$$

Differensial tenglama ikkinchi tartibli bo‘lib quyidagicha ifodalanadi:

$$i_{2(t)} = i_{2(t)}' + i_{2(t)}'' = i_{2(t)}' + A_1e^{p_1t} + A_2e^{p_2t} \quad (3)$$

(2) tenglamaga asosan xarakteristik tenglama ildizini aniqlaymiz:

$$p^2 + \frac{1}{RC}p + \frac{1}{CL} = 0$$

Ildizlari: $$p_{12} = -\frac{1}{RC} \pm \sqrt{\frac{1}{4R^2C^2} - \frac{1}{CL}} \quad (4)$$

Elektr zanjirda kommutatsiyagacha bo‘lgan tok va kuchlanish

$$i_{1(0^-)} = 0,\ u_{C(0^-)} = 0$$

Kommutatsiya qonuniga asosan t = 0 bo‘lganda:

$$i_{2(0)}=i_{2(0^-)}=i_{2(0^+)}=0 \quad (5)$$

$$u_{C(0)}=u_{C(0^-)}=u_{C(0^+)}=0$$

Kommutatsiyadan keyingi turg‘un holatdagi tok:

$$i_2' = \frac{U}{R} \quad (6)$$

(3) tenglamadan $t = 0$ bo‘lganda:

$$i_{2(0)} = i_{2(0)}' + A_1 + A_2 = \frac{U}{R} + A_1 + A_2 = 0 \quad (7)$$

(1) tenglamalar sistemasidagi: $u_{L(t)} = L\frac{di_{2(t)}}{dt}$ ga (3) tenglamadagi $i_{2(t)}$ tok hosilasini (1) tenglamaga qo‘yamiz:

Bunda: $u_{L(t)} = (A_1P_1e^{p_1t} + A_2P_2e^{p_2t})$ (8)

yoki $t = 0$ bo‘lganda: $u_{L(0)} = A_1P_1 + A_2P_2 = 0$

(7) va (8) tenglamalar sistemasini yechish bilan integrallash koeffitsienti A_1va A_2aniqlanadi:

$$\begin{cases} A_1 + A_2 + \frac{u}{R} = 0 \\ A_1P + A_2P = 0 \end{cases}$$

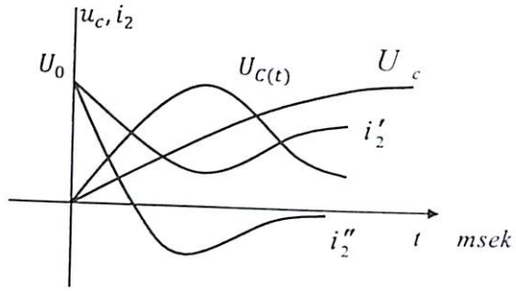
Bundan: $A_1 = \frac{UP_2}{R(P_1-P_2)};\quad A_2 = \frac{UP_1}{R(P_1-P_2)};$

Topilgan barcha qiymatni (3) tenglamada qo‘yish bilan o‘tkinchi jarayondagi tokni va kuchlanishni $i_{2(t)}$ topamiz:

$$i_{2(t)} = \frac{U}{R} + \frac{U}{R(P_1 - P_2)}(p_2e^{p_1t} - P_1e^{p_2t})$$

$$u_{C(t)} = L\frac{di_2}{dt} = \frac{ULp_1p_2}{R(p_1 - p_2)}(e^{p_1t} - e^{p_2t})$$

Agarda: $p_1 = p_2 = \frac{1}{LC}$ bo‘lsa $u_{C(t)} = \frac{U}{RC(p_1-p_2)}(p_1e^{p_1t} - P_2e^{p_2t})$ aperiodik zaryadsizlanish holati yuzaga keladi.



O'tkinchi jarayon grafigi

10.10–Masala. 10.9 masaladagi elektr zanjir parametri: $R = 50Om$, $L = 300(mGn)$ $C = 100(mkF)$ bo'lib, $u = 1000sin314t\ (V)$ sinusoidal o'zgaruvchan kuchlanishga ulanganda, $i_{(t)}$ o'tkinchi jarayon toki aniqlansin.

Yechish.

3. Bu elektr zanjirda kommutatsiyagacha bo'lgan tarmoqdagi tok nolga teng: $i_{(0^-)} = 0,\ i_{L(0^-)} = 0,\ i_{C(0^-)} = 0$
4. Kalit ulangandan keyin turg'un holatdagi tokni aniqlaymiz:

Umumiy tarmoqdagi tok:

$$\dot{I}'_m = \frac{\dot{U}_m e^{j0}}{\underline{Z}} = \frac{100}{R+\frac{jx_L(-jx_C)}{jx_L-jx_C}} = \frac{1000}{10+\frac{31{,}8e^{j90°}\cdot 34e^{-j90°}}{j31{,}8-j34}} = 14{,}4e^{j44°}$$

Tok oniy qiymati: $i' = 14{,}4\sin(314t + 44°)$

Bunda: $t = 0$ bo'lganda $i'_0 = 14{,}4\sin 44°$

Induktivlik: $\dot{I}'_{mL} = \frac{\dot{U}_{ab}}{Z_{ab}} = \dot{I}'_m \frac{jx_C}{jx_L-jx_C} = 14{,}4e^{j44°}\cdot\frac{-j34}{j31{,}8-j34} - 7{,}22e^{j44°}$

yoki: $i'_L = -7{,}22\sin(314t + 44°)$

Bunda: $t = 0$ bo'lganda $i'_{L(0)} = -7{,}22\sin 44° = -5{,}1\ A$

Sig'imdagi tok: $\dot{I}'_{mC} = \dot{I}'_m \frac{jx_L}{jx_L-jx_C} = 14{,}4e^{j44°}\cdot\frac{-j3{,}18}{j31{,}8-j34} = 21{,}66e^{j44°}$ yoki $i'_C = 21{,}66\sin(314t + 44°)$ Bunda $t = 0$ bo'lganda $i'_{C(0)} = 21{,}66\sin 44° = 15{,}1\ A$

5. Xarakteristik tenglama ildizni $Z_{(P)} = 0$ uchun aniqlaymiz:

Bunda: $R + \frac{PL\cdot\frac{1}{PC}}{PL+\frac{1}{PC}} = \frac{RP^2CL+R+RL}{PC} = 0$ yoki: $P^2 + \frac{1}{RC}P + \frac{1}{CL} = 0$

$$P_{12} = -\frac{1}{2RC} \pm \sqrt{\frac{1}{4R^2C^2} - \frac{1}{CL}}$$

$$P_1 = -100 + j153\cdot\left(\frac{1}{sek}\right) \text{ yoki } P_2 = -100 - j153\left(\frac{1}{sek}\right)$$

6. Ushbu zanjirda o'tkinchi jarayonni ifodalovch differensial tenglama yechimi quyidagicha ifodalanadi:

$$i_{(t)} = i'_{(t)} + Ae^{P_1t} + Ae^{P_2t} \quad (1)$$

Hosilasi: $\frac{di''_{(t)}}{dt} = A_1P_1e^{P_1t} + A_2P_2e^{P_2t}$ (2)

yoki $t = 0$ bo'lganda: $\left.\begin{aligned} i''_{(0)} &= A_1 + A_2 \\ \frac{di''_{(0)}}{dt} &= A_1P_1 + A_2P_2 \end{aligned}\right\}$ (3)

Bu tenglamani yechish uchun kommutatsiya qonuniga asosan erkin tok qiymatini aniqlaymiz, yoki $t = 0$ bo'lganda

$$i''_{(0)} = i' + A_1 + A_2 = i''_{(0^-)} = 0$$

yoki: $i''_{(0)} = 0 - 10 = -10$ Bundan: $A_1 + A_2 = -10;\quad A_2 = A_1 - 10$

(2) tenglamadan $\frac{di''_{(t)}}{dt}$aniqlash uchun Kirxgof qonuniga asosan zanjir differensial tenglamasini tuzamiz:

$$\left.\begin{aligned} i'' &= i''_L + i''_C \\ 0 &= Ri'' + L\frac{di''_{(0)}}{dt} \\ L\frac{di''_L}{dt} &= \frac{1}{C}\int i''_C\,dt \end{aligned}\right\} \quad \begin{matrix}(*)\\(**)\\(***)\end{matrix}$$

(**) tenglamadan: $i'' = -\frac{L}{R}\frac{di''_L}{dt}$. Hosilasi $\frac{di''}{dt} = -\frac{L}{R}\frac{di''^2_L}{dt^2}$ (4)

(***) tenglama hosilasi: $\frac{di''^2_L}{dt^2} = \frac{1}{LC}i''_C$

Bu ifodani (4) tenglamaga qo'ysak: $\frac{di''}{dt} = -\frac{1}{RC}i''_C$ (5)

Bundan $t = 0$ bo'lganda induktivlikdagi tok kommutatsiya qonuniga asosan $i''_{L(0^-)} = i''_{L(0^+)} = 0$. Hamda:

$$i''_{C(0)} = -i''_{L(0)} - i''_{(0)} = -10 - 5{,}1 = -15{,}1\ A$$

Topilgan qiymatni (5) tenglamaga qo'ysak: $\frac{di''}{dt} = -\frac{1}{RC}(-15{,}1) =$ 3020

Barcha aniqlangan qiymatni (3) tenglama sistemasiga qo'yib tenglamani yechamiz:

$$\left.\begin{aligned} A_2 &= -A_1 - 10 \\ A_1P_1 + A_2P_2 &= A_1(-100 + j153) + (A_1 + 10)\cdot(100 + j153) = 3020 \end{aligned}\right\}$$

yoki: $A_1 = \frac{2020-j1530}{j306} = -5 - j6{,}6 = -8{,}3e^{j53^\circ}$

Bunda: $A_2 = -5 - j6{,}6 - 10 = -5 + j6{,}6 = -8{,}3e^{j53^\circ}$

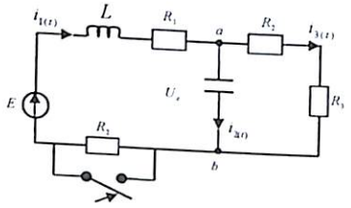
Integrallash koeffitsienti A_1 va A_2 qiymatni (1) tenglamaga qo'yamiz:

$$i'' = A_1e^{P_1t} + A_2e^{P_2t} = -8{,}3e^{j53^\circ} \cdot e^{(-100+j153)t} - 8{,}3e^{j53^\circ} \cdot e^{(-100+j153)t} = -8{,}3e^{j53^\circ} \cdot \left[e^{j(153t+53^\circ)} + e^{-j(153t+53^\circ)}\right] = -8{,}3e^{-100t} \cdot 2\cos(153t + 53^\circ) = -16{,}6e^{-100t}\cos[90^\circ - (153t + 53^\circ)] = -16{,}6e^{-100t} \cdot \sin(153t + 37^\circ)$$

o'tkinchi jarayondagi tok $i_{(t)}$:

$$i_{(t)} = 14{,}4\sin(314t + 44^\circ) - 16{,}6e^{-100t}\sin(153t + 37^\circ)\ A$$

10.11-Masala. Elektr zanjir parametri: $L = 10^{-3}GN;\ C = 1{,}5 \cdot 10^{-3}\Phi, R_1 = 2\ Om, R_2 = 13\ Om, R_3 = 1\ Om,\ R_4 = 4\ Om$ bo'lib, $E = 50\ V$ o'zgarmas kuchlanishga ulangan. R_2 qarshilik qisqa tutashtirilgan holat uchun $i_{1\,(t)}$ o'tkinchi jarayondagi tok va induktivlik, sig'im qarshiligidagi kuchlanishlar topilsin.



Yechish. a) kommutatsiyagacha bo'lgan tok qiymatini topamiz:

Sig'imdan o'zgarmas tok o'tmasligi sababli: $i_{2\,(0)} = 0$.

Om qonuniga asosan:

$$i_{1\,(0^-)} = i_{2\,(0^-)} = \frac{E}{R_1 + R_2 + R_3 + R_4} = \frac{50}{20} = 2{,}5A$$

Sig'imdagi kuchlanish: $U_{c\,(0^-)} = i_{3\,(0^-)} \cdot (R_2 + R_3) = 2{,}5 \cdot 5 = 12{,}5V$

b) kommutatsiyadan keyingi turg'un holatdagi tok va sig'imdagi kuchlanishni aniqlaymiz.

Bu holatda: $i'_{2(0^+)} = 0;$

Birinchi tarmoqdagi tok: $i'_{1(0^+)} = i'_{3(0^+)} = \frac{E}{R_1 + R_3 + R_4} = \frac{50}{7} = 7{,}1A$

Sig'imdagi kuchlanish: $U'_c = i'_3(R_2 + R_3) = 7{,}5 \cdot 5 = 35{,}5V$

Xarakteristik tenglama ildizlarini topamiz:

$$z_{(p)} = PL + R_1 + \frac{\frac{1}{PC}(R_3 + R_4)}{\frac{1}{PC} + R_3 + R_4} = PL + R_1 + \frac{\frac{R_3+R_4}{PC}}{\frac{1+PCR_3+PCR_4}{PC}} = \frac{PL + R_1 + P^2LCR_3 + PCR_1R_3 + P^2LCR_4 + R_3 + R_4}{1 + PCR_3 + PCR_4} = 0$$

Ushbu tenglamadan: $P^2 \cdot 6 \cdot 10^{-6} + 18 \cdot 10^{-3}P + 7 = 0$

Bundan:

$$P_{12} = \frac{-9\cdot10^{-3} \pm \sqrt{(-9\cdot10^{-3})^2 - 7\cdot6\cdot10^{-6}}}{6\cdot10^{-6}} = \frac{-9\cdot10^{-3} \pm \sqrt{39\cdot10^{-6}}}{6\cdot10^{-6}}\left(\frac{1}{sek}\right)$$

$$P_{12} = \frac{-9\cdot10^{-3} \pm \sqrt{(-9\cdot10^{-3})^2 - 7\cdot6\cdot10^{-6}}}{6\cdot10^{-6}} = \frac{-9\cdot10^{-3} \pm \sqrt{39\cdot10^{-6}}}{6\cdot10^{-6}}\left(\frac{1}{sek}\right)$$

$$P_1 = \frac{-2800}{6} = -470\left(\frac{1}{sek}\right);\quad P_2 = \frac{-15200}{6} = -2530\frac{1}{sek};$$

Xarakteristik tenglama ildizi $P_1 \neq P_2$ ga teng emas, haqiqiy sonlar bo'lganligi uchun o'tkinchi jarayon ifodasi: (*)

$$\left.\begin{aligned} i''_1 &= A_1e^{P_1t} + A_2e^{P_2t} \\ \frac{di'_1}{dt} &= P_1Ae^{P_1t} + P_2Ae^{P_2t} \end{aligned}\right\} \quad (*)$$

yoki $t = 0$ bo'lganda:

$$\left.\begin{aligned} i''_{1(0)}A_1 + A_2 \\ \frac{di_{1(0)}}{dt} = P_1A_1 + P_2A_2 \end{aligned}\right\} \quad (**)$$

Kalit ulangandagi o'tkinchi jarayon:

$$i_{1(t)} = i'_1 + i''_1 = i'_1 + A_1e^{P_1t} + A_2e^{P_2t}$$

Kommutatsiya qonuniga asosan:

$$t = 0 \text{ da } i_{1(0)} = i_{1(0^-)} = i_{1(0)} = 2{,}5A$$

Sig'imdagi kuchlanishi: $U_{c(0^-)} = U_{c(0^+)} = U_{c(0)} = 12{,}5V.$

Shunga asosan: o'tkinchi jarayondagi tok va sig'imdagi kuchlanish:

$$i''_1 = i_{1(0)} - i_{1(0^+)} = 2{,}5 - 7{,}5 = -5A$$

$$U''_c = U_{c(0)} - U_{c(0^+)} = 12{,}5 - 35{,}5 = 23V$$

(*) tenglamada $\frac{di''_1}{dt}\Big| t = 0$ qiymatni topish uchun Kirxgof qonuniga asosan tenglama tuzamiz:

$$\left.\begin{aligned} i''_{1(0)} &= i''_{2(0)} + i''_{3(0)}(1) \\ \left(L\frac{di''_1}{dt}\right)_{t=0} &+ i''_{1(0)}R_1 + U'_{c(0)} = 0(2) \\ -U'_{c(0)} &- i''_{3(0)}(R_1 + R_4) = 0(3) \end{aligned}\right\} \quad (***)$$

(***) tenglamadan: $\frac{di''_{1(0)}}{dt} = \frac{-i''_{(0)}R - U''_{c(0)}}{L} = \frac{10+23}{10^{-3}} = 33 \cdot 10^3 \frac{a}{cek}$

Aniqlangan qiymatni (**) tenglamaga qo'yish bilan integrallash koeffitsienti A_1 va A_2 ni topamiz:

$$\begin{cases} -5 = A_1 + A_2 \\ 33 \cdot 10^3 = -470A_1 + 2530A_2 \end{cases}$$

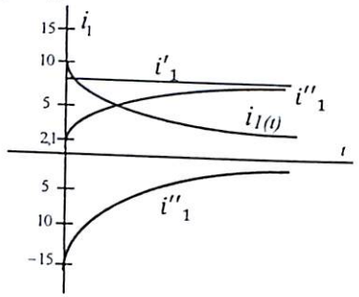
Tenglama yechimi: $33 \cdot 10^3 = 470A_2 + 2350 - 2530A_2$

Bundan: $A_2 = \frac{-300}{20} = -15, A_1 = -5 - A_2 = -5 + 15 = 10$

O'tkinchi jarayon: $i_{(t)}$ tok:

$$i_{1(t)} = i'_1 + A_1 e^{P_1 t} + A_2 e^{P_2 t} = 7{,}1 + 10e^{-470t} - 15e^{-2530t} (\text{A})$$

O'tkinchi jarayon grafigi:



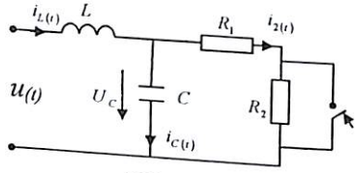
Induktivlikda o'tkinchi jarayondagi kuchlanishi:

$$U_L = L\frac{di_{1(t)}}{dt} = 10^{-3}(-470 \cdot 10e^{-470t} + 2530 \cdot 15e^{-2530t}) = -4{,}7e^{-470} + 38e^{-2530t}$$

Sig'imdagi o'tkinchi jarayondagi kuchlanish:

$$U_C = \frac{1}{C}\int i(t)\,dti = \frac{10^3}{1{,}5}\left(\frac{1}{-470}e^{-470t} - \frac{10{,}6}{-2530}e^{-2530t}\right) = -1{,}7e^{-470t} + 3e^{-2530t}$$

10.12–Masala. Elektr zanjir parametri $R_1 = 30\ Om$, $R_2 = 10\ Om$, $C = 5\ 10^{-5} F$ bo'lib, chastotasi $f = 50\ Gs$ bo'lgan sinusoidal o'zgaruvchan kuchlanish $u = 220\sin(\omega t)\ V$ ga ulangan. Zanjirning R_2 qarshiligi qisqa tutashtirilganda (kalit ulanganda) o'tkinchi jarayondagi tok $i_{L(t)}$ va kuchlanish $u_{C(t)}$ aniqlansin.



Yechish. 1. Kommutatsiyagacha bo'lgan tok va kuchlanish qiymatini topamiz.

Umumiy qarshilik:

$$\underline{Z} = j\omega L - \frac{j\frac{R_1+R_2}{\omega C}}{R_1+R_2-j\frac{1}{\omega C}} = j1{,}5 + 33{,}8e^{-33^\circ} = 28{,}6 + j133 = 136e^{j77^\circ}$$

Induktivlikdagi tok: $\dot{I}_{L(0^-)} = \frac{\dot{U}}{\underline{Z}} = \frac{220}{136e^{j77^\circ}} = 1{,}62e^{-j77^\circ}$

Tok oniy qiymati: $i_{L(0^-)} = 2{,}3\sin(314t - 77^\circ)$; yoki: $t = 0$ bo'lganda: $i_{L(0^-)} = -2{,}24\ A$

Sig'imdagi kuchlanish:

$$\dot{U}_{C(0^-)} = \dot{I}_L \cdot \frac{\frac{R_1+R_2}{j\omega C}}{R_1+R_2-j\frac{1}{\omega C}} = 1{,}62e^{-j77^\circ}33{,}8e^{j33^\circ} = 54{,}8e^{j110^\circ}$$

Kuchlanish oniy qiymati: $u_{C(0^-)} = 54{,}8\sin(314t - j10^\circ)$; yoki: $t = 0$ bo'lganda: $U_{L(0^-)} = -73{,}5\ (V)$

Aktiv qarshilikdagi tok: $\dot{I}_{2(0^-)} = \frac{\dot{U}_{C(0^-)}}{R_1+R_2} = \frac{54{,}8e^{-j110^\circ}}{40} = 1{,}37e^{-j110^\circ}$

Oniy qiymati: $i_{2(0^-)} = 1{,}37\sin(314t - 110^\circ)$; yoki: $t = 0$ bo'lganda: $i_{2(0^-)} = -1{,}25\ A$

2. Kommutatsiyadan keyingi turg'un holatdagi tok va kuchlanishni aniqlaymiz.

To'la kompleks qarshilik: $\underline{Z} = j\omega L - \frac{j\frac{R_1}{\omega C}}{R_1 - j\frac{1}{\omega C}} = 142e^{j80^\circ}$

Induktivlikdagi tok: $\dot{I}_{L(0^+)} = \frac{\dot{U}}{\underline{Z}} = \frac{220}{142e^{j80^\circ}} = 1{,}65e^{j80^\circ}$

yoki: $i'_{L(0^-)} = 1{,}65\sin(314t - 80^\circ)$; $t = 0$ bo'lganda: $i'_{L(0^-)} = 2{,}65$

Sig'imdagi tok: $\dot{I}'_C = \dot{I}'_L\frac{R_1}{R_1 - j\frac{1}{\omega C}} = 0{,}66e^{-j15^\circ}$

Oniy qiymat: $i'_C = 0{,}66\sin(314t + 15^\circ)$ yoki: $t = 0$ bo'lganda:

$$i'_{C(0^+)} = -0{,}6\ A$$

Tok: $\dot{I}'_2 = \dot{I}'_1 \cdot \frac{-j\frac{1}{\omega C}}{R_1 - \frac{1}{j\omega C}} = 1{,}4e^{-j105^\circ}$

Oniy qiymat: $i'_2 = 1{,}4\sin(314t + 105^\circ)$ yoki: $t = 0$ bo'lganda:

$$i'_{2(0^+)} = -1{,}3\ A$$

Sig'imdagi kuchlanish: $\dot{U}'_C = I'_2 \cdot R_1 = 1{,}4e^{-j105^\circ}30 = 42e^{-j105^\circ}$.

Oniy qiymat: $u'_C = 42\sin(314t - 105^\circ)$ yoki: $t = 0$ bo'lganda: $U_{C(0^+)} = -56{,}5\ (V)$

3. Kommutatsiyadan keyingi o'tkinchi jarayon erkin tok va kuchlanishni aniqlash uchun (kommutatsiya qonunini inobatga olgan holda) Kirxgof qonuniga asosan tenglama tuzamiz:

$$\left.\begin{aligned} i_L'' &= i_C'' + i_2'' \quad (*) \\ L\frac{di_L''}{dt} + i_2''R_1 &= 0 \quad (**) \\ L\frac{di_L''}{dt} + \frac{1}{C}\int i_C''\,dt &= 0 \quad (***) \end{aligned}\right\} \qquad (1)$$

(*) tenglamadan: $i_2'' = i_L'' + i_C''$

Buni (**) tenglamadagi i_2'' o'rniga qo'yamiz:

$$L\frac{di_L''}{dt} + i_L''R_1 - i_C''R_1 = 0$$

Bundan: $i_C'' = \frac{1}{R}\left(L\frac{di_L''}{dt} + i_L''R_1\right) = \frac{L}{R_1}\frac{di_L''}{dt} + i_L'' \qquad (2)$

Ushbu ifodani (***) tenglamaga qo'yib differensiallaymiz:

$$L\frac{d^2i_L''}{dt^2} + \frac{1}{C}i_C = L\frac{d^2i_L''}{dt^2} + \frac{1}{C}\left(\frac{L}{R_1}\frac{di_L''}{dt} + i_L''\right) = L\frac{d^2i_L''}{dt^2} + \frac{L}{CR_1}\frac{di_L''}{dt} + \frac{1}{C}i_L'' = 0 \qquad (3)$$

Bundan: $\frac{d^2i_L''}{dt^2} + \frac{L}{CR_1}\frac{di_L''}{dt} + \frac{1}{C}i_L'' = 0 \qquad (4)$

4. Differensial tenglama yechimi:

$$\left.\begin{aligned} i_L'' &= A_1e^{P_1t} + A_2e^{P_2t} \\ \frac{di_L''}{dt} &P_1A_1e^{P_1t} + P_2A_2e^{P_2t} \end{aligned}\right\} \qquad (5)$$

Xarakteristik tenglama (4) dan ildizlari P_1 va P_2 ni topamiz:

Ya'ni: $P^2 + \frac{1}{R_1C}P + \frac{1}{LC} = 0$

$$P_{1,2} = \frac{-L \pm \sqrt{L(R_1 - 4R_1^2C)}}{2R_1CL} = \frac{-0{,}48 \pm 0{,}38}{144\cdot10^{-5}} \quad P_1 = -69{,}5; \quad P_2 = -596$$

Induktivlikdagi tok ; $i_L'' = A_1e^{-69{,}5t} + A_2e^{-596t}$

Sig'imdan o'tuvchi tok (2) tenglamadan:

$$i_C'' = \frac{L}{R_1}(-69{,}5)A_1e^{-69{,}5t} + \frac{L}{R_1}(-596)A_2e^{-596t} + A_1e^{-69{,}5t} + A_2e^{-596t}$$

Endi sig'imdagi kuchlanishni aniqlash uchun i_C'' tokni integral-laymiz:

$$U_C'' = \frac{1}{C}\int i_C''\,dt = \frac{1}{C}\left[\left(\frac{0{,}11}{69{,}5}A_1e^{-69{,}5t} + \frac{8{,}65}{596}A_2e^{-596t}\right)\right] = 316A_1e^{-69{,}5t} + 290A_2e^{-596t}$$

Kommutatsiya birinchi qonuniga asosan induktivlikda:

$$i_{L_{(0^-)}} = i_{L_{(0^+)}} = -2{,}24A$$

Kommutatsiya ikkinchi qonuniga asosan sig'imdagi kuchlanish:

$$U_{C_{(0^-)}} = U_{C_{(0^+)}} = -73{,}5B$$

Demak $t = 0$ bo'lganda (5) tenglamadan:

$$\left.\begin{aligned} -2{,}24 &= -2{,}16 + A_1 + A_2 \\ -73{,}5 &= -53{,}5 + 316A_1 + 290A_2 \end{aligned}\right\} \text{ yoki: } \left.\begin{aligned} -0{,}08 &= A_1 + A_2 \\ -17 &= 316A_1 + 290A_2 \end{aligned}\right\}$$

Bundan: $A_1 = \frac{6{,}2}{26}0{,}258; \quad A_2 = -0{,}338$

Demak:

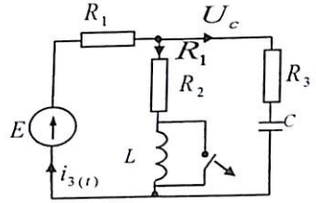
$i_{L(t)} = i' + i'' = 2{,}24\sin(314t - 80°) + 0{,}25e^{-69{,}5t} - 0{,}33e^{-596t}$

$U_{C(t)} = U_C' + U_C'' = 42\sin(314t - 105°) + 316\cdot0{,}258e^{-69{,}5t} -$

$290\cdot0{,}338e^{-596t} = 42\sin(314t - 105°) + 81e^{-69{,}5t} - 98e^{-596t}$

Demak, tok va kuchlanish tenglamasida o'tkinchi jarayon aperiodik qonunga asosan o'zgarar ekan.

10.13-Masala. Elektr zanjir parametri: $R_1 = 8{,}5\ Om$, $R_2 = 11\ Om$, $R_3 = 197{,}4\ Om$, $L_1 = 11\ Gn$, $C = 1\ mkF$ bo'lib, $E = 24\ B$ o'zgarmas tok manbaiga ulangan. Induktivlikdagi kalit uzilgan holatda o'tkinchi tok $i_{1(t)}$ va $U_{L(t)}$ aniqlansin.



Yechish.

1. Kommutatsiyagacha bo'lgan tok va kuchlanishni aniqlaymiz:

$$i_{1(0^-)} = \frac{E}{R_2+R_1} = \frac{24}{11+8{,}5} = 1{,}16\ A$$

Sig'imdan o'zgarmas tok o'tmasligi sababli:

$$i_{2(0^-)} = 0$$

$$i_{3(0^-)} = i_{1(0^-)} = 1{,}16\ A$$

Sig'imdagi kuchlanish: $U_{C_{2(0^-)}} = \frac{E}{R_3+R_1}R_1 = i_{1(0^-)}R_2 = 1{,}16\cdot11 = 13V$

2. Kommutatsiyadan keyingi turg'un holatdagi tok va kuchlanish kommutatsiyagacha bo'lgan tokga teng bo'ladi:

$$i_1' = \frac{E}{R_2+R_1} = 1{,}16\ A$$

$$i_2' = 0 \quad i_3' = i_1' = 1{,}16\ A$$

Sig'imdagi kuchlanish:

$$U_C' = i_1'R_1 = 13V$$

3. O'tkinchi jarayon tok kuchlanishini aniqlash uchun Kirxgof qonuniga asosan elektr zanjir uchun differensial tenglama tuzamiz:

$$\left.\begin{aligned} -i_{1(t)} - i_{2(t)} + i_{3(t)} = 0 \ (*) \\ i_{1(t)}R_1 + L\frac{di_{1(t)}}{dt} + i_{3(t)}R_3 = E \ (**) \\ i_{2(t)}R + \frac{1}{C_2}\int i_{2(t)}\,dt - L\frac{di_{1(t)}}{dt} + i_{1(t)}R_1 = 0 \ (***) \end{aligned}\right\}$$

Bunda (**) tenglamadan:

$$\frac{di_{1(t)}}{dt} = \frac{E - i_{1(t)}R_2 - i_{3(t)}R_1}{L} \qquad (1)$$

4. Xarakteristik tenglama ildizini aniqlash uchun $Z_{(P)} = 0$ bo'lganda:

$$Z_{(P)} = R_1 + \frac{(PL_1+R_2)\cdot\left(R_3+\frac{1}{PC_2}\right)}{R_3+R_2+\frac{1}{PC_2}+PL_1} = 0$$

$$P^2 + P\frac{R_3R_1+R_3R_2+R_2R_1+\frac{L}{C}}{(R_3+R_2)L} + \frac{R_3+R_1}{(R_2+R_3)LC} = 0$$

Bundan: $P^2 + P46{,}8\cdot 10^3 + 5972\cdot 10^6 = 0$

yoki: $P_{1,2} = -\frac{46{,}8\cdot 10^3}{2} \pm \sqrt{\left(\frac{46{,}8\cdot 10^3}{2}\right)^2 - 5972\cdot 10^6} =$

$= -23\cdot 10^3 \pm j73\cdot 10^3$ (2)

5. (**) differensial tenglama yechimi:

$$\left.\begin{aligned} i_{1(t)} = i'_{1(t)} + i''_{1(t)} = i'_{1(t)} + A_1e^{P_1t} + A_2e^{P_2t} \\ \frac{di''_{1(t)}}{dt} = A_1P_1e^{P_1t} + A_2P_2e^{P_2t} \end{aligned}\right\} \qquad (3)$$

Integrallash koeffitsienti A_1 va A_2 boshlang'ich shartga binoan kommutatsiya birinchi qonunida, $t = 0$ bo'lganda: $i_{1(0^-)} = 1{,}16\ A$

(1) tenglamadan:

$$\frac{di''_{1(t)}}{dt} = \frac{E - i_{1(0)}R_2 - i_{3(0)}R_1}{L_1} = \frac{24 - 1{,}16\cdot 19{,}5}{807\cdot 10^{-6}} = 4{,}8\cdot 10^3\left(\frac{A}{sek}\right)$$

Ushbu qiymatni (3) tenglamaga qo'ysak ($t = 0$):

$$\left.\begin{aligned} 1{,}16 = 1{,}16 + A_1 + A_2 \\ 4{,}8\cdot 10^3 = A_1(-23\cdot 10^3 + j73\cdot 10^3) + A_2(-23\cdot 10^3 - j73\cdot 10^3) \end{aligned}\right\} (4)$$

(4) tenglamani yechish natijasida:

$$A_1 = 0{,}058e^{-j179^\circ};\quad A_2 = 0{,}058e^{j179^\circ};$$

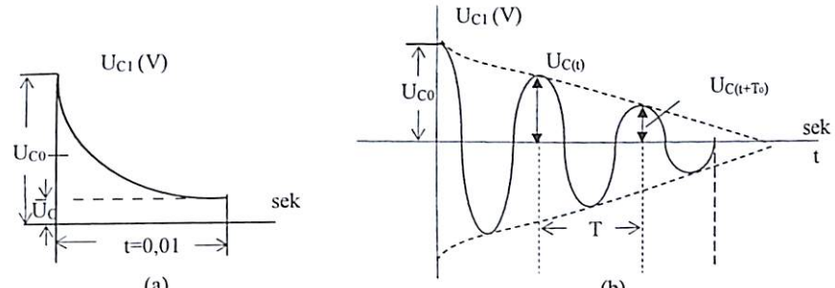
Aniqlangan barcha qiymatni (3) tenglamaga qo'ysak, o'tkinchi jarayondagi $i_{1(t)}$ tok ifodasi:

$$i_{1(t)} = i'_{1(t)} + i''_{1(t)} = 1{,}16 + A_1e^{P_1t} + A_2e^{P_2t} = 1{,}16 + 0{,}058e^{-j179^\circ}\cdot e^{(-23{,}4\cdot 10^{-3}+j73{,}6\cdot 10^3)t} + 0{,}058e^{(-23{,}4\cdot 10^{-3}+j73{,}6\cdot 10^3)t} = 1{,}16 + 1{,}16e^{-23{,}4\cdot 10^{-3}t}\sin(73{,}6t\cdot 10^3 - 89^\circ)A$$

Induktivlikdagi o'tkinchi jarayon kuchlanish:

$$U_{L_{(t)}} = L_1\frac{di_{(t)}}{dt} = 8{,}07\cdot 10^6\cdot 0{,}058e^{-23{,}4\cdot 10^{-3}t} = -23{,}4\cdot 10^{-3}t\sin(73{,}6\cdot 10^3 - 89^\circ) + 73{,}6\cdot 10^3\cos(73{,}6\cdot 10^3 - 89^\circ) = 3{,}6(73{,}6\cdot 10^3 t + 89^\circ)$$

10.14-Masala. R, L, C zanjirda o'tkinchi jarayon aperiodik yoki tebranuvchan grafiklaridan zanjir parametrlari va so'nish dekrement koeffitsenti topilsin.



Yechish: Sig'imdagi kuchlanish aperiodik razryatlanishda agar R qiymati malum bo'lsa; $U_{C_{(t)}} = U_{C0}e^{\frac{t}{RC}}$ ifodadan :$C = \frac{t_1}{ln\frac{Uc0}{U_c}R} = \frac{0{,}01}{ln\frac{100}{10}\cdot R} =$

$\frac{0{,}01}{1\cdot 100} = 0{,}01\cdot 10^2 = 1mkF.$

b) rasimdan agar sig'imdagi kuchlanish tebranuvchan razryadlanishiga ega bo'sa so'nish dekrimenti ifodasi $\delta = \frac{U_{c(t)}}{U_{c(t+T)}} = e^{\delta T_0}$;

yoki lagarifimik so'nish ko'yfitsenti $\Delta = ln\frac{U_{c(t)}}{U_{c(t+T_0)}} = \delta T_0$

b) rasmdagi grafikdan $t = 0{,}01\,sek$ da $U_{c(t)}$ uch martta razryadlanadi n=3 .

Demak $T_0 = \frac{t}{n} = \frac{0{,}01}{3} = 0{,}0033sek$; yoki $T_0 = \frac{2\pi}{w_0}$

Bundan : $\omega_0 = \frac{2\pi}{T_0} = \frac{6{,}28}{3{,}3*10^{-3}} = 2000\frac{rad}{sek}$

Burchak chasto'ta ifodasidan : $\omega_0 = \frac{1}{\sqrt{LC}}$: yoki $C = 1mkF$ bo'lsa

$$L = \frac{1}{w_{0C}^2} = \frac{1}{4\cdot 10^6\cdot 10^{-6}} = 0{,}25Gn$$

Agar R=100 Om bo'lganida so'nish dekrimenti koeffitsenti

$$\delta = \frac{R}{2L} = \frac{100}{2\cdot 0{,}25} = 200$$

Elektr zanjirida o'tkinchi jarayonni operator usulida hisoblash

10.15-Masala. 10-1 masalani operator usulida yechilsin:

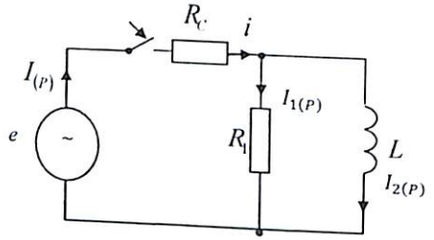
Yechish: $z_{(p)} = 0$ shartga asosan xarakteristik tenglamadan operator qarshiligini topamiz:

$$z_{(p)} = PL + R = 0 \; yoki \; P = -\frac{R}{L} = -250\frac{1}{sek} \quad (10\text{-}21)$$

tenglamalar asosan : utkinchi jarayon toki :

$$i(t) = \frac{U}{z_{(p)}} + U\sum_{k=1}^{k=n}\frac{e^{pkt}}{pk\left(\frac{dz_{(p)}}{dp}\right)_{p=pk}} = \frac{U}{R} + U\frac{e^{-\frac{R}{L}t}}{-\frac{R}{L}L} = \frac{U}{R} - \frac{U}{R}e^{-\frac{R}{L}t} = 10 - 10e^{-250t}\,(A)$$

10.16-Masala. Aktiv qarshiligi $R = R_1 = 50\,Om$, induktivligi $L = 0{,}033$ bo'lgan elektr zanjir $U_m = 200\sqrt{2}\sin(\omega t + 90°)$ sinusoidal kuchlanishga ulanganda hosil bo'ladigan $i_{2(t)}$ o'tkinchi jarayondagi tok operator usulida topilsin.



Yechish.

Umumiy operator qarshiligini aniqlaymiz

$$Z_{(P)} = R + \frac{R_1 PL}{R_1 + PL} = \frac{RR_1 + PL(R + R_1)}{R_1 + PL}$$

Induktivlikdan o'tuvchi $I_{2(P)}$ tokning operator ifodasi Om qonuniga asosan:

$$I_{2(P)} = I_{(P)}\frac{R_1}{R_1 + PL}$$

yoki:

$$I_{2(P)} = \frac{U_{(P)}}{Z_{(P)}} = \frac{R_1}{R_1 + PL} = \frac{U_{(P)}(R_1 + PL)R_1}{[RR_1 + PL(R + R_1)](R_1 + PL)} = \frac{U_{(P)}R_1}{RR_1 + PL(R + R_1)} = \frac{U_{(P)}}{Z_{2(P)}}$$

Bundan: $Z_{2(P)} = \frac{RR_1 + PL(R + R_1)}{R_1}$

Tenglama ildizi $Z_{2(P)} = 0$ asosan: $PL(R + R_1) + RR_1 = 0$

$$P = -\frac{RR_1}{L(R + R_1)} = -\frac{25}{10L} = -78{,}2\,\frac{1}{cek}$$

$i_{2(t)}$ o'tkinchi jarayondagi tokni operator ifodasida aniqlash uchun (9.22) tenglamaga asoslanadi:

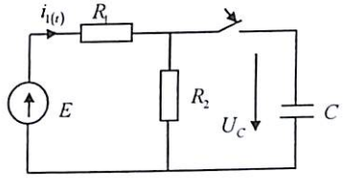
$$i_{2(t)} \neq M\left[\frac{U_m e^{j(\omega t + \Psi)}}{Z_{2(j\omega)}} + \sum_{K=0}^{n}\frac{U_m e^{j\varphi} e^{P_K t}}{(P_K - j\omega)Z'_{2(P)}}\right] \quad (1)$$

Bundan: $Z'_{2(P)} = \frac{L(R+R_1)}{R_1} = 0{,}064$

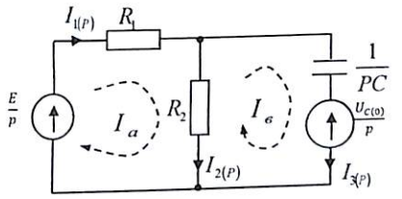
Aniqlangan qiymat (1) tenglamaga qo'yish bilan:

$$i_{2(t)} = \left[\frac{310e^{j(\omega t + 90°)}}{20{,}55e^{j76°}} + \frac{310e^{j-90°}e^{-78{,}2°t}}{322e^{-j104°}0{,}064}\right] = 15\sin(\omega t - 166°) + 15\sin 14°\, e^{-78{,}2°t} = 15\sin(\omega t - 166°) + 3{,}74e^{-78{,}2°t}$$

10.17–Masala. Parametri $R_1 = R_2 = 10\,Om, C = 1\,mkF$ bo'lgan elektr zanjirning o'zgarmas manbai $E = 10$ V bo'lib, sig'im ulanganda hosil bo'ladigan $i_{1(t)}$o'tkinchi jarayon tok operator usuliga asosan aniqlansin.



Yechish. Kommutatsiyadan keyingi operator sxemasini tuzamiz:



Konturli tok usuliga asosan tenglama yozamiz:

$$\begin{cases} I_{a(p)}(R_1 + R_2) - I_{b(p)}R_2 = \frac{E}{p} \\ -I_{a(p)}R_2 + I_{b(p)}\left(R_2 + \frac{1}{PC}\right) = -\frac{U_{C(P)}}{p} \end{cases}$$

Son qiymatini qo‘yamiz:

$$\begin{cases} I_{a(p)}20 - 10I_{b(p)} = \frac{10}{p} \\ -I_{a(p)}10\left(\frac{10^6}{P} + 10\right) I_{b(p)} = -\frac{U_{C(0)}}{p} \end{cases}$$

Bundan:

$$I_{a(p)} = I_{1(p)} = \frac{10^7+100P-U_{C(0)}10P}{100P^2+2\cdot10^7P} = \frac{10P-U_{C(0)}10P+10^6}{10P(P+2\cdot10^5)} = \frac{F_{1(p)}}{F_{2(p)}}$$

Tenglamadan ildiz $-P$ ni topamiz: $Z_{(p)} = 0$

$$Z_{(p)} = P + 2\cdot10^5 = 0; \quad P = -2\cdot10^5\left(\frac{1}{sek}\right)$$

Yoyish teoremasiga asosan ushbu operator tenglamani kasr tenglamalar yig‘indisi ko‘rinishida yozamiz:

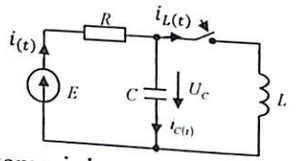
$$I_{1(p)} = \frac{10P}{10P(P+2\cdot10^5)} - \frac{U_{C(0)}P\cdot10}{10P(P+2\cdot10^5)} + \frac{10^6}{10P(P+2\cdot10^5)} = \frac{1}{P+2\cdot10^5} - \frac{U_{C(0)}}{P+2\cdot10^5} + \frac{10^5}{1P(P+2\cdot10^5)}$$

O‘tkinchi jarayondagi tok $i_{1(t)}$ haqiqiy ifodasini aniqlashda o‘tish jadvalidan foydalanamiz.

Bunda:

$$i_{1(t)} = e^{-2\cdot10^5t} - U_{C(0)}e^{-2\cdot10^5t} + \frac{1}{2}\left(1 - e^{-2\cdot10^5t}\right) = \frac{1}{2}\left(1 + e^{-2\cdot10^5t}\right) - \frac{U_{C(0)}}{10}e^{-2\cdot10^5t}$$

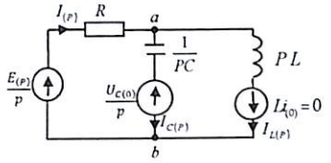
10.18-Masala. Elektr zanjir parametri $R = 10Om, C = 100mkF, L = 29{,}4mGn$ bo‘lib, o‘zgarmas $E = 100V$ manbaga ulangan. Zanjirga induktivlik ulanganda sig‘imdan $i_{1(t)}$ o‘tuvchi o‘tkinchi jarayondagi tok operator usulda aniqlansin.



Yechish. Operator sxemasini tuzamiz:

Bunda: $U_{C(0)} = 100(V)$ bo‘lib, induktivlikdagi tok kommutatsiya birinchi qonuniga asosan $t = 0$ $i_{(0^-)} = i_{(0^+)} = i_{(0)} = 0$, yoki $Li_{(0)} = 0$

$I_{C(P)}$ tokni topish uchun ushbu sxemani ekvivalent sxemaga almashtiramiz:

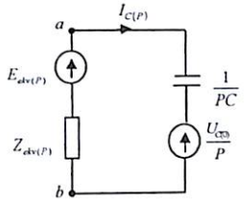


Bunda:

$$U_{ab} = E_{ekv} = \frac{\frac{E_{(p)}}{p}Y_1 - Li_{(0)}Y_2}{Y_1+Y_2} = \frac{\frac{E_{(3)}}{p}\frac{1}{3} - Li_{(0)}\frac{1}{LR}}{\frac{1}{R}+\frac{1}{LR}} = \frac{10\cdot10P\cdot29{,}4}{P(P29{,}4+10^4)} = \frac{29{,}4}{p2{,}94+10}$$

Bunda: $Z_{ekv} = \frac{1}{Y_{ekv}} = \frac{29{,}4}{2{,}94P+10^3}$

Ekvivalent sxema tuzamiz:



Bundan:

$$I_{C(P)} = \frac{E_{ekv(P)} - \frac{U_{C(0)}}{P}}{Z_{ekv(P)} + \frac{1}{PC}} = \frac{294P - 294P - 10^5}{29{,}4P^2+10^4\cdot2{,}94P+10^7} = \frac{-10^5}{29{,}4P^2+29{,}4\cdot10^3P+10^7} = \frac{F_1(P)}{F_2(P)}$$

Umumiy operator qarshilikdan $Z_{ekv} = 0(F_2(P) = 0)$ ildizni aniqlaymiz: $29{,}4P^2 + 29{,}4\cdot10^3P + 10^7 = 0$

yoki: $P_{12} = \frac{-29{,}4\cdot10^3 \pm \sqrt{(29{,}4)^2\cdot10^6 - 4{,}29\cdot4\cdot10^7}}{58{,}8} = \frac{-29{,}4\cdot10^3 \pm 17{,}8\cdot10^3}{58{,}8}$

$$P_1 = (-500 + j300)\frac{1}{sek}; \quad P_2 = (-500 - j300)\frac{1}{sek}$$

Yoyish teoremasiga asosan operator ifodadan haqiqiy tok $i_{C(t)}$ o‘tish formulasidan:

$$i_{(t)} = 2Re\sum_{k=1}^{n}\frac{F_1(P_K)}{F_2'(P_K)}\cdot e^{P_Kt}$$

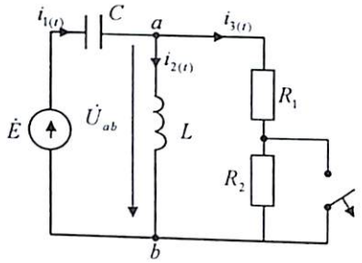
Bundan: $F_1(P_K) = -10^5$

$F_2(P_K) = (58{,}8P + 29{,}4\cdot10^3) = 58{,}8(-500 + j300) + 29{,}4\cdot10^3 = -29{,}4\cdot10^3 + 17{,}8\cdot10^3j + 29{,}4\cdot10^3 = j17{,}8\cdot10^3$

Aniqlangan son qiymatini yoyish tenglamasiga qo'yib $i_{C(t)}$ o'tkinchi jarayondagi tokni aniqlaymiz:

$$i_{C(t)} = 2Re\left[\frac{-10^5}{j17,6}e^{-500t}e^{j300t}\right] = 2Re\left[\frac{-10^5}{j17,6\cdot10^3}e^{-500t}(\cos 300t + j\sin 300t)\right] = 2Re\left[\frac{-10^5}{j17,6}\cos 300t + \frac{j\sin 300t(-10^2)}{j17,6}\right]e^{-500t} = 2(-5,6\sin 300t\cdot e^{-500t}) = 11,3e^{-500t}\sin 300t$$

10.19–Masala. Elektr zanjir parametri: $I_1 = R_1 = 5Om, L = 4\cdot 10^{-2}\,GN,\ C = 2\cdot 10^{-4}$ bo'lib, $e = 100\sin(1000t + 120°)$sinusoidal kuchlanishga ulangan. R_2 qarshilik kalit uzilgan holatda o'tkinchi jarayondagi tok $i_{3(t)}$ klassik va operator usulga asosan yechilsin.



Yechish.

1. Klassik usul.

a) xarakteristik tenglama ildizini topamiz:

$$z_p = \frac{1}{PC} + \frac{PL(R_1+R_2)}{PL+R_1+R_2} = \frac{PL+R_1+R_2+PC[PL(R_1+R_2)]}{PC(PL+R_1+R_2)} = 0$$

Bundan: $PL + R_1 + R_2 + PC[PL(R_1 + R_2)] = 0$

yoki: $8\cdot 10^{-5}P^2 + 4\cdot 10^{-2} + 10 = 0$

Tenglama yechimi:

$$P_{12} = \frac{-4\cdot10^{-2}\pm\sqrt{16\cdot10^6-4\cdot8\cdot10^{-6}\cdot10}}{2\cdot8\cdot10^{-6}} = \frac{-4\cdot10^{-2}\pm j4\cdot10^{-2}}{160\cdot10^{-6}} = \frac{5,65e^{j135}}{160\cdot10^{-4}} = 0,0354\cdot10^{-4}\cdot e^{j135}$$

Ildizini aniqlaymiz: $P_1 = -250 \pm j250; P_2 = -250 - j250$

Demak, ildiz kompleks son bo'lganligi uchun, o'tkinchi jarayondagi tok quyidagicha ifodalanadi:

$$i'' = Ae^{-Pt}\sin(\omega_0 t + \gamma) = e^{+250t}\sin(250t - 8)$$

yoki:

$$\left.\begin{array}{l} t = 0\ bo'lganliga\ e''_{(0)} = A\sin\gamma \\ \left.\frac{di''}{dt}\right|_{t=0} = -\delta A\sin\gamma + \omega_0 A\cos\gamma \end{array}\right\} \quad (*)$$

Hosilasi:

b) kommutatsiyagacha bo'lgan tok va sig'imdagi kuchlanish qiymatini topish uchun ikkita tugun potensiallar usulidan foydalanamiz:

$$\dot{U}_{ab} = \frac{\dot{E}y_1}{y_1+y_2+y_3} = \frac{71e^{j120°}\cdot0,2e^{j90°}}{j0,2-j0,025+0,2} = \frac{14,2e^{j210°}}{0,2+j0,175} = \frac{14,2e^{j210°}}{0,260e^{j420°}} = 53,4e^{j168°} = -52,3 + ji0,3V$$

Om qonuniga asosan tarmoqdagi tokni topamiz:

$$\dot{I}_1 = \frac{\dot{I}-\dot{U}_{ab}}{x_C} = \frac{16,7+j51,2}{5e^{-j90°}} = \frac{54\cdot e^{j72°}}{5e^{-j90°}} = 10,8e^{j162°} = -10,25 + j3,34A$$

$$\dot{I}_2 = \frac{\dot{U}_{ab}}{x_L} = \frac{53,4\cdot e^{j168°}}{40e^{-j90°}} = 1,33e^{j78°} = -0,258 + j1,3A$$

$$\dot{I}_3 = \frac{\dot{U}_{ab}}{R_1} = \frac{53,4\cdot e^{j168°}}{5} = 10,7e^{j162°50'} = -10,5 + j2,07A$$

Oniy qiymat:

$$i_1 = 10,8\sqrt{2}\sin(\omega t + 162°) = 15,2\sin(\omega t + 162°)$$

$t = 0$ bo'lganda $i_{1(0^-)} = 4,7A$

$$i_2 = 1,33\sqrt{2}\sin(\omega t + 78°) = 1,87\sin(\omega t + 78°)\,A$$

$t = 0$ bo'lganda $i_{2(0^-)} = 1,83A$

$$i_3 = 10,7\sqrt{2}\sin(\omega t + 168°) = 15,1\sin(\omega t + 168°)$$

$t = 0$ bo'lganda $i_{3(0^-)} = 1,8A$

Sig'imdagi kuchlanish:

$\dot{U}_c = \dot{I}_1(-jx_c) = 108e^{j162°}\cdot 5e^{j90°} = 54e^{j72°}$

Oniy qiymati: $U_c = \sqrt{254}\sin(\omega t + 72°) = 76\sin(\omega t + 72°)$

$t = 0$ bo'lganda $U_{c(0^-)} = 72V$

d) kommutatsiyadan keyingi turg'un holatdagi tokni topamiz:

$$\dot{U}_{ab} = \frac{E_1 y_1}{y_1+y_2+y_3} = \frac{14,2e^{j120°}}{0,1-j0,175} = 67,5e^{j149°} = -58,4 + j34V$$

Tokning kompleks ifodasi:

$$\dot{I}_1 = \frac{\dot{E}_1-\dot{U}_{ab}}{x_s} = \frac{22,9+j27,5}{5e^{-j90°}} = \frac{39e^{j50°}}{5e^{-j90°}} = 7,2e^{j140°} = -5,5 + j4,65A$$

$$\dot{I}_2 = \frac{\dot{U}_{ab}}{x_L} = \frac{67,5e^{j149°}}{40e^{-j90°}} = 1,7e^{j78°} = 0,85 + j1,46A$$

$$\dot{I}_3 = \frac{\dot{U}_{ab}}{R_1+R_1} = \frac{67,5e^{j168°}}{10} = 67,5e^{j149°} = -5,85 + j3,4$$

Oniy qiymat: $i_1 = 7,2\sqrt{2}\sin(\omega t + 140°) = 10,1\sin(\omega t + 140°)$

Bunda: $t = 0; i_{1(0^+)} = 4,7A$

$$i_2 = 1,7\sqrt{2}\sin(\omega t + 60°) = 2,38\sin(\omega t + 60°)\,A$$

$t = 0\ ;\ i_{2(0^+)} = 2,06A$

$$i_3 = 6{,}75\sqrt{2}\sin(\omega t + 149°) = 9{,}5\sin(\omega t + 149°)\ A$$

$$t = 0; i_{3(0^+)} = 4{,}75A$$

Sig‘im kuchlanishi:

$\dot{U}_c = \dot{I}_1(-jx_c) = 72e^{j140°} \cdot 5e^{-j90°} = 36e^{j50°}$

Oniy qiymati: $U_c = 50{,}7\sin(\omega t + 50°)$;

$$t = 0;\ U_{c(0^+)} = 38{,}8V$$

e) kommutatsiya qonunini hisobga olgan holda o‘tkinchi jarayon, ya’ni erkin holatdagi tok va sig‘imdagi kuchlanishni topamiz:

$$i_1'' = i_{1(0^-)} - i_{1(0^+)} = 4{,}7 - 6{,}5 = -1{,}8A$$

$$i_2'' = i_{2(0^-)} - i_{2(0^+)} = 1{,}83 - 2{,}06 = -0{,}23A$$

$$U_c'' = U_{c(0^-)} - U_{c(0^+)} = 33{,}2\ V$$

O‘tkinchi jarayondagi i_3'' tokni topish uchun tenglama tuzamiz:

$$i_{1(0)}'' - i_{2(0)}'' - i_{3(0)}'' = 0 \qquad (*)$$

$$\frac{1}{C}\int i_{1(0)}''\,dt + i_{3(0)}''(R_1 + R_2) = 0 \qquad (**)$$

$$\frac{1}{C}\int i_{1(0)}''\,dt + L\frac{di_{2(0)}''}{dt} = 0 \qquad (***)$$

O‘tkinchi jarayon uchun hisoblab topilgan tok va sig‘imdagi kuchlanish qiymatiga (**) tenglamadan i_3'' tokni topamiz:

$t = 0;\ U_{c(0)}'' + i_{3(0)}''(R_1 + R_2) = 0$; ya’ni $i_{3(0)}'' = \frac{Ui_{(0)}''}{R_1+R_2} = \frac{-33{,}2}{10} = -33{,}2\ A$

$t = 0$ bo‘lganda hosilasi:

$$\left.\frac{di_3''}{dt}\right|_{t=0} = \frac{i_{1(0)}''}{C(R_1+R_2)} = \frac{\left(i_{2(0)}'' + i_{3(0)}''\right)}{C(R_1+R_2)} = \frac{-0.23-3{,}32}{2\cdot10^{-4}\cdot10} = \frac{3{,}55}{2}\cdot10^3 = 1{,}77\cdot10^3\ a/sek$$

Integrallash koeffitsientini topish uchun aniqlangan tok qiymatini (*) tenglamaga qo‘yamiz:

$$\begin{cases} -3{,}32 = A\sin\gamma \\ 1{,}77\cdot10^3 = -250A\sin\gamma + 250A\cos\gamma \end{cases}$$

Tenglamani yechish uchun:

$940 = 250\ A\ cos$ yoki: $A\cos\gamma = 3{,}76$

$\operatorname{tg}\gamma = -\frac{3{,}32}{3{,}76} = -0{,}885$; yoki $\gamma = -42°50'\ \sin(\gamma) = -0{,}676$

yoki: $A = \frac{3{,}32}{0{,}676} = 4{,}92$

Demak: $i_3'' = 4{,}92e^{-250t}\sin(250t - 42°30')$;

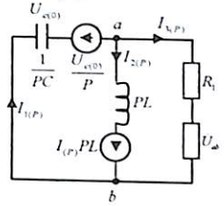
O‘tkinchi jarayondagi tok:

$i_{3(t)}'' = i_3' + i_3'' = 9{,}5\sin(250t - 149°) + 4{,}92e^{-250t}\sin(250t - 42°30')$

2. Operator usul.

Ekvivalent operator sxemasini chizamiz.

Bunda: $U_{c(0)} = 33{,}2\ V \quad i_{2(0)}\cdot L = -0{,}23\cdot4\cdot10^2 = -0{,}92\cdot10^2$



Yechish. Ikki tugun potensiallar usuliga asosan:

$$U_{ab(p)} = \frac{-\frac{U_{c(0)}}{P}PC - i_{2(0)}L\frac{1}{P}}{PC + \frac{1}{PL} + \frac{1}{R}} = \frac{[-U_{c(0)}PC + (-i_{2(0)})]PLR}{P(P^2LCR + R + PL)} =$$

$$\frac{[-U_{c(0)}PC - i_{2(0)}]\frac{LR}{RLC}}{P^2 + \frac{R}{RLC} + \frac{PL}{RLC}} = \frac{-U_{c(0)}P - \frac{i_{2(0)}}{C}}{P^2 + \frac{1}{4\cdot10^{-2}\cdot2\cdot10^{-4}} + \frac{P}{10\cdot2\cdot10^{-4}}} = \frac{-33{,}2P + 1150}{P^2 + 500P + 12{,}5\cdot10^4}$$

$$I_{3(0)} = \frac{U_{c(0)}}{P} = \frac{-33{,}2 + 1150}{(P^2 + 500P + 12{,}5\cdot10^4)R} = \frac{-33{,}2P + 1150}{P^2 + 500P + 12{,}5\cdot10^4};$$

Yoyish teoremasiga asosan operator ifodadan haqiqiy tokga o‘tish formulasi:

$$i_{3(t)} \cong 2Re\sum_{k=1}^{n}\frac{F_1(P_k)}{F_2'(P_k)}\cdot e^{P_k t} \qquad (*)$$

Bundan:

$F_{1(P_1)} = -3{,}32(-250 + j250) + 115 = 830 - j650 + 115$

$= 945 - j830;$

$F_{2(P_1)}' = 2(-250 + j250) + 500 = j500;$

Aniqlangan qiymatni (*) tenglamaga qo‘yamiz:

$i_{3(t)} = 2Re\sum\frac{945 - j830}{j500}e^{-250t}\cdot e^{j250t} = 2Re(1{,}66 -$

$j1{,}89)e^{-250t}\cdot e^{j250t} = 2\cdot2{,}46e^{-250t}Re\left[e^{j(250t-227°)}\right] =$

$4{,}92e^{-j250t}\sin(250t - 227°)$

$i_{3(t)}$ o‘tkinchi jarayondagi tok ifodasi:

$i_{3(t)} = i_3' + i_3'' = 9{,}5\sin(\omega t + 149°50'') +$

$4{,}93e^{j250t}\sin(250t - 42°)30'$

Elektr zanjirda o‘tkinchi jarayonini Dyuamel integrali usulida hisoblash

10.20-Masala. Ketma-ket ulangan R, L zanjir parametri $R = 100m, L = 40\ MGn$ bo‘lib, ekspotensial funksiyasi $U_{(t)} = Ue^{-\gamma t}$ bo‘lgan kuchlanishga ulanganda o‘tkinchi jarayondagi tok $i_{(t)}$ Dyuamel integrali usuliga asosan aniqlansin $\left(U = 100(V)\ \ \gamma = 500\left(\frac{1}{sek}\right)\right)$

Yechish. Aktiv va induktiv zanjirni o‘zgarmas tokga ulaganda o‘tkinchi jarayondagi tok (9.12) tenglamaga asosan yechiladi:

$$i_{(t)} = \frac{U}{R}\left(1 - e^{-\frac{t}{\tau}}\right)$$

Yoki o‘tkinchi o‘tkazuvchanlik ifodasi bo‘yicha:

$$y_{(t)} = \frac{1}{R}\left(1 - e^{-\frac{t}{\tau}}\right) = \frac{1}{R}\left(1 - e^{-\delta t}\right)$$

Bunda: $\delta = \frac{R}{L} = \frac{10}{40 \cdot 10^{-3}} = 250\left(\frac{1}{sek}\right)$

(9.3) tenglama Dyuamel integrali birinchi ifodasidan foydalanamiz:

$$i_{(t)} = U_{(0)}y_{(t)} + \int_0^t y(t-x)U'_{(x)}\,dx \qquad (1)$$

Bunda $t = 0$ bo‘lganda; $U_{(0)} = U = 100V$

$$y_{(t-x)} = \frac{1}{R}\left(1 - e^{-\delta(t-x)}\right) = \frac{1}{R}\left(1 - e^{-\delta t}e^{\delta\tau}\right);$$

$$U'_{(x)} = \left.\frac{dU}{dt}\right|_{t=x} = -\gamma U e^{-\gamma x}$$

Aniqlangan qiymatni (1) tenglamaga qo‘yib integrallaymiz:

$$i_{(t)} = \frac{U}{R}\left(1 - e^{-\delta(t)}\right) + \int_{x=0}^{x=t}\frac{1}{R}\left(1 - e^{-\delta t}e^{\delta x}\right)(-\gamma U)e^{-\gamma x}dx =$$

$$\frac{U}{R}\left(1 - e^{-\delta(t)}\right) - \frac{\gamma U}{R}\int_{x=0}^{x=t}\left(e^{-\gamma x} - e^{-\delta t}e^{(\delta-\gamma)x}\right)dx$$

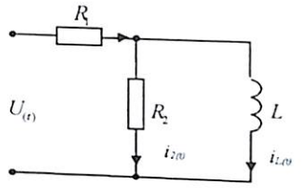
$$i_{(t)} = \frac{U}{R}\left(1 - e^{-\delta(t)}\right) - \frac{\gamma U}{R}\left(-\frac{1}{\gamma}\right)e^{-\gamma x}\Big|_0^t + \frac{\gamma U}{R}e^{-\delta x}\frac{1}{\delta - \gamma}\Big|_0^t$$

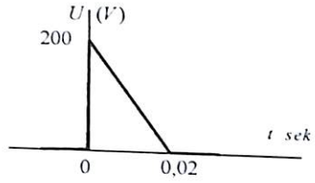
$$= \left(e^{-\gamma x}e^{-\delta x}\right)$$

Aniqlangan qiymatni tenglamaga qo‘yamiz:

$$i_{(t)} = \frac{250}{250-500}\frac{100}{10}\left(e^{-500t} - e^{-250t}\right) = 10\left(e^{-250t} - e^{-500t}\right)A$$

10.21-Masala. Parametri: $R_1 = 5\ Om, R_2 = 10\ Om, L = 100\ MGn$ bo‘lgan elektr zanjir arrasimon impulsli kuchlanishga ulanganda $i_{1(t)}$o‘tkinchi jarayondagi tok Dyuamel integraliga asosan aniqlansin.





Yechish. Kuchlanish analitik ifodasi:$U = 10^4(0{,}02 - t)\ (V)$
$U = 10^4(0{,}02 - t)\ (V)$ bo‘lib: $t = 0\ \ U = 200\ \ (V)$ va $t = 0{,}02\ (sek)\ \ U = 0.$

Demak $t = 0$ bo‘lganda: $U_{(0)} = 200\ (V)\ \ U'_{(0)} = -10^4\ (V)$

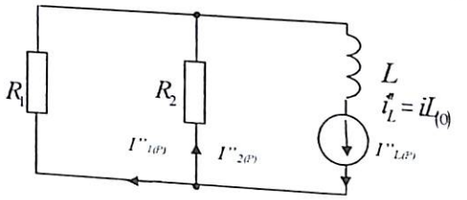
O‘tkinchi jarayondagi tok: $i_{(t)} = U \cdot y_{(t)}$ agar $U = 1;\ \ i_{(t)} = y_{(t)}$

Umumiy $i_{1(t)}$ o‘tkinchi jarayondagi tok:

$i_{1(t)} = i'_1 + i''_1$bo‘lib, qiymatini aniqlaymi:

Bunda $i' = \frac{U}{R_1} = \frac{1}{5} = 0{,}2\ A$

i'' –o‘tkinchi erkin hisoblanadi, tokni topish uchun operator usulidan foydalanamiz. Buning uchun operator sxemasini chizamiz:



Kirxgof qonuniga asosan tenglama tuzamiz:

$$\left.\begin{aligned} R_2 i''_2 &= R_1 i''_1 \\ i''_2 + i''_1 &= 0{,}2 \end{aligned}\right\}$$

Bundan:

$i''_2 = 0{,}2 - i''_1$yoki:$10(0{,}2 - i''_1) = 5 \cdot i''_1;\ \ i''_1 = \frac{2}{15} = 0{,}13\ A$

Om qonuni operator ifodasiga asosan:

$$I''_{1(P)} = \frac{(i_1 L)R_2}{R_1 \cdot R_2 + R_1 PL + R_2 PL} = \frac{0{,}02 \cdot 10}{50 + 50P0{,}1 + 10P0{,}1} = \frac{0{,}2}{50 + 1{,}5}$$

Bundan:

$$50 + 1{,}5P = 0;\ P = \frac{50}{1{,}5} = -33\left(\frac{1}{sek}\right)$$

Operator ifodasining o‘tish teoremasiga asosan:

$$i''_{1(t)} = \frac{F_{(P)}}{F_{2(P)}}e^{Pt} = \frac{0{,}2}{1{,}5}e^{-33t} = 0{,}13e^{-33t}$$

$$i''_{1(t)} = 0{,}13e^{-33t}$$

O‘tkinchi o‘tkazuvchanlik ifodasi:

$$y_{(t)} = 0{,}2 + 0{,}13e^{-33t} \qquad y_{(t-x)} = 0{,}2 + 0{,}13e^{-33(t-x)}$$

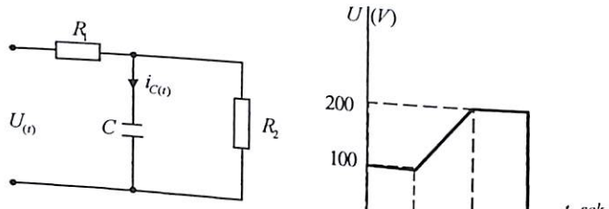
$0 < t < t_1$ Interval uchun Dyuamel integrali ifodasidan $i_{(t)}$ o‘tkinchi tok:

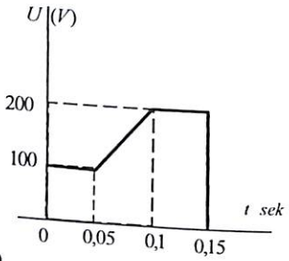
$$i_t = U_{(0)}y_{(t)}\int_0^t U''_{(x)} + y(t-x)dx = 200\left(0{,}2 + 0{,}13e^{-33t} + \int_0^t -10^4\left(0{,}2 + 0{,}13e^{-33(t-x)}\right)dx = 40 + 26e^{-33t} - 10^4\int_0^t (0{,}2 + 0{,}13e^{-33x}\cdot e^{-33t})\right)dx = 40 + 26e^{-33t} - 10^4\left[(0{,}2x)|_0^t + \frac{0{,}13e^{-33t}}{33}e^{-33x}\Big|_0^t\right] = 40 + 26e^{-33t} - 10^4\left[(0{,}2t - 0) - \frac{0{,}13e^0}{33} - \frac{0{,}13}{33}e^{-33t}\right] = 80 + 60e^{-33t} - 2000t$$

$t > t_1$ intervalda o‘tkinchi jarayondagi tokni aniqlaymiz:

$$i_{(t)} = U_{(0)}y_{(t)}\int_0^t U'_{(x)}\,y(t-x)dx - U_{(t_1)}y(t-t_1) = 200(0{,}2t - 0{,}13e^{-33t}) + \int_0^t -10^4\left(0{,}2t - 0{,}13e^{-33(t-x)}\right)dx = 40 + 26e^{-33t} - 2000t_1 + 40 + 40e^{-33t} = 11{,}2e^{-33{,}4t}$$

10.22-Masala. Parametri $R_1 = R_2 = 2\cdot 10^3\ Om, C = 10^{-4}\ F$ bo‘lgan elektr zanjir $U_{(t)}$ grafikda keltirilgan impulsli kuchlanishga ulanganda, $i_{C(t)}$ o‘tkinchi jarayondagi tok Dyuamel integrali usuliga asosan aniqlansin.





Yechish.

$i_{C(t)}$ tokni $0 < t < 0{,}05, 0{,}05 < t < 0{,}1, 0{,}1 < t < 0{,}15$ va $t > 0{,}5$ sek intervallarda aniqlaymiz:

Kalitga ulanganda o‘tkinchi jarayondagi o‘zgaruvchanlik:

$$y_{(t)} = \frac{1}{R}e^{-Pt}$$

Bundan: $P = -\frac{R_1+R_2}{R_1R_2C} = \frac{4\cdot 10^3}{4\cdot 10^6\cdot 10^4} = -10\left(\frac{1}{sek}\right)$

O‘tkinchi jarayondagi tok $i_{C(t)}$: $\frac{0<t<0{,}05.}{1}$ intervalda:

a) $i_{2(t)} = U_{(0)}y_{(t)} = 100\left(\frac{1}{2\cdot 10^3}e^{-10t}\right) = 0{,}05e^{-10t}$

b) $i_{2(t)} = 0{,}05e^{-10t} + \int_{0{,}05}^t y\,(t-x)U'_{(x)}dx = 0{,}05e^{-10t} + \int_0^t 2000\left(\frac{1}{2\cdot 10^3}e^{-10(t-x)}\right)dx = 0{,}05e^{-10t} + \frac{1}{10}e^{-10t}e^{-10X}\Big|_{0{,}05}^t = 0{,}05e^{-10t} + 0{,}1 - 0{,}1e^{-10(0{,}5-10t)} = 0{,}1 + 0{,}05e^{-10t} + 0{,}1e^{-5t}$

c) interval: $t = 0{,}1 \div 0{,}15(sek)$

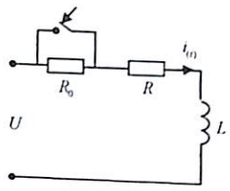
$$i_{2(t)} = 0{,}05e^{-10t} + \int_{0{,}05}^t 2000\,e^{-10(t-x)}dx + 0 = 0{,}05e^{-10t} + 0{,}1e^{-10(t-0{,}1)} - 0{,}1e^{-10(t-0{,}05)}$$

d) interval: $t > 0{,}15(sek)$

$$i_{2(t)} = 0{,}05e^{-10t} + 0{,}1e^{-10(t-0{,}1)} - 0{,}1e^{-10(t-0{,}05)} + U'_{(t_3)}y(t-t_3) = 0{,}05e^{-10t} + 0{,}1e^{-10(t-0{,}1)} - 0{,}1e^{-10(t-0{,}05)} - 200\frac{1}{2\cdot 10^3}e^{-10(t-0{,}15)} = 0{,}05e^{-10t} - 0{,}1e^{-10(t-0{,}15)} + 0{,}1e^{-10(t-0{,}1)} - 0{,}1e^{-10(t-0{,}05)}$$

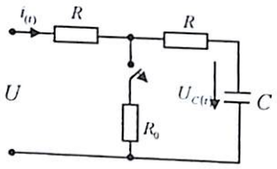
10.3. Mustaqil yechish uchun masalalar

10.1–Masala. Ketma-ket ulangan elektr zanjir parametri: $R_0 = 30\ Om, R = 10Om, L = 100\ MGn$ bo'lib, $U = 120\ V$ o'zgarmas kuchlanishga ulangan. R_0qisqa tutashtirilganda (kalit ulanganda) o'tkinchi jarayondagi $i_{(t)}$ tok klassik va operator usulda aniqlansin va grafigi chizilsin:



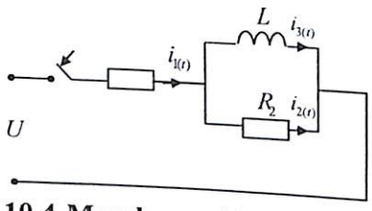
Javob: $i_{(t)} = (12 - 9e^{-100t})$

10.2-Masala. Parametri: $R_0 = 2\ Om, R = 20\ Om, C = 10^{-2}\ F$ bo'lgan elektr zanjiri $U = 220\ V$ o'zgarmas tok kuchlanishga ulangan bo'lib, R_0 qarshilik ulangan tarmoq uzilganda sig'imda hosil bo'lgan o'tkinchi jarayondagi $U_{C(t)}$ kuchlanish aniqlansin.



Javob: $U_{C(t)} = 220 - 200e^{-\frac{t}{2RC}}\ (V)$

10.3-Masala. Parametri: $R_1 = 4\ Om, R_2 = 2\ Om, L = 100\ MGn$ bo'lgan elektr zanjir $U = 100\ V$ o'zgarmas kuchlanishga ulanganda hosil bo'ladigan o'tkinchi jarayondagi tok: $i_{1(t)}, i_{2(t)}, i_{3(t)}$, klassik va operator usulda aniqlansin.



Javob:

$i_{1(t)} = 25\left(1 - \frac{1}{3}e^{-\frac{t}{0,1}}\right)\ (A),$

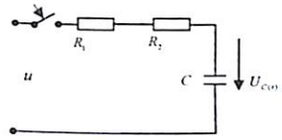
$i_{2(t)} = \frac{32}{3}e^{-\frac{t}{0,1}}\ (A),$

$i_{3(t)} = 25\left(1 - e^{-\frac{t}{0,1}}\right)\ (A)$

10.4-Masala. 10-1 masaladagi zanjir parametri:$R_1 = R_2 = 2\ Om, \omega L = 3\ Om\ bo'lib, f = 50\ Gs, u = 127sin(\omega t - 50°)\ V$ sinusoidal o'zgarmas kuchlanishga ulangan. R_1 qarshilik qisqa tutashtirilganda o'tkinchi jarayondagi tok $i_{(t)}$ klassik va operator usulida aniqlansin.

Javob: $i_{(t)} = 35\sin(314 - 106°) + 8{,}5e^{-210t}A$

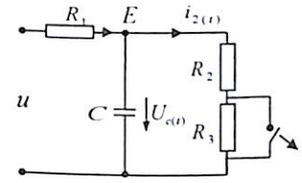
10.5-Masala. Parametri:$R_0 = 2Om, R = 20\ Om, C = 10^{-2}\ F$ bo'lgan elektr zanjir sinusoidal kuchlanish $u = 1000\sqrt{2}\sin(314t + 82°)\ (V)$ ga ulangan o'tkinchi jarayondagi $i_{(t)}$ tok va sig'imdagi $U_{C(t)}$ kuchlanish aniqlansin.



Javob: $i_{(t)} = (314t + 90°) - 3e^{-\frac{t}{0,025}}\ (A)$

$u_{C(t)} = 178\sin 314t + 77\,e^{-\frac{t}{0,025}}\ (V)$

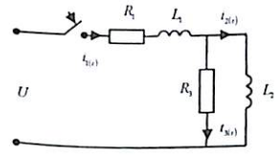
10.6-Masala. Parametri: $R_1 = 50Om, R_2 = 30\ Om, R_3 = 20\ Om, C = 10\ mkF$ bo'lgan elektr zanjir $U = 80\ V$ o'zgarmas kuchlanishga ulangan. R_3 qarshilik qisqa tutashtirilganda hosil bo'ladigan o'tkinchi jarayondagi $i_{2(t)}$ tok va sig'imdagi $U_{C(t)}$ kuchlanish ifodasi klassik va operator usulda aniqlansin.



Javob: $i_{2(t)} = 0{,}8 + 0{,}2e^{-4\cdot10^4 t}\ A,$

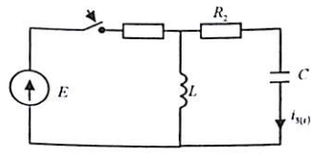
$U_{C(t)} = 40 + 10e^{-4\cdot10^4 t}\ (V)$

10.7-Masala. Parametri $R_1 = 160\ Om, R_3 = 90\ Om, L = 100\ MGn, L_2 = 36\ MGn$ bo'lgan elektr zanjir $U = 48\ V$ o'zgarmas kuchlanishga ulanganda $i_{2(t)}$ o'tkinchi jarayondagi tok klassik va operator usulga asosan aniqlansin.



Javob: $i_{2(t)} = 0{,}3 - 0{,}4e^{-1000t} + +0{,}1e^{-4000t}$

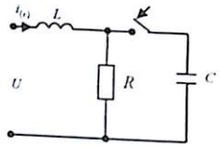
10.8–Masala. Parametri $R_1 = R_2 = 10\ Om, L = 1\ Gn, C = 1000\ mkF$ bo'lgan elektr zanjir $E = 100\ V$ o'zgarmas manbaga ulanganda $i_{3(t)}$o'tkinchi jarayondagi tok klassik va operator usulida aniqlansin.



Javob:

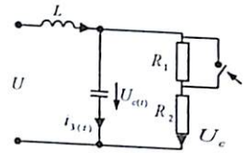
$i_{3(t)} = 6{,}481e^{-43t} - 1{,}81e^{-11t}$

10.9–Masala. Ketma-ket ulangan elektr zanjiri parametrlari $R = 100\ Om, L = 0{,}32\ Gn$ bo‘lib, $u = 2000sin(314t + 90°)\ V$ o‘zgaruvchan kuchlanishga ulangan. Zanjirga $C = 16\ mkF$ bo‘lgan sig‘im ulanganda hosil bo‘ladigan o‘tkinchi jarayon tok $i_{(t)}$aniqlansin.



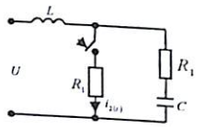
Javob: $i_{(t)} = 20\sin(314t + 58°) + 2\sqrt{10}e^{-314t} \cdot \sin(314t - 71°)$

10.10-Masala. Parametri $R_1 = R_2 = 10\ Om, L = 0{,}04\ MGn, C = 55\ mkF$ bo‘lgan elektr zanjirga $u = 100sin(1000t + 30°)$ sinusoidal o‘zgaruvchan kuchlanish ulangan. R_1 qarshilkni qisqa tutashtirilganda hosil bo‘ladigan o‘tkinchi jarayondagi tok $i_{3(t)}$ va $u_{C(t)}$ klassik va operator usulida aniqlansin va grafigi chizilsin.



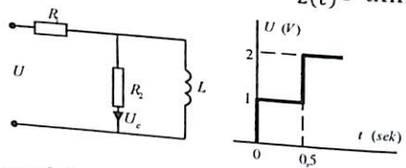
Javob: $i_{3(t)} = 1{,}825e^{-1500t} - 0{,}04e^{-300t} + 1{,}32sin(1000t + 13°)$

10.11–Masala. Parametri $R_1 = 25\ Om, R_2 = 50\ Om, L = 0{,}25\ Gn, C = 400\ mkF$ bo‘lgan elektr zanjir $u = 400\sqrt{2}sin(314t - 90°)$ ulangan. Zanjirga R_2qarshilik ulanganda hosil bo‘la-digan o‘tkinchi jarayondagi tok $i_{2(t)}$ klassik va operator usulga asosan aniqlansin.



Javob: $i_{2(t)} = 1{,}81sin(314t - 179°) - 0326e^{-50t}sin(64{,}4t - 4°)\ A$

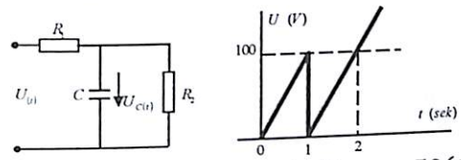
10.12–Masala. Elektr zanjir parametri $R_1 = R_2 = 10\ Om, L = 5\ MGn,$ bo‘lib, bosqichma-bosqich o‘suvchi impulsi kuchlanishga ulangan. Dyuamel intervalidan foydalanib $i_{2(t)}$o‘tkinchi jarayondagi tok aniqlansin.



Javob: $interval\ 0 < t < 0{,}5\ msek\ \ i_{2(t)} = 0{,}05e^{-10^3t}\ (mA)$

$interval\ t > 0{,}5\ msek\ \ i_{2(t)} = 0{,}132e^{-10^3t}\ (mA)$

10.13-Masala. Elektr zanjir parametri $R_1 = R_2 = 10\ Om, C = 200\ mkF$ bo‘lib, grafik berilgan $U_{(t)}$ kuchlanishga ulangan. Dyuamel integraliga asosan $U_{C(t)}$ o‘tkinchi jarayondagi tok aniqlansin.



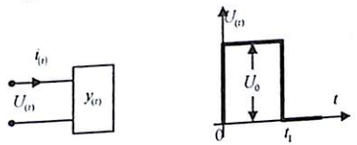
Javob: $interval\ 0 < t < 1\ msek\ \ U_{C(t)} = 50(t - 1 +)e^{-t}\ (V)$

$interval\ t > 1\ msek\ \ U_{C(t)} = 50t - 100 + 186e^{-t}\ (V)$

Nazorat savollari

1. Elektr zanjirda hosil bo‘ladigan o‘tkinchi jarayon deganda nimani tushunasiz?
2. Qachon va nima sababdan elektr zanjirlarda o‘tkinchi jarayon hosil bo‘ladi?
3. Nima uchun induktivlikdagi tok yoki sig‘imdagi kuchlanish sakrab o‘zgara olmaydi?
4. Kommutatsiya qonunining fizik ma’nosini tushuntirib bering.
5. O‘tkinchi jarayon, turg‘un holatdagi tok va kuchlanishning fizik ma’nosini bilasizmi?
6. Nima uchun o‘tkinchi jarayondagi tok, turg‘un holat va o‘tkinchi tok yig‘indisi ko‘rinishida ifodalanadi va chiziqli elekrt zanjir uchun ishlatiladi?
7. O‘tkinchi jarayon vaqti nima, qanday ifodalanadi?
8. RL, RC zanjir uchun o‘tkinchi jarayon vaqti nimaga teng?
9. O‘tkinchi jarayon integrallash koeffitsienti qanday aniqlanadi?
10. O‘tkinchi jarayon boshlang‘ich sharti deganda nimani tushunasiz va qanday aniqlanadi?
11. O‘tkinchi jarayon vaqtida elektr va magnit maydon energiyalari qanday o‘zgaradi?
12. Elektr zanjir manbaga ulanganda uzilish, qisqa tutashuv holatlarida nima uchun uchqun chiqadi?
13. Kondensator razryadlanganda elektr energiyasi qayerda sarflanadi?
14. $R, L\, C$ zanjirning differensial tenglamasiga asosan xarakteristik tenglamasini yozing va ildizlarini aniqlang.
15. $R, L\, C$ zanjirida o‘tkinchi jarayon tok yoki kuchlanish tebranuvchan, so‘nuvchan (aperiodik) hamda kritik holatda o‘zgarishiga sabab nima?
16. Qaysi vaqtda induktiv g‘altak sinusoidal o‘zgaruvchan elektr zanjiriga ulanganda o‘tkinchi jarayon hosil bo‘lmaydi va aksincha?
17. O‘tkinchi jarayondagi tok yoki kuchlanish grafigidan o‘tkinchi jarayon vaqti τ qanday aniqlanadi?
18. Ketma-ket ulangan R, L zanjirning o‘zgarmas tok manbai U dan uzilgan holatdagi o‘tkinchi jarayondagi $i_{(t)}$ tok ifodasini yozing.

19. Ketma-ket R, C zanjirining o‘zgaruvchan $U_{(t)}$ kuchlanishga ulanganda $U_{(t)}$ o‘tkinchi jarayon tenglamasini yozing.
20. O‘tkinchi jarayondagi tokni operator usulida hisoblash qanday amalga oshiriladi?
21. Elektr zanjirda o‘tkinchi jarayondagi tokni hisoblashda ekvivalent operator sxemasi qanday tuziladi?
22. Om va Kirxgof qonuni operator ifodasini yozing.
23. Operator formadan originaliga o‘tish formulasini ifodalab bering.
24. O‘tkinchi jarayondagi tokni Dyuamel integraliga asosan hisoblash qanday amalga oshiriladi?
25. Dyuamel integrallash formulasini yozing.
26. Passiv ikki qutbli zanjirga o‘tkinchi jarayon o‘tqazuvchanligi $y_{(t)}$ga impulsli formada $U_{(t)}$ kuchlanish ulangan $0 \le t \le t_1$ intervalda $i_{(t)}$ o‘tkinchi jarayondagi tok ifodasini aniqlang.



27. Tebranish dekramenti nima va qanday ifodalanadi.
28. Konturning so’nish koefitsienti ifodasini yozing.
29. R,L,C zanjir xarakteristik tenglama ildizlariga nisbatan o’tkinchi jarayon qanday kechadi.
30. Tompson formulasi ifodasini yozing.
31. R,L,C zanjirda qanday xolatda tok $i_{(t)}$ yoki kuchlanish $U_{(t)}$, so’nmas sinusoidal o’zgaruvchan bo’ladi.

11. TARQOQ PARAMETRLI ELEKTR ZANJIR

11.1. Asosiy nazariy tushunchalar

1. Bir jinsli tarqoq parametrli elektr zanjirning asosiy tenglamasi.

Bunday elektr zanjirning nisbiy uzunlikdagi birlamchi parametri: aktiv R_0, induktiv L_0, aktiv o'tqazuvchanligi g_0 va sig'im C_0 bo'ladi.

Ikkilamchi parametri: to'lqin qarshiligi $\underline{Z}_C$ va doimiy tarqalish koeffitsienti γ.

Bir jinsli liniyaning **to'lqin** yoki **tavsifiy qarshiligi** quyidagicha ifodalandi.

$$\underline{Z}_C = \sqrt{\frac{R_0 + j\omega L_0}{g_0 + j\omega C_0}} = \underline{Z}_C e^{j0} \qquad (11.1)$$

Liniyaning **tarqalish koeffitsienti:**

$$\underline{\gamma} = \sqrt{(R_0 + j\omega L_0)(g_0 + j\omega C_0)} = \alpha + j\beta \qquad (11.2)$$

Bunda α – **so'nish koeffitsienti;** β – **faza koeffitsienti.**

Odatda liniya birlamchi parametri berilgan bo'lib (11.2) tenglamadan α va β ni aniqlashda doimiy kompleks ifodasidan foydalaniladi.

$$\left.\begin{aligned} \alpha &= Re(\gamma) \\ \beta &= I_m(\gamma) \end{aligned}\right\} \qquad (11.3)$$

Elektromagnit **to'lqin tarqalish tezligi:** $v = \frac{\omega}{\beta}$ (11.4)

ω – tok va kuchlanish burchak chastotasi.

To'lqin uzunligi: $\lambda = \frac{v}{f} = \frac{2\pi}{\beta}$ (11.5)

Liniyadagi tok va kuchlanish **qaytish to'lqini** quyidagicha ifodalanadi:

$$K_U = -K_i = \frac{\underline{Z}_2 + \underline{Z}_C}{\underline{Z}_2 + \underline{Z}_C} \qquad (11.6)$$

$\underline{Z}_2$ – liniyaning oxiriga ulangan kompleks qarshiligi.

Bu yerda: $\underline{Z}_2 = \underline{Z}_C$ bo'lganda to'lqin qaytmaydi. $K_U = K_i = 0$

Liniyaning salt ishlash holatida $\underline{Z}_2 = \infty$ bo'lib to'lqin qaytish koeffitsienti yoki kuchlanishning tushuvchi to'lqin koeffitsienti:

$$K_U = \frac{1 - \underline{Z}_2 \underline{Z}_C}{1 - \underline{Z}_2 + \underline{Z}_{yuk}} = 1 \quad \text{va} \quad K_I = K_U = -1 \qquad (11.7)$$

Biror-bir (x) masofadagi liniya boshidan hisobga olinsa tok va kuchlanish effektiv kompleks ifodasi:

$$\left.\begin{aligned} \dot{U}_X &= \dot{U}_1 ch\gamma X - \dot{I}_1 \underline{Z}_C sh\gamma X \\ \dot{I}_X &= \dot{I}_1 ch\gamma X - \frac{\dot{U}_1}{\underline{Z}_C} sh\gamma X \end{aligned}\right\} \qquad (11.8)$$

$\dot{U}_1$ va $\dot{I}_1$ – liniya boshidagi tok va kuchlanish.

Agar liniya oxiridagi tok va kuchlanish qiymati berilgan bo'lsa, biror (x) masofadagi liniya oxiriga nisbatan tenglama:

$$\left.\begin{aligned} \dot{U}_X &= \dot{U}_2 ch\gamma X - \dot{I}_2 \underline{Z}_C sh\gamma X \\ \dot{I}_X &= \dot{I}_2 ch\gamma X - \frac{\dot{U}_2}{\underline{Z}_C} sh\gamma X \end{aligned}\right\} \qquad (11.9)$$

Demak, liniyaning boshi va oxiridagi tok va kuchlanish bog'lanish tenglamasi quyidagicha ifodalanadi:

$$\left.\begin{aligned} \dot{U}_1 &= \dot{U}_2 ch\gamma X - \dot{I}_2 \underline{Z}_C sh\gamma X \\ \dot{I}_1 &= \dot{I}_2 ch\gamma X - \frac{\dot{U}_2}{\underline{Z}_C} sh\gamma X \end{aligned}\right\} \qquad (11.10)$$

Liniya boshidagi kompleks qarshilik $\underline{Z}_1 = \frac{\dot{U}_1}{\dot{I}_1}$ desak, (11.10) tenglamadan biror ixtiyoriy qarshilik ulangan holatdagi kompleks qarshilik:

$$\underline{Z}_2' = \underline{Z}_C \frac{\underline{Z}_2 + \underline{Z}_C th\gamma l}{\underline{Z}_2 th\gamma l + \underline{Z}_C} \qquad (11.11)$$

Liniya qarshiligi salt ishlash holatda $\underline{Z}_2 = \infty$ ($\underline{Z}_\infty$ bilan belgilaymiz) va qisqa tutashtirilganda $\underline{Z}_0 = 0$ bo'lib ($\underline{Z}_0$ bilan belgilaymiz) (11.11) tenglamaga asosan:

$$\left.\begin{aligned} \underline{Z}_\infty &= \underline{Z}_C cth\gamma l \\ \underline{Z}_0 &= \underline{Z}_C th\gamma l \end{aligned}\right\} \qquad (11.12)$$

2. Bir jinsli liniya xususiy holatdagi ikkilamchi parametri.

a) yuqori chastotali liniya parametri:

Agar bir jinsli liniya chastotasi $\frac{\omega L_0}{R_0} \geq 5$; $\frac{\omega L_0}{g_0} \geq 5$; bo'lsa, liniya parametri quyidagi tenglama ko'rinishida ifodalanadi:

$$\underline{Z}_C = \sqrt{\frac{L_0}{C_0}};\ \beta = \omega\sqrt{L_0 C_0};\ \alpha = \frac{R_0}{2}\sqrt{\frac{L_0}{C_0}} + \frac{g_0}{2}\sqrt{\frac{L_0}{C_0}} \qquad (11.13)$$

b) signal shaklini buzmaydigan liniya parametri:

uzun liniyaning eng muhim parametri uzun liniya bo'ylab energiya uzatishni ta'minlovchi elektromagnit to'lqinlarning miqdor va sifatdosh o'zgarishini tavsiflovchi so'nish koeffitsienti – α, faza koeffitsienti – β va tavsifiy qarshiligi $\underline{Z}_C$ deb belgilanadi. Bular bir jinsli liniyaning ikkilamchi parametri yoki tavsifi deyiladi.

So'nish koeffitsienti – α, to'lqin qarishligi – $\underline{Z}_C$ va to'lqin fazoviy tarqalish tezligi – $v = \frac{\omega}{\beta}$ ning burchak chastotasi – ω ga teng bo'lmasligi uchun birlamchi parametri quyidagi nisbatda tanlanishi lozim:

$$\frac{R_0}{L_0} = \frac{g_0}{C_0}$$

Signal shaklini buzmaydigan liniyada to'lqin qarshiligi $\underline{Z}_B$ va faza koeffitsienti β (11.1), (11.2), (11.13) tenglama asosida aniqlanadi.

So'nish koeffitsienti esa (11.2) dan:

$$\alpha = \frac{g_0}{C_0}\sqrt{L_0C_0} = \frac{R_0}{L_0}\sqrt{L_0C_0} = \sqrt{R_0g_0} \qquad (11.14)$$

Barcha yuqori chastotalar ushbu turdagi liniyada to'lqin tarqalish tezligi quyidagicha ifodalanadi:

$$v = \frac{1}{\sqrt{L_0C_0}} \qquad (11.15)$$

Uzatish liniyasida to'lqin tarqalish tezligi: $v = 3 \cdot 10^5\ km/sek$

b) isrofsiz liniya parametri.

Radiotexnikada foydalaniladigan chastotasi yuqori bo'lgan liniyalarda aktiv qarshilik parametri $R_0 \ll \omega L_0$ dan va aktiv o'tkazuvchanlik $g_0 \ll \omega C_0$ juda ham kichik bo'lganligi uchun hisobga olinmaydi, shu sababli bu turdagi liniyaga **isrofsiz liniya** deyiladi. Bunday liniya ikkilamchi parametrli (11.13) tenglamadan aniqlanadi. Bu yerda koeffitsient $\alpha = 0$.

3. Bir jinsli liniyaning turli holatda ishlashi.

a) bir jinsli liniyaga $\underline{Z}_2$ to'la qarshilik ulangan bo'lib, to'lqin qarshiligiga teng: $\underline{Z}_2 = \underline{Z}_C$

Bunda (11.10) tenglamaga asosan tok $\dot{U}_2$va $\dot{I}_2$ giperbolik funksiyasidan kompleks formada quyidagi tenglik bilan ifoda qilinadi:

$$\dot{U}_2 = \dot{U}_1 e^{-\gamma l}; \quad \dot{I}_2 = \dot{I}_1 e^{-\gamma l}; \qquad (11.16)$$

Bularning nisbati:

$$\frac{\dot{U}_2}{\dot{U}_1} = \frac{\dot{I}_2}{\dot{I}_1} = e^{-\gamma l} = \varphi_{U_1} - \varphi_{U_2} = \varphi_{i_1} - \varphi_{i_2} = \beta l \qquad (11.17)$$

(11.11) yoki (11.12) tenglamaga asosan liniyaga kiruvchi qarshilik:

$$\bar{Z}_{kir} = \bar{Z}_C \qquad (11.18)$$

(11.17) tenglamaga asosan **liniya foydali ish koeffitsienti** quyidagi tenglamadan aniqlanadi:

$$h = \frac{P_2}{P_1} = e^{-2\gamma l}$$

b) liniya rostlashgan holatida maksimal quvvat uzatish mumkin bo'ladi:

$$P_{2max} = I_H^2\rho = \frac{U_H^2}{\rho} \qquad (11.19)$$

Liniya juda uzun bo'lganda $(2l \geq 1{,}5)$ va $\underline{Z}_2 \neq \underline{Z}_C$.

Bu holatda yuqorida keltirilgan tenglamadan zarur bo'lgan miqdorning barchasi hisoblab topiladi.

d) isrofsiz liniya. Isrofsiz liniya uchun (11.8) tenglamani quyidagicha yozamiz:

$$\left.\begin{aligned} \dot{U}_X &= \dot{U}_1 \cos\beta X - j\dot{I}_1\underline{Z}_C \cos\beta X \\ \dot{I}_X &= \dot{I}_1 \cos\beta X - j\frac{\dot{U}_1}{\underline{Z}_C}\cos\beta X \end{aligned}\right\} \qquad (11.20)$$

Shunga o'xshash (11.10) tenglamani ham quyidagicha belgilab olamiz:

$$\left.\begin{aligned} \dot{U}_X &= \dot{U}_2 \cos\beta X - j\dot{I}_2\underline{Z}_C \cos\beta X \\ \dot{I}_X &= \dot{I}_2 \cos\beta X - j\frac{\dot{U}_2}{\underline{Z}_C}\cos\beta X \end{aligned}\right\} \qquad (11.21)$$

Agar liniya masofasi x oxiridan hisoblansa (11.11) va (11.5) tenglamaga binoan:

$$\underline{Z}_{kir} = \underline{Z}_C \frac{\underline{Z}_2 - j\underline{Z}_C tg\frac{2\pi}{\lambda}l}{j\underline{Z}_C tg\frac{2\pi}{\lambda}\underline{Z}_C} \qquad (11.22)$$

4. Turg'un (qo'zg'almas) to'lqinlar.

Odatda turg'un to'lqinlar isrofsiz liniyada salt va qisqa tutashuv holatlarida yuzaga kelib, to'g'ri va teskari to'lqinlarning amplitudalari bir xil bo'lganda, ya'ni ikkita kiruvchi to'lqinni ushlashdan iborat. Bundan tashqari, liniyaga ulangan iste'molchida aktiv, reaktiv quvvat sarf bo'lmasligi kerak.

a) (11.21) tenglamaga asosan liniya salt ishlash holati:

$$\dot{I}_2 = 0; \ \underline{Z}_2 = \infty$$

$$\dot{U}_X = \dot{U}_C \cos\beta X, \ \dot{I}_X = j\frac{\dot{U}_2}{\underline{Z}_C}\cos\beta X \qquad (11.23)$$

Liniya qanday masofa va vaqtiga bog‘liq bo‘lmagan holda:

$$X = k\frac{\pi}{\beta} = k\frac{\lambda}{2}$$

Haqiqatan ham $X = 0, \lambda/2, \lambda, 3\lambda/2$ va hokazo hollarda $\cos\beta X = \pm 1$ bo‘lib, $X = \lambda/4, 3\lambda/4, 5\lambda/4$ va hokazo bo‘lganda $\cos\beta X = 0$

X masofada kuchlanish ham xuddi shunday qonuniyat bilan o‘zgarib $\cos\beta X = \pm 1$ da kuchlanishlar «**bo‘rtiq**»larini, $\cos\beta X = 0$ bo‘lganda kuchlanish «**tugun**» larini hosil qiladi.

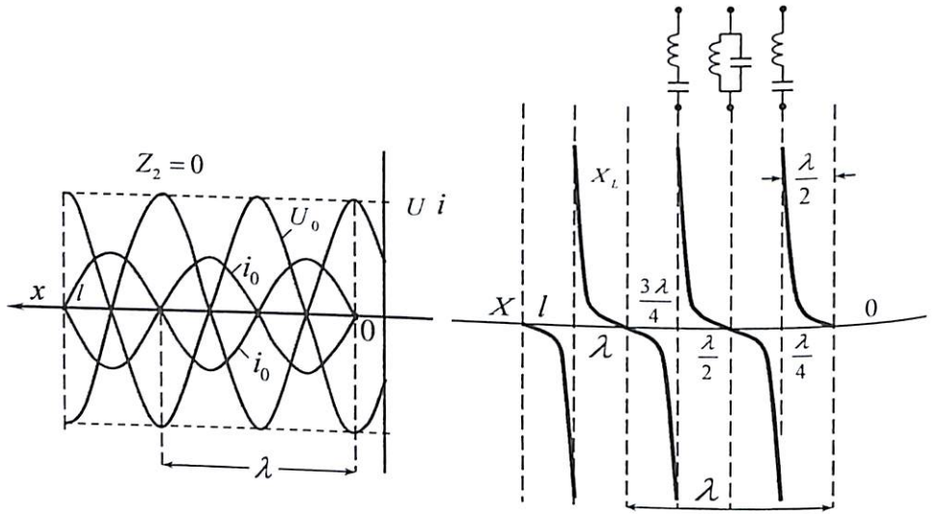
Isrofsiz liniya salt ishlaganda (11.20) formulaga binoan uning kirish qarshiligi:

$$\underline{Z}_0 = \frac{\dot{U}_{10}}{\dot{I}_{10}} = \frac{\underline{Z}_C}{jtg\beta l} = -j\underline{Z}_C ctg\beta l = jXl \qquad (11.24)$$

Bunda Xl - liniya tavsifiy qarshiligi, «**moduli**» shu sababli

$$\theta = 0, \qquad \underline{Z}_C = X_C$$

Liniyaga kiruvchi qarshilik sof reaktiv qarshilik bo‘lib, uning qiymati, ishorasi liniyaning uzunligi X va manba kuchlanishi bilan o‘lchanadi.



Agar liniya uzunligi $l = k\frac{\lambda}{2}$ bo‘lsa, kirish qarshiligi induktivlik xususiyatiga ega bo‘lib, o‘zini xuddi tok rezonansi rejimida ideal parallel konturdek tutadi.

Agar liniya uzunligi $l = (2k+1)\frac{\lambda}{4}$ bo‘lganda, uning kirish qarshiligi sig‘im xususiyatiga ega bo‘lib, o‘zini xuddi kuchlanish rezonansi rejimidagi ideal ketma-ket tebranish konturidek tutadi.

b) isrofsiz liniyada qisqa tutashuv $\underline{Z}_2 = 0$ va $\dot{U}_2 = 0$. Bunday liniyaning kirish qarshiligi (11.22) tenglamaga asosan quyidagicha ifodalanadi:

$$\underline{Z}_K = \frac{\dot{U}_{1K}}{\dot{I}_{1K}} = j\underline{Z}_C \qquad tg\beta l = jXl \qquad (11.25)$$

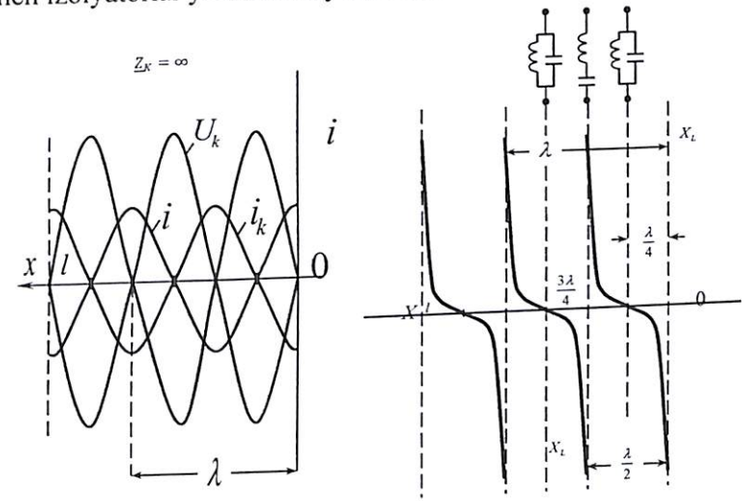
liniyaning har qanday nuqtasida tok va kuchlanish quyidagicha aniqlanadi:

$$\dot{U}_K = j\dot{I}_{2K}\underline{Z}_C \sin\beta X, \quad \dot{I}_K = \dot{I}_{2K}\cos\beta X \qquad (11.26)$$

Qisqa tutashuvda hosil bo‘ladigan turg‘un to‘lqin hududi salt ish-lash holatidek faqat fazalari jihatidan $\lambda/4$ masofaga siljigan. Liniya-ning uzunligi $l = 0, \lambda/2, \lambda$ va hokazo bo‘lganda, liniyadagi tok bo‘r-tiqlari va kuchlanish tugunlarining liniya oxiridan $l = \lambda/4,\ 3\lambda/4, 5\lambda/4$ va h.k. masofalardagi nuqtalarda esa kuchlanish bo‘rtiqlari $\dot{U}_K$ va tok tugunlari i_K ning hosil bo‘lishi kuzatiladi. Uzunligi $l = \lambda/2, \lambda, 3\lambda/2$ va h.k bo‘lib, oxirida qisqa tutashgan liniyaning kirish qarshiligi $\underline{Z}_2 = 0$ va bunday liniya o‘zini xuddi kuchlanish rezonansi zanjiriday tutadi.

Uzunligi $l = \lambda/4,\ 3\lambda/4,\ \lambda, 5\lambda/4$ va h.k. bo‘lgan liniyaning kirish qarshiligi $\underline{Z}_K = \infty$o‘zini xuddi toklar rezonansi zanjiriday tutadi.

Bunday isrofsiz liniyaning yuqori chastotali qurilmalar uchun sof tayanch izolyatorlar yasashda foydalaniladi.



11.2. Masalalar yechish va uslubiy ko‘rsatmalar

11.1-Masala. Bir jinsli liniyaning boshlang‘ich parametri: $R_0 = 2.25\ \frac{Om}{km}$, $L_0 = 2\cdot 10^{-3}\frac{Gn}{km}$, $C_0 = 6\cdot 10^{-9}\frac{F}{km}$, $g_0 = 10^{-6}\frac{1}{Om\cdot km}$ uzunligi $l = 100\ km$ chastota $f = 800Gs$ ga teng, to‘lqin qarshiligi – Z_C, doimiy tarqalish koeffitsienti–γ, to‘lqin tarqalish tezligi – υ va uzunligi – λ hamda $\frac{I_{2m}}{I_{1m}} = \frac{U_{2m}}{U_{1m}}$ nisbat aniqlansin.

Yechish. Mis simdan tortilgan havo liniyasining to‘lqin qarshiligi:

$$\underline{Z_C} = \sqrt{\frac{R_0 + j\omega L_0}{g_0 + j\omega C_0}} = \sqrt{\frac{2{,}25 + j10}{10^{-6}(1 + j30)}} = 585\cdot e^{-j6^{\circ}5}\ Om;$$

Doimiy tarqalish koeffitsienti:

$$\underline{\gamma} = \sqrt{(R_0 + j\omega L_0)(g_0 + j\omega C_0)} = (\gamma)e^{j\omega} = 17{,}6\cdot 10^{-3}e^{j82^{\circ}}\left(\frac{1}{km}\right)$$

So‘nish koeffitsienti: $\beta = |\gamma|\sin 82^{\circ} = 2{,}44\cdot 10^{-3}\left(\frac{1}{km}\right)$

Faza koeffitsienti: $\alpha = |\gamma|\sin 82^{\circ} = 17{,}6\cdot 10^{-3}\left(\frac{1}{km}\right)$

Liniya bo‘ylab to‘lqin tarqalish tezligi:

$$\upsilon = \frac{\omega}{\alpha} = \frac{2\pi\cdot 800}{17{,}6\cdot 10^{-3}} = 289000\left(\frac{km}{sek}\right)$$

To‘lqin uzunligi: $\lambda = \frac{2\pi}{\alpha} = \frac{2\cdot 3{,}14}{17{,}6\cdot 10^{-3}} = 360km$

Liniyaning boshi va oxirida so‘nuvchi to‘lqin tok va kuchlanishlar amplituda nisbati:

$$\frac{I_{2m}}{I_{1m}} = \frac{U_{2m}}{U_{1m}} = e^{\beta l} = \frac{1}{e^{2{,}44\cdot 10^{-3}\cdot 100}} = 0{,}785$$

11.2-Masala. Uzunligi $l = 200\ m$ va boshlang‘ich parametrlari $L_0 = 2\cdot 10^{-6}\ Gn/km$, $C_0 = 5{,}55\cdot 10^{-6}\ mkF/m$ bo‘lgan isrofsiz liniyada to‘lqin uzunligi $\lambda = 60\ m$ ga teng. Liniya oxiriga $L = 0{,}01\ mGn$ induktivlik ulangan.

a) to‘lqin qarshiligi; b) liniyada bo‘rtiq to‘lqinlar tok va kuchlanish hosil bo‘lishini isbotlash; d) liniya oxiridan qanday X masofada tok va kuchlanish bo‘rtig‘i hosil bo‘ladi; e) tok va kuchlanishlar uchun liniya oxiridan bo‘rtiq amplituda nisbatlari; f) tok va kuchlanish uchun liniya boshida bo‘rtiq amplituda nisbati;

g) liniyaga kirish qarshiligi aniqlansin.

Yechish. To‘lqin qarshiligi: $\bar{Z}_C = \sqrt{\frac{L_0}{C_0}} = 600\ Om.$

Faza koeffitsienti: $\alpha = \frac{2\pi}{\lambda} = \frac{6\cdot 28}{60} = 0{,}105\left(\frac{1}{m}\right)$

(10.20) va (10.21) liniyaning kompleks tenglamasiga binoan hamda masalaning shartiga ko‘ra: $\underline{Z_{kir}} = \underline{Z_C}$, $\gamma = j\alpha$ va tok $\dot{I}_2 = \frac{\dot{U}_2}{\underline{Z_2}}$ yoki: $\underline{Z_2} = X_L = j\omega L = 2\pi fL = 314\ Om$ bo‘lib, quyidagi bir jinsli liniya kompleks tenglamasini yozamiz:

$$\left.\begin{aligned}\dot{U}_X &= \dot{U}_2\left(\cos\alpha X - \frac{\underline{Z_C}}{\underline{Z_2}}\sin\alpha X\right) = \frac{\dot{U}_2}{\cos\delta}\cos(\alpha X - \delta)\\ \dot{I}_X &= \dot{I}_2\left(\cos\alpha X - \frac{\underline{Z_2}}{\underline{Z_C}}\sin\alpha X\right) = \frac{\dot{I}_2}{\cos\delta}\cos(\alpha X - \delta)\end{aligned}\right\}$$

Bunda $\delta = arctg\frac{\underline{Z_C}}{\underline{Z_2}} = arctg\frac{600}{314} = 63^{\circ}20' = 1{,}1\ rad.$

Kuchlanish boshlang‘ich fazasi $\varphi_U = 0$ ekanligi inobatga olinib, tok va kuchlanishni oniy qiymat orqali ifodalaymiz:

$$\left.\begin{aligned}u_X &= \frac{\sqrt{2U_2}}{\cos\delta}\cos(\alpha X - \delta)\sin\omega t = U_{2m}\cos(\alpha X - \delta)\sin\omega t\\ i_X &= \frac{\sqrt{2I_2}}{\sin\delta}\sin(\alpha X - \delta)\cos\omega t = I_{2m}\sin(\alpha X - \delta)\cos\omega t\end{aligned}\right\}$$

Keltirilgan tenglamaga asosan liniyada turg‘un holatdagi tok yuzaga kelishi mumkun. Liniya oxiridagi bo‘rtiq kuchlanish

$$(\cos\alpha X_1 - \delta) = 1$$

Bundan: $\alpha X_1 - \delta = 0$ $X_1 = \frac{\delta}{\alpha} = \frac{1{,}09}{0{,}1} = 10{,}5\ m$

Liniya oxirida hosil bo‘lgan bo‘rtiq tok masofasi:

$$X_2 = X_1 + \frac{\lambda}{4} = 10{,}5 + \frac{60}{4}m$$

Liniya oxiridagi bo‘rtiq tok va kuchlanish amplituda nisbati:

$\frac{U_2}{\cos\delta} : U_2 = \frac{1}{\cos\delta} = 2{,}15$ va $\frac{I_2}{\cos\delta} : I_2 = \frac{1}{\cos\delta} = 1{,}13$

Liniya boshida bo‘rtiq tok va kuchlanish amplituda nisbati:

$$\frac{U_2}{\cos\delta} : \frac{U_2}{\cos\delta}\cos(\alpha l - \delta) = \frac{1}{\cos(1047\cdot 10^{-4}\cdot 200 - 1{,}09)}$$

$$= \frac{1}{\cos 57^{\circ}30'} = 1{,}86$$

Tok uchun: $\frac{I_2}{\cos\delta} : \frac{I_2}{\cos\delta}\sin(\alpha l - \delta) = \frac{1}{\sin 57^{\circ}30'} = 1{,}19$

11.3-Masala Uzunligi $l = 2$ km ga teng bir jinsli isrofsiz liniyaga $\dot{U}_2 = 120\sin 30000t$ bo'lgan o'zgaruvchan kuchlanish ulangan. Iste'molchi qarshiligi bilan to'lqin qarshiligi: $\underline{Z}_2 = \underline{Z}_C$ va $\underline{Z}_2 = 2\underline{Z}_C$ bo'lgan holat uchun liniya kirish qismidagi (boshidagi) $\dot{U}_1$ kuchlanish, $\underline{Z}_2 = 2\underline{Z}_C$ bo'lganda to'lqin qaytish hamda yuguruvchi koeffitsient aniqlansin.

Yechish. Isrofsiz liniyada to'lqin tarqalish tezligi: $v = 3 \cdot 10^5 \left(\frac{km}{sek}\right)$. Shu sababli (11.17) tenglamaga binoan liniya oxiridagi kuchlanish U_2 ga nisbatan boshidagi U_1 kuchlanishga nisbatan fazadagi farq:

$$\Delta\varphi = \beta l = \frac{\omega t}{v} = \frac{3 \cdot 10^4 \cdot 2}{3 \cdot 10^5} = 0{,}2\ rad$$

(11.17) tenglamaga asosan $\underline{Z}_2 = \underline{Z}_C$ bo'lsa:

$$u_1 = 120\sin(30000t + 0{,}2) = 120\sin(30000t + 12°)\ (V)$$

Iste'molchi $\underline{Z}_2 = 2\underline{Z}_C$ bo'lganda liniya kirish qismidagi kuchla-nishni (11.21) tenglamaga binoan quyidagicha yozamiz:

$\dot{U}_1 = \dot{U}_2\left(\cos\beta l + \frac{1}{2}j\sin\beta l\right)$.Demak: $\varphi = \varphi_{U1} - \varphi_{U1} arctg\frac{1}{2}tg\beta l$

Tangens kichik burchagi o'zining burchagiga teng bo'lib: $\Delta\varphi = 0{,}1\ rad = 6°$

U_{1m} kuchlanish amplitudasi U_{2m} dan kichik bo'lib:

$$U_{1m} = U_{2m}\cos\beta l\sqrt{1 + \left(\frac{1}{2}tg\beta l\right)^2} = U_{2m}\cos 0{,}2\sqrt{1 + 0{,}1^2} =$$

$$U_{2m}0{,}98(1 + 0{,}005) = 0{,}98U_{2m}$$

Liniya boshidagi kuchlanish oniy qiymati:

$$u_1 = 1200{,}985\sin(30000t + 6°) = 118\sin(30000t + 6°)\ \text{V}$$

Iste'molchi qarshiligi $\underline{Z}_2 = 2\underline{Z}_C$ bo'lganda (11.6) tenglamaga asosan to'lqin qaytish koeffitsienti : $K_U = \frac{\underline{Z}_2 - \underline{Z}_C}{\underline{Z}_2 + \underline{Z}_C} = \frac{2-1}{2+1} = \frac{1}{3}$

Yuguruvchi to'lqin koeffitsienti: $K = \frac{1-K_U}{1+K_U} = \frac{1-\frac{1}{3}}{1+\frac{1}{3}} = 0{,}5$

11.4-Masala. Uzunligi $l = 900\ km$, uch fazali liniya chastotasi $f = 50\ Gs$, to'lqin tarqalish umumiy koeffitsienti $\underline{\gamma} = (0{,}1 + j1{,}7)10^{-3}$ va to'lqin qarshiligi $\underline{Z}_C = 400e^{-j6°}Om$, liniya oxiridagi kuchlanishi $U_{л2} = \sqrt{3} \cdot 220\ kV$ ga teng. Liniya boshidagi U_{1L} kuchlanish, liniya boshidagi va oxiridagi tok $\dot{I}_1, \dot{I}_2$ liniyadagi tok quvvati va foydali ish koeffitsienti aniqlansin.

Yechish. Liniya sof quvvati $\underline{Z}_\phi + \underline{Z}_C$ bo'lganda liniya oxiridagi quvvat qiymati hisoblanadi:

$$P_2 = 3\frac{(220 \cdot 10^3)^2}{400}\cos 6° = 363 \cdot 10^6 Vt = 363MVt$$

(11.16) tenglamaga asosan: $\dot{U}_{1L} = \dot{U}_2 e^{\gamma l} = \dot{U}_2 e^{\alpha l} \cdot e^{\beta l} = 220e^{0{,}09} \cdot e^{j0{,}963}220 \cdot 1{,}094e^{j55°} = 241e^{j55°}\ kV$

yoki: $U_{1L} = 241\sqrt{3} = 417\ (kV)$

Liniya boshidagi kiruvchi tok:

$$\dot{I}_1 = \frac{\dot{U}_{1л}}{\underline{Z}_C} = \frac{214e^{j55°}10^3}{400e^{-j6°}} = 602{,}5e^{j61°}\ \ (A)$$

Liniya oxiridagi tok: $\dot{I}_1 = \frac{\dot{U}_{2л}}{\underline{Z}_C} = \frac{220 \cdot 10^{-3}}{400e^{-j6°}} = 550e^{j6°}\ \ (A)$

Liniya foydali ish koeffitsienti tenglamasiga binoan:

$$\eta = e^{-2\gamma l} = e^{-0{,}18} \approx 0{,}83$$

11.5-Masala. Bir necha jinsli uch fazali liniya uzunligi $l = 200\ km$, to'lqin tarqalish koeffitsienti $\gamma = (0{,}59 + j1{,}21)10^{-3}\left(\frac{1}{km}\right)$, to'lqin qarshiligi $Z_C = 475e^{-j26}(Om)$ ga teng. Liniya oxiridagi liniya kuchlanishi $U_L = 100KV, cos\,\varphi = 0{,}8$ bo'lgan iste'molchi quvvati $P = 10\ MVt$ nimstansiyaga ulangan. Liniya boshidagi kuchlanish $\dot{U}_{1L}$ va liniya oxiridagi kuchlanish $\dot{U}_{2L}$ va ular orasidagi fazadagi farq aniqlansin.

Yechish. Uch fazali liniyada iste'molchi qarshiligi simmetrik bo'lganligi uchun: $\varphi = arc\cos 0{,}8 = 37°$ fazadagi qarshilik:

$$Z_\phi = \frac{U_{л2}^2}{P}\cos\varphi = \frac{10^{10}}{10^7}0{,}8 = 800\ Om$$

yoki: $\underline{Z}_\phi = Z_\phi e^{j\varphi} = 800e^{j137°} = (640 + j480)\ Om$

(11.10) tenglamadan foydalanamiz: $\dot{U}_1 = \dot{U}_2\left(ch\gamma e + \frac{\underline{Z}_C}{\underline{Z}_\phi}sh\gamma e\right)$

Giperbolik funksiya argumentini kompleks ifoda orqali yozamiz:

$sh\gamma l = \frac{1}{2}(e^{\gamma l} - e^{\gamma l})$ $ch\gamma l = \frac{1}{2}(e^{\gamma l} + e^{-\gamma l})$

Bunda: $\gamma l = (0{,}59 + j1{,}21) \cdot 10^{-3} \cdot 200 = 0{,}118 + j0{,}242$

Giperbolik funksiya kompleks ifodasidan haqiqiy argumentga o'tishda tablitsadan foydalaniladi:

$sh\gamma l = \frac{1}{2}\left(e^{0{,}118} \cdot e^{-j0{,}242} - e^{-0{,}118} \cdot e^{-0{,}242}\right) = \frac{1}{2}[1{,}125(\cos 0{,}242 +$

$j\sin 0{,}242) - 0{,}89(\cos 0{,}242 + j\sin 0{,}242)] = 0{,}114 + j0{,}242$

Ikkinchi giperbolik funksiya ifodasi:

$$ch\gamma l(0{,}118 + j0{,}242) = 0{,}98 + j0{,}028$$

Aniqlangan kompleks qiymatni kuchlanish tenglamasiga qo‘yamiz:

$$\dot{U}_1 = \dot{U}_2\left[(0{,}98 + j0{,}028) + \frac{475e^{-j26^\circ}}{800e^{37^\circ}}(0{,}114 + j0{,}242)\right] = \dot{U}_2[0{,}98 + j0{,}028 + 0{,}6e^{-j63^\circ} \cdot (0{,}114 + j0{,}242)] = \dot{U}_2(1{,}14 + j0{,}035)$$

Liniya boshidagi: $\dot{U}_1 \approx 1{,}14\dot{U}_2 = 114\ kV$

Liniya boshidagi va oxiridagi kuchlanish orasidagi fazadagi farq kompleks mavhum ifodadagi haqiqiy songa nisbati bilan aniqlanadi:

$$tg\varphi_U = \frac{0{,}035}{1{,}14} = 0{,}0306$$

Tangens burchak juda ham kichik bo‘lsa, uning argumenti o‘ziga teng bo‘ladi, yoki: $\varphi_U \approx 0{,}0306 = 1{,}75^\circ$

11.6-Masala. Isrofsiz liniya parametri $L = 2{,}25\frac{mGn}{km}$, $C = 4{,}6\frac{mkF}{km}$ bo‘lib, uzunligi $l = 200\ km$ ga teng. Liniya oxirida chastota: $f = 50\ Gs\ va\ U_2 = 100\ kV$ kuchlanishga ulangan. Iste’molchi qarshiligi liniya xarakteristik tenglamasiga teng $\underline{Z}_2 = \underline{Z}_C$.

Liniya boshidagi tok I_1 va kuchlanish $\dot{U}_1$ qiymati va fazadagi farq aniqlansin.

Yechish. Isrofsiz liniya tavsifiy qarshiligi sof aktiv qarshiligi bo‘lib:

$$Z = R = \sqrt{\frac{L}{C}} = \sqrt{\frac{2{,}25\cdot10^{-3}}{4{,}5\cdot10^{-9}}} = 1000 \cdot 0{,}7 = 700\ Om$$

Liniya oxiridagi tok: $I_2 = \frac{U_2}{Z_H} = \frac{U_2}{Z} = \frac{100000}{700} = 143\ A$

Liniya boshi va oxiridagi kuchlanish $\dot{U}_1$ va$\dot{U}_2$ muvozanati:

$$\dot{U}_1 = \dot{U}_2 e^{\gamma l} = \dot{U}_2 e^{j\alpha l}$$

Bunda isrofsiz liniya bo‘lganligi uchun faza koeffitsienti:$\beta = 0$

Xuddi shunga o‘xshash tok tenglamasi: $\dot{I}_1 = \dot{I}_2 e^{j\alpha l}$

Faza koeffitsientini aniqlaymiz:

$$\alpha = \omega\sqrt{LC} = 314\sqrt{2{,}25 \cdot 4{,}6 \cdot 10^{-3} \cdot 10^{-9}} = 1{,}02 \cdot 10^{-3}\frac{1}{km}$$

To‘lqin uzunligi:

$$\lambda = vT = \frac{1}{\sqrt{LC}\cdot f} = \frac{2\pi}{\omega\sqrt{LC}} = \frac{2\pi}{\alpha} = \frac{2\pi\cdot10^3}{1{,}02} = 6160\ (km)$$

yoki: $\alpha l = 2\pi\frac{l}{\lambda} = 2\pi\frac{200}{6160} = 0{,}204$

$\dot{U}_2$kuchlanish haqiqiy son ekanligini hisobga olganda liniya boshidagi kuchlanish: $\dot{U}_1 = 100e^{j11{,}7^\circ}$ (кВ)

Tok esa: $\dot{I}_1 = 143e^{j11{,}7^\circ}$ (A)

11.7-Masala. Signal shakli o‘zgarmas bir jinsli liniyaning parametri: $L = 1\frac{MGn}{km}$, $C = 11{,}2 \cdot 10^{-3}\frac{mkF}{km}$ va $R = 8\ Om/km$ bo‘lib, liniya oxiriga $R_H = 100\ Om$ aktiv qarshilik ulangan. Liniya uzunligi $l = 40\ km$, chastotasi $f = 10^4 Gs$, liniya oxiridagi kuchlanish $U_2 = 1000\ V$ bo‘lganda, liniya boshidagi kuchlanish aniqlansin.

Yechish. Liniya birlamchi parametrini bog‘lovchi tenglamadan o‘tkazuvchanlik aniqlanadi:

$$\frac{R}{L} = \frac{g}{C};\ g = \frac{RC}{L} = \frac{8\cdot11{,}2\cdot10^{-9}}{10^{-3}} = 89{,}6 \cdot 10^{-6}\frac{1}{Om\cdot km}$$

Faza koeffitsienti:

$$\beta = \sqrt{Rg} = \sqrt{89{,}6 \cdot 8 \cdot 10^{-6}} = 26{,}8 \cdot 10^{-3}\frac{1}{km}$$

So‘nish koeffitsienti:

$$\alpha = \omega\sqrt{LC} = 6{,}28 \cdot 10^{-3}\sqrt{1 \cdot 11{,}2 \cdot 10^{-3} \cdot 10^{-9}} = 0{,}21\frac{1}{km}$$

To‘lqin uzunligi: $\lambda = \frac{2\pi}{\alpha} = \frac{6{,}28}{0{,}21} = 30\ km$

To‘lqin tavsifiy qarshiligi: $Z = \sqrt{\frac{L}{C}} = \sqrt{\frac{10^{-3}}{11{,}2\cdot10^{-9}}} = 300\ Om$

Liniya oxiridagi tok kompleks ifodasi: $\dot{I}_2 = \frac{\dot{U}_2}{R_H} = \frac{1000}{100} = 10\ A$

(11.10) tenglamani kuchlanish $\dot{U}_2$ va tok $\dot{I}_2$ qavsdan tashqariga chiqariladi:

$$\left.\begin{aligned}\dot{U}_1 &= \dot{U}_2\left(ch\gamma X + \frac{\underline{Z}}{\underline{Z}_H}sh\gamma X\right)\\ \dot{I}_1 &= \dot{I}_2\left(ch\gamma X - \frac{\underline{Z}_H}{\underline{Z}}sh\gamma X\right)\end{aligned}\right\}(*)$$

$$X = l = 40\ km.$$

Bunda:$\beta l = 26{,}8 \cdot 10^{-3} \cdot 40 = 1{,}07$ $\alpha l = 0{,}21 \cdot 40 = 8{,}4$

yoki:

$ch(\beta l + j\alpha l) = ch(1{,}07 + j8{,}4) = ch\ 1{,}07 \cdot \cos 8{,}4 + jsh\ 1{,}07 \cdot \sin 8{,}4 = 1{,}6(-0{,}5) + j1{,}29 \cdot 0{,}866 = -0{,}815 + j1{,}12$

$sh(\beta l - j\alpha l) = sh1{,}07 \cdot \cos 120^\circ + jch1{,}07 \cdot \sin 120^\circ = -0{,}645 + j1{,}41$

Liniyadagi qarshilik nisbati: $\frac{\underline{Z}}{\underline{Z}_H} = \frac{300}{100} = 3$

Aniqlangan qiymat (*) tenglamadagi tok va kuchlanish ifodasiga qo‘yiladi:

$$U_1 = U_2[-0{,}815 + j1{,}12 + 3(0{,}645 + j1{,}41)] = U_2(-2{,}85 + j5{,}354) = 1000 \cdot 6 \cdot 07e^{j118^\circ} = 6070e^{j118^\circ}$$

Kuchlanish haqiqiy qiymati: $U_1 = 6070\ V$

$$\dot{I}_1 = \dot{I}_2\left[-0{,}815 + j1{,}12 + \frac{1}{3}(0{,}645 + j1{,}41)\right] = \dot{I}_2(-1{,}03 + j1{,}6) = 10 \cdot 1{,}9e^{j123^\circ} = 19e^{j123^\circ}$$

tok haqiqiy qiymati: $I_1 = 19\ A$.

11.3. Mustaqil yechish uchun masalalar

11.1-Masala. Ikki simli uzatish liniyasi birlamchi parametri: $R_0 = 6\frac{Om}{km}$, $L_0 = 1{,}6 \cdot 10^{-3}\frac{Gn}{km}$, $g_0 = 10^{-6}\frac{1}{Om \cdot km}$, $C_0 = 6{,}4 \cdot 10^{9}\frac{F}{km}$, Liniya chastotasi $f_1 = 100\ Gs$ va $f_2 = 100\ Gs$ bo'lgan hollarda to'lqin tarqalish koeffitsienti, to'lqin uzunligi, to'lqin qarshiligi aniqlansin.

Javob: $\underline{\gamma}_1 = 5{,}3 \cdot 10^{-3}e^{j44^\circ}\frac{1}{km}$, $\underline{Z}_{C1} = 1150 \cdot e^{-j34^\circ 30'}\frac{1}{km}$,

$\alpha_1 = 3{,}82 \cdot 10^{-3}\frac{1}{km}$, $\beta_1 = 3{,}65 \cdot 10^{-3}\frac{1}{km}$,,

$v_1 = 173 \cdot 10^3\ km/sek$, $\lambda_1 = 173km$.

$\underline{\gamma}_2 = 22{,}9 \cdot 10^{-3}e^{j74^\circ}\frac{1}{km}$, $\underline{Z}_{C2} = 510 \cdot e^{-j15^\circ}Om$,

$\alpha_1 = 6{,}4 \cdot 10^{-3}\frac{1}{km}$, $\beta_2 = 22 \cdot 10^{-3}\frac{1}{km}$

$v_2 = 288 \cdot 10^3\ km/sek$, $\lambda_2 = 288\ km$.

11.2–Masala. Koaksial kabel parametri:$R = 7\frac{Om}{km}$, $L = 0{,}3 \cdot 10^{-3}\frac{Gn}{km}$, $C = 0{,}2\frac{mkF}{km}$, $g = 0{,}5 \cdot 10^{-6}\frac{1}{Om \cdot km}$, bo'lib, chastotasi $f = 800\ Gs$.

Kabel to'lqin qarshiligi $\underline{Z}_C, \alpha, \beta$ koeffitsienti, to'lqin tarqalish tezligi v va to'lqin uzunligi λ aniqlansin.

Javob: $\underline{Z}_C = 843e^{-j15^\circ}Om$, $\beta = 5{,}36 \cdot 10^{-2}\frac{1}{km}$, $\alpha = 6{,}62 \cdot 10^{-2}\frac{1}{km}$, $v = 0{,}75 \cdot 10^5\ km/sek$, $\lambda = 95\ km$.

11.3-Masala. Isrofsiz liniya to'lqin qarshiligi $\underline{Z}_C = 865\ Om$, uzunligi $l = 200\ km$ bo'lib, $f = 1000\ Gs$ chastotali o'zgaruvchan kuchlanish $U_1 = 50\ V$ ga ulangan. Liniya oxirida salt va qisqa tutashuv tajribalariga asosan liniya boshidagi kompleks qarshilik Z_{10} va $\underline{Z}_{1K}$qiymati aniqlansin.

Javob: $\underline{Z}_{10} = -j500$ Om, $\underline{Z}_{1K} = j1500\ Om$

11.4-Masala. Shakli o'zgarmas liniya koeffitsienti, $\beta = 26{,}8 \cdot 10^{-3}\frac{1}{km}$, $\alpha = 3{,}34 \cdot 10^{-6}\frac{1}{km}$ va to'lqin qarshiligi $\underline{Z}_C = 300\ Om$ ga teng. Liniya uzunligi $l = 100\ km$, $f = 400\ Gs$ bo'lganda salt ishlash va qisqa tutashuv holatidagi qarshilik Z_{10} va Z_{1K} aniqlansin.

Javob: $Z_1 = 300\ Om$; $Z_{1K} = 300\ Om$;

11.5-Masala. Uzunligi $l = 100\ km$, chastotasi $f = 1600\ Gs$ bo'lgan telefon liniyasida o'tkazilgan qisqa tutashuv va uzilgan holat uchun $\underline{Z}_{10} = 900e^{-j40^\circ}$ Om, $\underline{Z}_{1K} = 100e^{-j40^\circ}\ Om$ qarshilik qiymati aniqlangan.

Liniya to'lqin qarshiligi Z_C tarqalish koeffitsienti γ, induktivlik va sig'im parametrlari aniqlansin.

Javob: $\underline{Z} = 300\ Om,\ L = 10^{-8}\frac{Gn}{km},\ C = 11{,}2 \cdot 10^{-3}\frac{mkF}{km}$

$$\gamma = \beta + j\alpha = (2{,}5 \cdot 10^{-3} + j\,3/35 \cdot 10^{-2})\frac{1}{km}$$

11.6-Masala. Elektr energiya uzatish liniya uzunligi $l = 1000\ km$ ga teng bo'lib, birlamchi parametri: $R_0 = 0{,}035\frac{Om}{km}$, $\omega L_0 = 0{,}392\frac{Om}{km}$, $g_0 = 4{,}17 \cdot 10^{-8}\frac{sim}{km}$, $\omega C = 2{,}92 \cdot 10^{-6}\frac{Om}{km}$, liniya oxiriga ulangan iste'-molchi quvvati $P_2 = 300MVt$, kuchlanishi $U_2 = 220{,}3kV$ va $\cos\varphi = 1$ ga teng. Liniyaning ikkilamchi parametri va kirish qismidagi $\dot{I}_1$ tok va $\dot{U}_2$ kuchlanish qiymati aniqlansin.

Javob: $\underline{Z}_1 = 367e^{-j2^\circ15'}Om;\ g = 1{,}07 \cdot 10^{-3}e^{j87^\circ}\frac{1}{Om}$

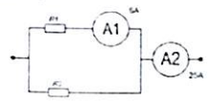
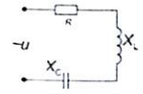
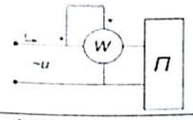
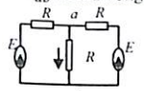
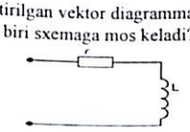
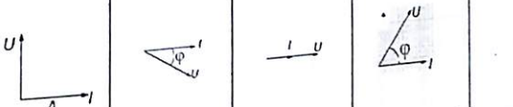
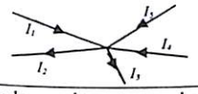
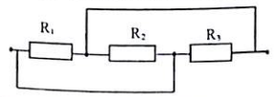
$\dot{U}_2 = 201e^{j57^\circ}kV,\ \dot{I}_1 = 570e^{-j65^\circ30'}A$

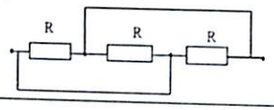
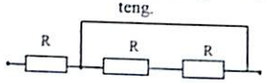
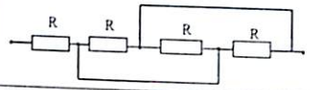
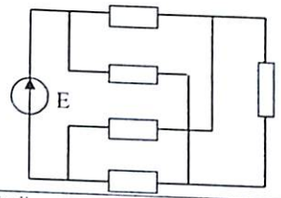
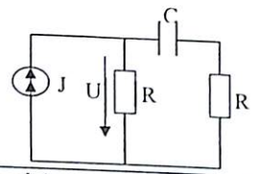
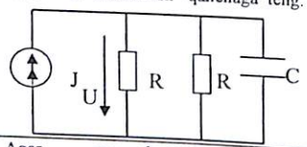
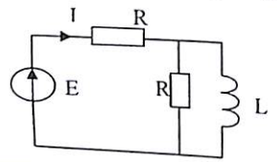
Nazorat savollari

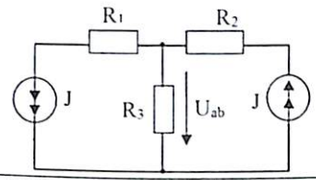
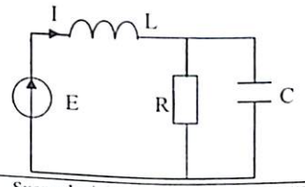
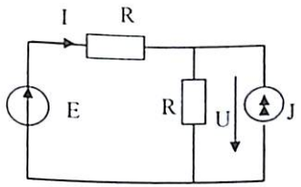
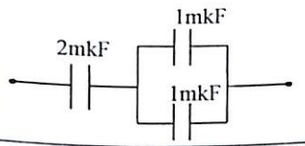
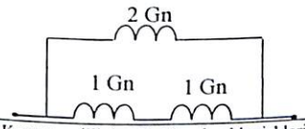
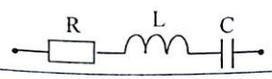
1. Tarqoq parametrli elektr zanjiri nima? Misol keltiring.
2. Tarqoq uzunlikdagi liniyaning qaysi parametri birinchi yoki ikkinchi hisoblanadi?
3. Bir jinsli liniya to'lqin yoki tavsifiy qarshiligi va liniya tarqalish koeffitsienti ifodalarini yozing.
4. Elektromagnit to'lqin tarqalish va to'lqin uzunligi tenglamasini yeching.
5. Bir jinsli tarqoq parametrli zanjirdagi tok ekvivalent sxemasini chizib, tenglamasini yozing.
6. Isrofsiz liniyaning salt holatdagi tok va kuchlanish tenglamasini yozing.
7. Bir jinsli uzun liniya to'rt qutbli T va Π sxemaga ekvivalent shaklda almashtirish mumkinmi?
8. Isrofsiz liniya nima ekanligini tushuntirib bering.
9. Qanday sharoitda elektromagnit jarayon liniyada turg'un to'lqin hosil qiladi?
10. Isrofsiz liniyada kuchlanish «bo'rtiq» lari va «tugun» lari qanday hosil bo'ladi?
11. To'lqin uzunligi bilan tarqalish fazasi qanday bog'langan? Ifodasini yozing.
12. Isrofsiz uzatish liniyasida elektromagnit to'lqin tarqalish tezligi qanchaga teng?
13. To'lqin tarqalish koeffitsient ifodasida so'nish koeffitsienti va faza koeffitsienti fizik ma'nosini tushuntirib, birligini yozing.
14. Iste'molchi qarshiligi liniya bilan muvofiqlashtirilganda qanday xususiyatga ega bo'ladi?
15. Elektromagnit jarayon turg'un to'lqin holatda bo'lganda energiya liniya bo'ylab tarqaladimi?

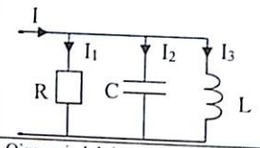
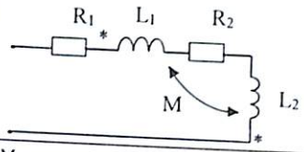
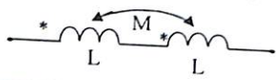
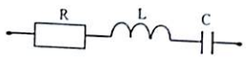
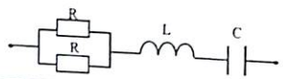
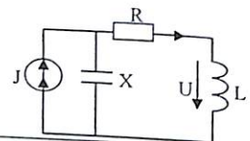
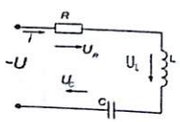
12. TEST SAVOLLARI

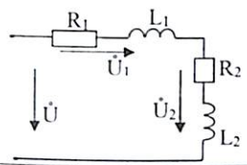
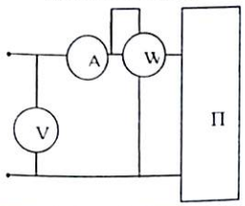
№	SAVOLLAR	Javob variantlari			
		A	B	C	D
1.	Kuchlanish $u = 30\sin(157t + 30°)$ Ifoda uchun ω va f topilsin.	157 rad/s; 50 Gs;	157 rad/s; 25 Gs;	157 rad/s; 157 Gs	25 rad/s; 157 Gs.
2.	$u = 141\sin(314t + 80°)$ $i = 14{,}1\sin(314t + 20°)$ Zanjirning aktiv quvvati aniqlansin.	500 Vt	616 Vt	1000 Vt	308 Vt,
3.	Kuchlanish va tok bo'yicha iste'molchining kompleks qarshiligi yozilsin. $u = 147\sin(\omega t + 80°40')$ $i = 42\sin(\omega t + 155°50')$	35	$(2{,}1 - j2{,}8)$	$(2{,}1 - j2{,}8)$	$(2{,}8 + j2{,}1)$
4.	Tenglamalardan qaysi biri o'zgaruvchan tok zanjirining to'la qarshiligini ifodalaydi.	$Z = \sqrt{R^2 + X^2}$	$Y = \sqrt{R^2 + X^2}$	$b = \frac{1}{\omega L} - \omega C$	$X = \omega L - \frac{1}{\omega C}$
5.	Formulalardan qaysi biri kommutatsiyaning birinchi qonunini ifodalaydi?	$u_{C(0-)} = u_{C(0+)}$	$L\frac{di_{L(0-)}}{dt} = L\frac{di_{L(0-)}}{dt}$	$i_{L(0-)} = i_{L(0+)}$	$\frac{dq_{L(0-)}}{dt} = \frac{dq_{L(0-)}}{dt}$
6.	Quvvatni ifodalovchi formulalarning qaysi biri xato yozilgan?	$P = UI\sin\varphi$	$S = UI$	$S = \sqrt{P^2 + Q^2}$	$Q = UI\sin\varphi$
7.	Formulalarning qaysi biri o'zgaruvchan tok zanjirining reaktiv qarshiligini ifodalaydi?	$Z = \sqrt{r^2 + x^2}$	$Y = \sqrt{g^2 + b^2}$	$b = \frac{1}{\omega L} - \omega C$	$X = \omega L - \frac{1}{\omega C}$
8.	Keltirilgan kompleks miqdorlarning qaysi biri trigonometrik tarzda ifodalangan?	$\dot{A} = Ae^{j\alpha}$	$\dot{A} = \alpha_1 + j\alpha_2$	$\dot{A} = (\cos\alpha + \sin\alpha)$	$\dot{A} = \dot{B} + \dot{C}$
9.	Transformatorning ishlash prinsipi:	Elektromagnit induksiyasi qonuniga asoslangan	Amper qonuniga asoslangan	Lens prinsipiga asoslangan	Hech qanday qonunga asoslanmagan
10.	Yulduzcha shaklida ulangan uch fazali tok zanjirida tok va kuchlanish munosabatlari qanday ifodalanadi?	$I_l = I_\varphi$ $U_l = \sqrt{3}U_\varphi$	$U_l = U_\varphi$ $I_l = \sqrt{3}I_\varphi$	$I_l = I_\varphi$ $\sum I_0 = 0$	$U_{00} = U_\varphi$ $I_l = I_\varphi$
11.	Elektr zanjirning kuchlanishi $U = 220$, toki $I = 10A$, aktiv quvvati $P = 1{,}1kVt$ ga teng bo'lganda, $cos\varphi$ nimaga teng?	$\cos\varphi = 0{,}75$	$\cos\varphi = 1$	$\cos\varphi = 0$	$\cos\varphi = 0{,}5$
12.	Neytral simli uch fazali tok zanjiri qanday sxemada ulanadi?	Uchburchak	Yulduzcha	Ketma-ket	Parallel
13.	4 qutbli zanjir simmetrik bo'lganda:	$B = D$	$B = C$	$A = D$ $A^2 - BC = 1$	$AD - BC = 0$
14.	Nosinusoidal tok R, L, C zanjiri k-yuqori garmonikadan iborat bo'lsa, to'la qarshiligi qanday ifodalanadi?	$z_k = \sqrt{r^2 + \left(k\omega L - \frac{1}{k\omega C}\right)^2}$	$y = \sqrt{g^2 + (b_L - b_C)^2}$	$X = kX_L - kX_L$	$z_k = \sqrt{R^2 \cdot (X_L - X_C)}$
15.	Rezonans holatda elektromagnit maydon energiyasi qanday munosabatda bo'ladi?	$W_E = W_M$	$W_E \neq W_M$	$W_E > W_M$	$W_E < W_M$
16.	Agar faza kuchlanishlari $U_A = U_B = U_C = 220\ V$ bo'lsa va yulduzcha shaklida ulangan aktiv va reaktiv iste'molchilarning qarshiliklari $R = 10\ Om$ $X_L = 10$ $X_C = 10\ Om$ bo'lsa, uch fazali zanjirning reaktiv quvvati qancha bo'ladi?	4840 var	14520 var	9680 var	0

17.	Agar sxemada $R_2 = 3\ Om$ va ampermetrlar ko'rsatishi $I_1 = 5A$, $I_2 = 25A$ bo'lsa, R_2 qar-shilik miqdori qanchaga teng? 	15 Om	20 Om	12 Om	25 Om
18.	Agar $R = 4\ Om, X_L = 4\ Om, X_C = 4\ Om$ bo'lsa, zanjirning to'la qarshiligi aniqlansin. 	$Z = 12\ Om$	$Z = 4\ Om$	$Z = 4\sqrt{2}0m$	$Z = 4/\sqrt{2}\ Om$
19.	Passiv ikki qutbli zanjir qismlaridagi kuchlanish va tokning kompleks amplituda qiymatlari $U_m = 100e^{130}\ V$ va $I_m = 10e^{130}\ A$ Vattmetrk ko'rsatishi aniqlansin. 	1000 Vt	500 Vt	250 Vt	200 Vt
20.	Rasmda ko'rsatilgan zanjirda $E_1 = 12V, E_2 = 24V, R_1 = R_2 = 2\ Om, R_3 = 1\ Om$ bo'lsa, A va B tugunlari orasidagi kuchlanish U_{ab} necha voltga teng? 	18 V	12 V	9 V	24 V
21.	Keltirilgan vektor diagrammalarning qaysi biri sxemaga mos keladi?  				
22.	Ushbu tugun uchun Kirxgof 1-qonuni asosida yozilgan qaysi tenglama to'g'ri keladi? 	$I_1 - I_2 - I_3 + I_4 + I_5 = 0$	$I_1 + I_2 + I_3 - I_4 - I_5 = 0$	$-I_1 + I_2 - I_3 + I_4 - I_5 = 0$	$I_1 + I_2 - I_3 - I_4 + I_5 = 0$
23.	Sxemada nechta tugun bor va elementlari qanday sxemada ulangan? 	4, ketma-ket	3, parallel	4, aralash	4, parallel

24.	Zanjir ekvivalent qarshiligi nimaga teng. 	3R	R/3	2R/3	0
25.	Zanjir ekvivalent qarshiligi nimaga teng. 	R	R/3	2R	3R
26.	Zanjir ekvivalent qarshiligi nimaga teng. 	4R	4R/3	R/4	R
27.	Sxema nechta tugun, shaxobcha va berk konturlardan iborat? 	5,4,3	4,6,5	2,4,6	4,6,3
28.	Zanjir parametrlari: J=1A, R=10 Om, C=10 pF bo`lsa U kuchlanish qanchaga teng? 	20 V	15 V	30 V	10 V
29.	Agar: J=1 A, R=10 Om, C=100pF bo`lsa U- kuchlanish qanchaga teng. 	10 V	5 V	15 V	20 V
30.	Agar sxemada E=10V,R=Om, L=1mGn bo`lsa, I tok qanchaga teng? 	1 A	0,5 A	0,1 A	2 A

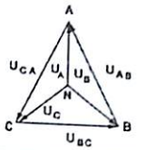
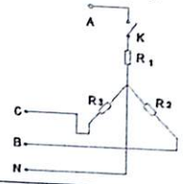
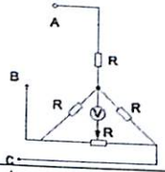
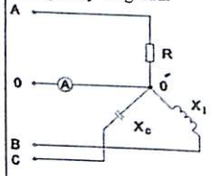
31.	Zanjir parametrlari E_1=12V, E_2=24V, R_1=R_2=2 Om, R_3=1 Om bo`lsa, Uab kuchlanish qancha voltga teng? 	24 V	9 V	18 V	12 V
32.	Zanjir parametrlari: E=10V, R=5 Om, L=1mGn, C=10 pF ga teng. I tok qiymatini toping. 	1 A	0,6 A	3 A	2 A
33.	Sxemadagi I-tok qanday ifodalanadi? 	I=Eg+J	I=-J+$\frac{E}{2R}$	I=$\frac{E}{2R}$	I=JR
34.	Sxemada umumiy sig`im qiymati qanchaga teng? 	1mkF	1,5 mkF	2 mkF	0,5 mkF
35.	Sxemada umumiy induktivlik qanchaga teng? 	0,1 Gn	1 Gn	4 Gn	0,4 Gn
36.	Kontur asilligi Q=10, kuchlanishlari U=U_R=10 V bo`lsa U_C, U_L- kuchlanishlari nimaga teng? 	U_C=10 V, U_L=20V	U_L= U_C=100V	U_L= U_C=40V	U_L= U_C=20V

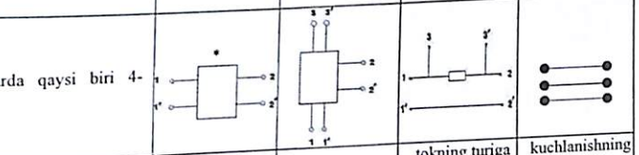
37.	Agar tarmoq toklari: I_1=5A, I_2=I_3=4A bo`lsa, I tok nimaga teng? 	10 A	13 A	5 A	9 A
38.	O`zaro induktiv bog`langan zanjir Z_{um} qarshilik tenglamasini yozing 	$R_1+R_2+j\omega(L_1+L_2)+j\omega M$	$2(R+j\omega M)$	$R_1+R_2+j\omega M$	$(R_1+R_2)+j\omega\cdot(L_1+L_2-2M)$
39.	Mos sxemada ulangan induktiv g`altak reaktiv qarshilik tenglamasini yozing 	$\omega(L_1+L_2+2M)$	$\omega(L_1+L_2)$	$\omega(L_1+L_2-M)$	$2\omega L$
40.	Rezonans vaqtida Z-to`la qarshilik nimaga teng? 	$Z=R$	$Z=\sqrt{R^2+X^2}$	$Z=\sqrt{R^2+(X_L-X_c)^2}$	$Z=X_L$
41.	Rezonansda to`la qarshilik Z nimaga teng? 	$j\omega L$	$\frac{1}{j\omega C}$	$j\omega L-\frac{1}{j\omega C}$	$\frac{1}{2}R$
42.	Sxemada $J=5\sqrt{2}\sin(314t+90^0)$, $R=X_C$=10 Om X_L=20 Om bo`lganda induktivlikdagi U_L kuchlanish kompleks ifodasini toping. 	$50e^{j45^0}$	$50\sqrt{2}e^{j45^0}$	$100e^{j45^0}$	$50e^{j90^0}$
43.	Ko`rsatilgan sxemada $U=25\,B$, $U_L=60B$ va $U_C=40\,B$ bo`lsa, resistordagi kuchlanish qancha? 	15V	115 V	75V	35V

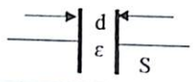
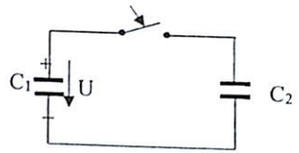
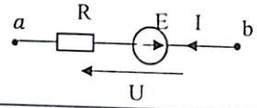
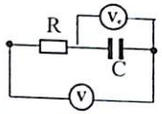
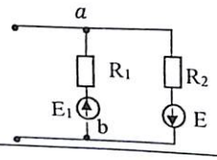
44.	Ketma-ket sxemada ulangan ikkita induktiv g`altak parametrlari : $P_2=600$ $cos\varphi_2=0{,}8$; $U_2=10\,kV$ bo`lsa U-kirishdagi kuchlanish qancha voltga teng? 	10kV	11,7kV	15kV	20 kV
45.	Ikki qutbli zanjir elektr o`lchov asboblari: U=120 V, I=5 A, P=360 Vt, $\varphi<0$ bo`lganda, ekvivalent X_C ning ketma-ket va parallel sxemada ulanishda qarshiliklar qiymatlarini toping. 	R=20 Om, g=0,2 $\frac{1}{Om}$, X_c=20 Om, $b_c=0{,}2\,\frac{1}{Om}$;	R=10 Om, g=0,1$\frac{1}{Om}$, X_c=20 Om, $b_c=0{,}2\,\frac{1}{Om}$;	R=15 Om, g=$\frac{1}{15}\frac{1}{Om}$, X_c=10 Om, $b_c=0{,}1\,\frac{1}{Om}$;	R=14,4 Om, g=0,025$\frac{1}{Om}$, X_c=19,2Om $b_c=0{,}033\frac{1}{Om}$
46.	Agar $u_1(t)=I_m\sin(\omega t+90^0)$ bo`lsa $u_L(t)$ induktivlikdagi kuchlanish oniy qiymatini toping	$U_m\sin(\omega t+90^0)$	$U_m\sin(\omega t-90^0)$	$U_m\sin\omega t$	$U_m\sin(\omega t+180^0)$
47.	$\underline{U}=5e^{j45^0}$ bo`lganda $u(t)$ kuchlanish oniy qoymatini toping.	$5\sin(\omega t+45)$	$\frac{5}{\sqrt{2}}\sin(\omega t+45^0)$	$5\sqrt{2}\sin(\omega t+45^0)$	$5\sqrt{2}\sin\omega t$
48.	Neytral sim tokini qanday aniqlaymiz	Vektor diagrammasi yordamida	Liniya toklari ta`sir etuvchi qiymatlari yig`indisi shaklida	Liniya tok larining o`rtacha qiymatlari yig`indisi shaklida	Faza toklarining o`rtacha qiymatlari yig`indisi shaklida
49.	Quyidagi qator $i=10\sin\omega t+3\sin 2\omega t$ ko`rinishda berilgan egri chiziq simmetriklik xususiyatini qaysi turiga tegishli ?	Abssissa o`qiga va koordinata boshiga nisbatan simmetrik bo`lgan egri chiziq	Abssissa va ordinata o`qlariga nisbatan simmetrik bo`lgan egri chiziq	Faqat koordinata boshiga nisbatan simmetrik bo`lgan nosinusoida funksiya	Faqat ordinata o`qiga nisbatan simmetrik bo`lgan egri chiziq
50.	Agar uch fazali tarmoqning faza kuchlanishlari bo`lsa va yulduz shaklida ulangan aktiv yuklamali istemol-chilarning qarshiliklari bo`lsa, uch fazali notekis zanjirning quvvati qancha bo`ladi?	4840 Vt	10260 Vt	7260 Vt	7744 Vt
51.	Tarmoqdagi tokning oniy qiymati $i=(3+4\sin\omega t)\ A$ quyidagicha bo`lsa, ulangan magnitoelektrik sistemali ampermetr qanday tokni ko`rsatadi ?	$3\ A$	$7\ A$	$5A$	$34A$
52.	Berilgan qiymatlar asosida $i=[5+5\sqrt{2}\sin\omega t-5\sqrt{2}\sin(2\omega t+45^0)]\ A$; r = 10 Ом, ωL = 10 Ом kuchlanishni U ta`sir etuvchi qiymati topilsin	$120\ B$	$100\ B$	$100\sqrt{2}\ B$	$125\ B$
53.	Berilganlar asosida $u=(100\sqrt{2}\sin\omega t+40\sqrt{20}\sin 2\omega t)\ B$; r = 20 Ом, ωL = 10 Ом elektr zanjirini aktiv quvvati aniqlansin.	380 Вт	400 Вт	440 Вт	500 Вт

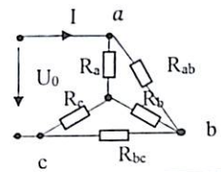
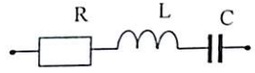
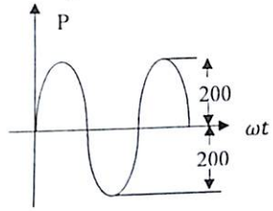
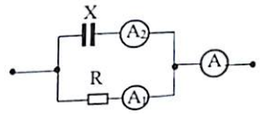
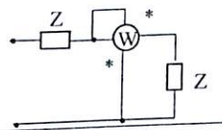
54.	Operator ta'svir berilgan (Laplas bo'yicha) $I(p)=U\frac{pL+2r}{p(4pLr+6r^2)}$ Original $i(t)$ topilsin.	$i(t)=\frac{U}{3r}(1-0{,}25e^{-\frac{3r}{2L}t})$	$i(t)=\frac{U}{2r}(1-0{,}25e^{-\frac{3r}{2L}t})$	$i(t)=\frac{U}{2r}-\frac{U}{2r}e^{-\frac{3r}{2L}t}$	$i(t)=\frac{U}{3r}(1-0{,}25e^{-\frac{3r}{2L}t})$
55.	Aperiodik zaryadsizlanish:	Konturning aktiv qarshiligi kritik qiymatdan katta bo'lgandagi kondensatorning chegaraviy zaryadsizlanishi	Konturning aktiv qarshiligi kritik qiymatga teng bo'lgandagi kondensatorning chegaraviy zaryadsizlanishi	Konturning aktiv qarshiligi kritik qiymatdan katta bo'lgan xoldagi zaryadsizlanish	Konturning aktiv qarshiligi kritik qiymatdan katta bo'lgandagi kondensatorning U kuchlanishgacha zaryadsizlanishi
56.	To'rtqutublikni qoeffisentlari A, B, C va D ma'lum bo'lganda, kirishdagi salt ishlash va qisqa tutashuv qarshiliklari ifodalansin	$Z_{1x}=\frac{A}{C}$ $Z_{1k}=\frac{B}{A}$	$Z_{1x}=\frac{A}{C}$ $Z_{1k}=\frac{B}{C}$	$Z_{1x}=\frac{A}{C}$ $Z_{1k}=\frac{B}{D}$	$Z_{1x}=\frac{D}{C}$ $Z_{1k}=\frac{B}{D}$
57.	Agar simmetrik to'rtqutublik xarakteristik qarshilikka yuklangan bo'lsa, u xolda quydagi shartlarni qaysi biri bajariladi:	$\frac{\dot U_1}{\dot I_2}=\frac{\dot U_2}{\dot I_1}$	$\frac{\dot U_1}{\dot I_1}=\frac{\dot U_2}{\dot I_2}$	$\dot I_1=\dot I_2$	$\dot U_1=-\dot U_2$
58.	To'rtqutublikni desibeldagi so'nishi:	$20\lg\lvert U_1/U_2\rvert$	$2\lg\lvert U_1/U_2\rvert$	$20\ln\lvert U_1/U_2\rvert$	$2\ln\lvert U_1/U_2\rvert$
59.	Simmetrik to'rtqutublik:	T- yoki П-shakldagi elektr zanjiri	Ikkita kirish va ikkita chiqish qismalariga ega bo'lgan elektr zanjiri	Zanjir bo'lagi bo'l tok va kuchlanishl bo'yicha tenglama tuzish uchun umulashtirlgan xarakteristikaga eg zanjir	Xususiyati ikkala tomondagi juft qismalar uchun bir xil bo'lgan zanjir
60.	O'zgarmas uzatuvchanlik g koeffisienti	$\lg(B+\sqrt{CD})$	$20\lg(B+\sqrt{CD})$	$\ln(A+\sqrt{BC})$	$20\ln(A+\sqrt{BC})$
61.	Qaysi xolda liniya boshi va oxirdagi kuchlanishlar $\frac{U_1}{U_2}$ nisbati liniya boshi va oxirdagi toklar $\frac{I_1}{I_2}$ nisbatiga teng.	Agar liniya oxiri ochiq bo'lsa	Agar liniya to'lqinli qarshilikka ulangan bo'lsa	Agar liniya oxiri qisqa tutashtirilgna bo'lsa	Agar liniya buzilishsiz bo'lsa (xar qanday yuklamada)
62.	Qanday xolda uzun liniyalar bir jinsli deb atalmaydi ?	Liniyani uzunligini pogonn parametrlari vaqtga bog'liq bo'lmasa	Liniyani uzunligini pogonn parametrlari x koordinatasiga bog'liq bo'lmasa	Liniyani uzunligini pogonn parametrlari vaqtga bog'liq bo'lsa	Liniyani uzunligini pogonn parametrlari x koordinatasiga bog'liq bo'lsa
63.	Uzun liniyalarni pogon parametrlari nima ?	Liniyalarni birlik uzunliklariga tegishli parametrlar	To'lqinli parametrlar	Yugurma va turuvchi to'lqinlarni koeffisientlari	Aks etuvchi to'lqinlarni koeffisientlari
64.	Uzun liniyani ikkilamchi parametrlari nima hisoblanadi ?	Yugirma va turuvchi to'lqinlar koeffisientlari	Pogonn parametrlari	To'lqinli parametrlar	Aks etuvchi to'lqinlarni koeffisientlari
65.	Qanday liniyalara qanday xollarda turuvchi to'lqinlar xosil bo'ladi ?	Buzulishsiz liniyalarda, yuklama moslashtirilgan xolatida	Buzulishsiz liniyalarda, salt ishlash xolatida	Buzulishsiz liniyalarda, qisqa tutashuv xolatida	Isrofsiz liniyalarda, iste'molchining aktiv quvvati nolga teng bo'lganda
66.	Chegaralangan uzinlikdagi liniya qisqa tutashuv yuklamasiga ishlasa, unda qanday to'lqinlar xosil bo'ladi ?	Yugirma to'lqinlar	Aks etuvchi to'lqinlar	Yutuvchi to'lqinlar	Turuvchi to'lqinlar
67.	Liniyani to'lqin qarshiligi Z_C bo'lganda, isrofsiz liniyani salt ishlash xolatidagi to'lqin uzunligi $\frac{1}{8}\lambda$ uchun kirish qarshiligi $Z_{кир}$ aniqlansin	$Z_{кир}=-jz_C$	$Z_{кир}=z_C$	$Z_{кир}=jz_C$	$Z_{кир}=j\frac{\sqrt{3}}{2}z_C$

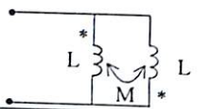
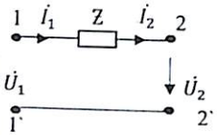
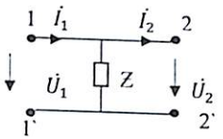
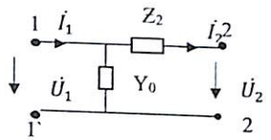
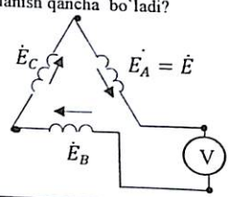
68.	Qanday xolda uzun liniyalar bir jinsli deb ataladi ?	Liniyani uzunligini pogonn parametrlari vaqtga bog'liq bo'lsa	Liniyani uzunligini pogonn parametrlari x koordinatasiga bog'liq bo'lsa	Liniyani uzunligini pogonn parametrlari x koordinatasiga bog'liq bo'lmasa	Liniyani uzunligini pogonn parametrlari vaqtga bog'liq bo'lmasa
69.	Uzun liniyani to'lqinli parametrlari:	To'lqin soni, to'lqi qarshiligi, tarqalis koeffisienti	Pogonn	YUgirma va turuvchi to'lqinlar koeffisientlari	Aks etuvchi to'lqinlar koeffisientlari
70.	Uzun liniyani birlamchi parametrlari nima hisoblanadi ?	Yugirma va turuvchi to'lqinlar koeffisientlari	To'lqinli parametrlar	Pogonn parametrlari	Aks etuvchi to'lqinlarni koeffisientlari
71.	Chegaralangan uzinlikdagi liniya moslangan yuklamaga ishlasa, unda qanday to'lqinlar xosil bo'ladi ?	Yugirma to'lqinlar	Aks etuvchi to'lqinlar	Yutuvchi to'lqinlar	Turuvchi to'lqinlar
72.	Uzun liniyani qanday ish xolatida akslanish bo'lmaydi?	Turuvchi to'lqinlar ish xolatida	Turuvchi to'lqinlar ish xolatida	Aralash to'lqinlar ish xolatida	Yugirma to'lqinlar ish xolatida
73.	Chegaralangan uzunlikdagi isrofsiz uzin liniyada yugirma to'lqinlar yuklamaning qanday xolatida kelib chiqadi ?	Yuklama rezistiv bo'lib, liniyani to'lqin qarshiligidan kichik bo'lsa	Yuklama kompleks bo'lsa	Yuklama induktiv bo'lsa	Yuklama rezistiv bo'lib, liniyani to'lqin qarshiligiga teng bo'lsa
74.	Chegaralangan uzunlikdagi isrofsiz uzin liniyada aralash to'lqinlar Yuklamaning qanday xolatida kelib chiqadi ?	Yuklama rezistiv bo'lib, liniyani to'lqin qarshiligiga teng bo'lsa	Yuklama kompleks yoki rezistiv bo'lib, liniyani to'lqin qarshiligiga teng bo'lmasa	Yuklama reaktiv bo'lsa	Yuklama rezistiv bo'lib, liniyani to'lqin qarshiligiga teng bo'lmasa
75.	Chegaralangan uzunlikdagi isrofsiz uzin liniyada turuvchi to'lqinlar yuklamaning qanday xolatida kelib chiqadi ?	Yuklama kompleks bo'lsa	Yuklama rezistiv bo'lib, liniyani to'lqin qarshiligiga teng bo'lsa	Yuklama reaktiv bo'lsa	Yuklama rezistiv bo'lib, liniyani to'lqin qarshiligidan kichik bo'lsa
76.	Nochiziqli zanjirlarni volt-amper xaraketristikalari to'g'ri chiziqli siniq bo'laklar bilan quydagi usul bilan hisoblashda almashtiriladi:	Grafikaviy usulda	Garmonik balanslar usulida	Ketma-ket intervallar usulida	Bo'lak chiziqli approksimasiyalash usulida
77.	Keltirilgan nisbatlarni qaysi biri magnit maydon kuchlanganligi bilan magnit maydon induksiyasi orasidagi bog'lanishni ko'rsatadi ?	$H=\frac{B}{\mu\mu_0}$	$D=\varepsilon\varepsilon_0E$	$H=\mu_0B$	$B=\frac{H}{\mu\mu_0}$
78.	Po'lat o'zakli g'altak sinusoidal kuchlanishga ulanganda o'zgaruvchan magnit maydoni xosil bo'lishi natijasida magnit o'tkazgichda nima sodir bo'ladi ?	Qoldiq magnitlanish darajasigachama gnitlanadi	To'yinguncha magnitlashadi	Davriy xolda magnitlasha boshlaydi	Nolgacha magnitsizlanadi
79.	Agar magnit zanjirida asosiy magnit oqimi zanjirni barcha ko'ndalang kesim bo'yicha bir xil bo'lsa, bu:	Tarmoqlanmaga n magnit zanjiri bo'ladi	nosimmetrik magnit zanjiri bo'ladi	simmetrik magnit zanjiri bo'ladi	Tarmoqlangan magnit zanjiri bo'ladi
80.	Magnit induksiyasini B o'lchov birligini ko'rsating	Tl	Gn	A/m	Vb
81.	Magnit kirituvchanligi μ_a nimani xarakterlaydi?	Elektr zanjirini	Elektrostatik maydonni	Magnit maydonini	Issiqlik maydonini
82.	Quyidagi A/m o'lchov birligi nimaga tegishli ?	F magnit oqimig	H magnit maydon kuchlanganligiga	V magnit induksiyasiga	E elektr maydon kuchlangnaligiga
83.	Quyidagi Gn/m o'lchov birligi nimaga tegishli ?	V magnit induksiyasiga	H magnit maydon kuchlanganligiga	μ_a absolyut magnit kirituvchanligiga	F magnit oqimiga
84.	Om qonunini differensial formasi qanday yoziladi ?	$\vec\delta=\gamma\vec E$	$\operatorname{div}\vec\delta=0$	$\nabla^2\varphi=0$	$\vec\delta=\gamma(\vec E+\vec E_{стор})$
85.	Kirxgofning ikkinchi qonuni differensial formada qanday yoziladi ?	$\vec\delta=\gamma(\vec E+\vec E_{стор})$	$\vec\delta=\gamma\vec E$	$\nabla^2\varphi=0$	$\operatorname{div}\vec\delta=0$

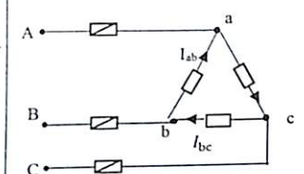
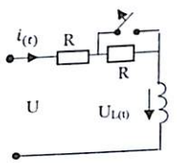
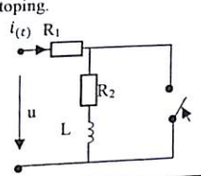
86.	Maksvellning birinchi tenglamasi:	Elektromagnit induksiya qonunini differensial formasi	Om qonunini differensial formasi	Kirxgofning ikkinchi qonunini differensial formasi	To'liq tok qonunini differensial formasi
87.	Elektr maydon energiyasini formulasini ko'rsating	$W=\frac{LI^2}{2}$	P = UI	$W=\frac{CU^2}{2}$	$\widetilde{S}=P+jQ$
88.	Magnit maydon energiyasini formulasini ko'rsating	$W=\frac{LI^2}{2}$	$W=\frac{CU^2}{2}$	$\widetilde{S}=P+jQ$	P = UI
89.	Vektor ifodadan $U_A=U_m sin\omega t$ bo'lganda qaysi ifoda xato yozilgan? 	$U_a=U_m\sin(\omega t-120°)$	$U_c=U_c\sin(\omega t-240°)$	$U_{ab}=\sqrt{3}U_m\sin(\omega t+30°)$	$U_{bc}=\sqrt{3}U_m\sin(\omega t+90°)$
90.	Uch fazali zanjir qarshiliklari $R_1=R_2=R_3$ bo'lib, A fazani uzganda toklar qanday o'zgaradi? Noto'g'ri javobni ko'rsating. 	I_B - o'zgarmaydi	I_C - o'zgarmaydi	I_N - kamayadi	I_N - ko'payadi
91.	Sxemada uch fazali zanjir liniya kuchlanishi $U_A=220\ B$ bo'lsa voltmetr necha volьtni ko'rsatadi? 	127 V	110 V	63,5 V	190 V
92.	Agar uch fazali zanjirdagi $x_l=x_c$ bo'lib, o'rinlari almashtirilsa neytral sim toki qanday o'zgaradi 	o'zgarmaydi	$\sqrt{3}$ marta ko'payadi	$\sqrt{3}$ marta kamayadi	3,7 martaga ko'payadi
93.	Agar simetrik uch fazali Yulduzcha sxemadan uchburchakka ulansa liniya kuchlanishi qanday o'zgaradi?	$\sqrt{3}$ ko'payadi	$\sqrt{3}$ kamayadi	O'zgarmaydi	3 marta ko'payadi
94.	Djoul-Lens qonuni differensial formada qanday yoziladi ?	$\frac{I^2R}{V}=\gamma E^2$	$\vec{\delta}=\gamma\vec{E}$	RI^2	$\nabla^2\varphi=0$
95.	Simetrik uch fazali zanjir uchun kaysi reaktiv quvvat ifodasi xato yozilgan:	$\sqrt{S^2-P^2}$	$\sqrt{3}\,UI\sin\varphi$	$*3UI\sin\varphi$	$3\,U_\varphi I_\varphi\sin\varphi$

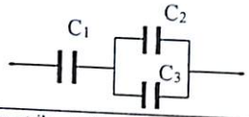
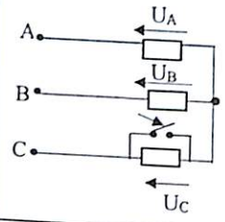
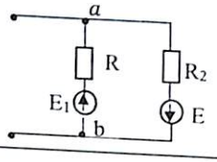
96.	Maksvellning ikkinchi tenglamasi:	Kirxgofning birinchi qonunini differensial formasi	Elektromagnit induksiya qonunini differensial formasi	To'liq tok qonunini differensial formasi	Om qonunini differensial formasi
97.	4-qutbli zanjir $\underline{Y}$-formadagi yozilgan tenglamasini toping?	$\dot{U}_1=\underline{Z}_{11}\dot{I}_1+Z_{12}\dot{I}_2,$ $\dot{U}_2=\underline{Z}_{21}\dot{I}_1+Z_{22}\dot{I}_2$	$\dot{Z}_1=\underline{Y}_{11}\dot{U}_2+Y_{12}\dot{U}_1,$ $\dot{I}_2=\underline{Y}_{21}\dot{U}_1+Y_{22}\dot{U}_1$	$\dot{I}_1=\underline{Y}_{11}\dot{U}_1+Y_{12}\dot{U}_2,$ $\dot{I}_2=\underline{Y}_{21}\dot{U}_1+Y_{22}\dot{U}_2$	$\dot{U}_1=\underline{Y}_{11}\dot{I}_1+Y_{12}\dot{I}_2,$ $\dot{U}_2=\underline{Y}_{21}\dot{I}_1+Y_{22}\dot{I}_2$
98.	4-qutbli zanjir $\underline{A}$-formadagi yozilgan tenglamasini toping?	$\dot{U}_2=A\dot{I}_2+B\dot{U}_1,$ $\dot{I}_2=C\dot{I}_1+D\dot{U}_1$	$\dot{U}_1=A\dot{U}_2+B\dot{I}_2,$ $\dot{I}_1=C\dot{U}_2+D\dot{I}_2$	$\dot{I}_2=A\dot{U}_1+B\dot{I}_1,$ $\dot{I}_1=C\dot{I}_2+D\dot{U}_2$	$\dot{I}_1=A\dot{U}_1+B\dot{I}_2,$ $\dot{I}_2=C\dot{I}_1+D\dot{U}_2$
99.	Tenglamalarning qaysi biri $\underline{A}$-koeffisent bilan to'g'ri bog'langan?	AB – SD = 1	AS – BD = 1	AD – BS = 1	–AD + BS = 1
100.	T-shaklda ulangan 4-qutbli zanjir nechta mustaqil koeffisentlardan iborat?	4	3	2	1
101.	4-qutbli passiv va aktiv zanjir $\dot{U}_1$ va $\dot{I}_1$, $\dot{U}_2$ va $\dot{I}_2$ tenglamalari nechta ko'rinishda bog'lanadi?	2	3	5	6
102.	Keltirilgan sxemalarda qaysi biri 4-qutbli zanjir? 				
103.	Elektr energiyani uzatish liniyasi 4-qutbli zanjirmi?	ha	yo'q	tokning turiga bog'liq	kuchlanishning turiga bog'liq
104.	Sig'im tok $i_{C(t)}=I_m sin(\omega t+30°)$ bo'lsa $u_{c(t)}$- kuchlanishning oniy qiymat ifodasini toping.	$U_m\sin(\omega t+30°)$	$U_m\sin(\omega t+120°)$	$U_m\sin(\omega t-60°)$	$U_m\sin(\omega t-30°)$
105.	Induktivlikdagi tok qiymat ifodasi $i_{L(t)}=I_m sin(\omega t+90°)$ bo'lganda u_L –oniy qiymat.	$U_m\sin(\omega t+180°)$	$U_m\sin(\omega t-90°)$	$U_m\sin\omega t$	$U_m\sin(\omega t+90°)$
106.	Kompleks to'la qarshilik ifodasi:	z=R+X_L	Z=R+X	Z=R+jX	Z=R+X
107.	Kuchlanishlar rezonans shartini toping.	R=0 ;	Z=0;	$\frac{1}{\omega C}=R;$	$\omega^2LC=1$
108.	Elektr zanjir parametrlarini toping.	U,I;	S,Q,R;	R,L,C va M;	H va B
109.	Kommutatsiya qonunlari ifodasini toping.	$i_R(0-)=i_C(0+);$ $U_L(0-)=U_L(0+)$	$i_L(0-)=i_L(0+);$ $U_C(0-)=U_C(0+);$	$i_L(0-)=i_L(0+);$ $U_C(0-)=U_C(0+);$	$i_C(0-)=i_L(0+);$ $U_L(0-)=U_L(0+)$
110.	Laplas integrali operator ifodasini toping.	$F(p)=\int f(t)e^{pt}dt$	$f(p)=\int F(p)e^{ft}dt;$	$F(p)=\int_0^\infty f(t)e^{-pt}dt;$	$f(p)=\int_0^\infty F(t)e^{pt}dt$
111.	Bir jinsli tarqoq parametrliu ikkita liniya xususiy tenglamasi:	$-\frac{\partial u}{\partial x}=Ri+L\frac{\partial i}{\partial t};$ $-\frac{\partial i}{\partial x}=gu+C\frac{\partial u}{\partial x};$	$\frac{\partial u}{\partial x}=gi+C\frac{\partial u}{\partial x};$ $-\frac{\partial i}{\partial x}=Ru+L\frac{\partial i}{\partial x};$	$\frac{\partial u}{\partial x}=Ri+C\frac{\partial u}{\partial t};$ $-\frac{\partial i}{\partial x}=Ri+C\frac{\partial u}{\partial t};$	$\frac{\partial u}{\partial x}=Ri+L\frac{\partial i}{\partial t};$ $\frac{\partial i}{\partial x}=gu+C\frac{\partial u}{\partial t}$
112.	Passiv 4 qutbli zanjir ekvivalent sxemasi:	M va N shaklda	T va P shaklda.	U va X shaklda	O va K shaklda
113.	Elektr zanjirlarida o'tkinchi jarayonlarni klassik usulda hisoblashda differensial tenglama yechimi:	5	2	4	3
114.	Kuchlanishlar rezonans xarakteristik tenglamasi:	$\rho=\omega_0\frac{1}{L}=\frac{1}{\omega_0 L}=\sqrt{\frac{R}{L}}$	$\rho=\frac{1}{\omega_0 L}=\omega_0 C=\sqrt{\frac{C}{L}}$	$\rho=\omega_0 L=\frac{1}{\omega_0 C}=\sqrt{\frac{L}{C}}$	$\rho=\omega_0 R=\frac{1}{\omega_0 Y}=\sqrt{\frac{C}{R}}$
115.	Kuchlanishlar rezonansida kontur asilligi:	$Q=\frac{R}{d}$	$Q=\frac{Y}{R};$	$Q=\frac{\rho}{R};$	$Q=\frac{L}{C};$
116.	Kuchlanishlar rezonas vaqtida tok ifodasi:	$I_0=\frac{U}{\omega_0 L};$	$I_0=\frac{U}{z}$	$I_0=\frac{U}{R};$	$I_0=U\omega_0 C;$
117.	O'zaro induktiv bog'langan zanjir Z_{um} qarshilik tenglamasini yozing	$R_1+R_2+j\omega(L_1+L_2)+j\omega M$	$2(R+j\omega M)$	$R_1+R_2+j\omega M$	$(R_1+R_2)+j\omega(L_1+L_2-2M)$

118.	Mos sxemada ulangan induktiv g`altak reaktiv qarshilik tenglamasini yozing.	$2\omega L$;	$\omega(L_1+L_2)$.	$\omega(L_1+L_2-M)$.	$\omega(L_1+L_2+2M)$
119.	Zanjirda X_L va X_C larning qanday nisbatlarida vattmetr ko`rsatkichi eng katta qiymatga erishadi?	$X_L=2X_C$;	$X_L=X_C$	$X_L=4X_C$;	$X_L=\frac{X_C}{2}$;
120.	Rezonans vaqtida Z-to`la qarshilik nimaga teng?	$Z=X_L$	$Z=R$	$Z=\sqrt{R^2+(X_L-X_C)^2}$	$Z=\sqrt{R^2+X^2}$;
121.	Rezonansda to`la qarshilik Z nimaga teng?	$\frac{1}{2}R$	$\frac{1}{j\omega C}$;	$j\omega L-\frac{1}{j\omega C}$;	$j\omega L$;
122.	Yassi kondensator parametrlari: $\varepsilon_1=\varepsilon_2$, $S_1=S_2$, $d_1=0{,}5d_2$ bo`lsa, qoplama sig`imlari qanday munosabatda bog`langan? 	$C_1=C_2$	$C_1=0{,}25C_2$	$C_1=0{,}5C_2$	$C_1=2C_2$
123.	Kalit ulangandan keyin U kuchlanish qanday o`zgaradi? 	2 marta oshadi	O`zgarmaydi	2 marta kamayadi	4 marta oshadi
124.	Zanjirda I tok qanday ifodalanadi? 	$I=\frac{E+U}{R}$	$I=-\frac{E+U}{R}$	$I=\frac{U-E}{R}$	I=(E+U)g
125.	Agar R=100 Om bo`lib zanjir o`zgarmas tok kuchlanish U=24V ulansa, sig`imga ulangan voltmetr qancha voltni ko`rsatadi? 	24V	10V	20V	Javobi yo`q
126.	Z qarshiligi bo`lgan elektr zanjirga oniy qiymatlari $i=4\sin(\omega t+45^0)$ $u=100\sin(\omega t-45^0)$ tok va kuchlanishga ulanganda aktiv va reaktiv quvvatlar qiymatini toping.	P=400 Vt; Q=400VA	P=200 Vt, Q=0	P=141 Vt Q=141 VAr	P=0 Q=0
127.	Parallel sxema ulangan generator parametrlari: E_1=70V, R_1=14 Om, E_2=50 V, R_2=10 Om bo`lsa, ekvivalent E.Yu.K qancha bo`ladi? 	$E_э$=0	$E_э$=120 V	$E_э$=20 V	$E_э$=120 V

128.	Zanjir parametrlari: $R_{ab}=R_{bc}$=3 Om bo`lib, U_0=60 V ulangan I-tok nimaga teng? 	30 A	20 A	45 A	40 A
129.	Zanjir parametrlari: $u=100sin\omega t$, R=20 Om, L=20 mGn, C=50 mkF bo`lsa, rezonans vaqtida sig`imdagi kuchlanish nimaga teng? 	$100\sin(\omega t+90^0)$	0	$100\sin(\omega t-90^0)$	$\frac{100}{\sqrt{2}}$
130.	Rasmdagi aktiv quvvat grafigidan S-to`la quvvat nimaga teng? 	100 VA	200 VA	0	400 VA
131.	Parrallel zanjir A-ampermetr 10 A A_1-ampermetr 6 A ko`rsatsa, $A_2$-ampermetr qancha tokni ko`rsatadi? 	5 A	16 A	4 A	8 A
132.	Sxemada $Z_1=5e^{-j30}Om$ bo`lsa, $Z_2$- to`la qarshilikning qanday qiymatida vattmetr maksimal quvvatni ko`rsatadi? 	$Z_2=5e^{-j30^0}$	$Z_2=2{,}5e^{j30^0}$	$Z_2=10e^{j0^0}$	$Z_2=5e^{j30^0}$
133.	Ikkita induktiv g`altak parametrlari $L_1$=0,05 Gn, $L_2$=0,2 Gn, M=0,08 Gn. Bog`lanish koeffesienti K nimaga teng?	K=1	K=0,8	K=1,2	K=0.08

134.	Parallel sxemada ulangan ikkita ideal g`altak bog`lanish koeffesienti K=1 bo`lsa ekvivalent induktivligi nimaga teng 	$\frac{M^2}{L_1+L_2+2M}$	∞	$\frac{L_1 \cdot L_2}{L_1+L_2}$	0
135.	To`rt qutbli zanjirning Z- qarshiligi ma`lum bo`lsa, koeffisientlari qanday aniqlanadi? 	A=0; B=Z; C=0; D=1	A=1; B=Z; C=0; D=1	A=1; B=Z; C=$\frac{1}{Z}$; D=1	A=0; B=Z; C=0; D=0
136.	Sxemadagi to`rt qutbli zanjir Z-qarshiligi ma`lum bo`lsa, doimiy koeffisientlari nimaga teng? 	A=1; B=$\frac{1}{Z}$; C=0; D=0	A=0; B=Z; C=0; D=1	A=1; B=0; C=$\frac{1}{Z}$; D=1	A=0; B=0; C=$\frac{1}{Z}$; D=0
137.	T-sxemadagi to`rt qutbli zanjir parametrlari koeffisientlari orqali qanday ifodalanadi? 	Z_2=C; Y_0=A	Z_2=B; Y_0=C	Z_2=B; Y_0=D	$Z_2=\frac{D}{C}$; $Y_0=\frac{1}{B}$
138.	Agar to`rt qutbli zanjir Z_C- tavsifiy qarshilikka ulansa qanday shart bajarilishi kerak?	$\dot{U}_1=-\dot{U}_2$	$\dot{I}_1=\dot{I}_2$	$\frac{\dot{U}_1}{\dot{I}_1}=\frac{\dot{U}_2}{\dot{I}_2}$	$\dot{I}_1=\frac{\dot{U}_2}{\dot{Z}_C}$
139.	To`rt qutbli zanjir doimiy koeffisientlari: A=D=0,028+j0,12, B=C=0,24$e^{j150^0}$ bo`lsa, to`lqin tarqalish koeffisienti γ qanchaga teng?	$\gamma=ln0{,}24++j45^0$	$\gamma=ln0{,}24++j90^0$	$\gamma=ln0{,}24--j45^0$	$\gamma=0{,}24j90^0$
140.	Simmetrik uch fazali generator uchburchak sxemada ulangan bo`lsa, voltmetrdagi kuchlanish qancha bo`ladi? 	U=3E	U=0	U=$\sqrt{3}E$	U=$\frac{\sqrt{3}}{2}$E

141.	Neytral simli simmetrik 3-fazali zanjir U_l=380 V ulangan bo`lib, faza qarshiliklari Z=10 Om bo`lsa, I_0-toki qancha bo`ladi?	40 A	38 A	0	22 A
142.	Faza toklari simmetrik: $I_{ab}=I_{bc}=I_{ca}=15A$ bo`lgan uchburchak sxemadagi uch fazali zanjir A liniya simidagi saqlagich uzilsa, $I_{ac}$ toki qanchaga teng bo`ladi 	0	$\frac{15}{\sqrt{3}}$	15 A	7,5 A
143.	$\alpha+a^2$ tenglamani $a=e^{j120^0}$ bo`lganda soddalashtiring.	$\alpha+a^2=2$	$\alpha+a^2=-1$	$\alpha+a^2=0$	$\alpha+a^2=1$
144.	Nosimmetrik uch fazali zanjir neytral sim toki I_0=5A. Bunda liniya toki nol ketma-ketlini tashkil etuvchisi teng?	$\frac{5}{3}$	15 A	$5\sqrt{3}$	$\frac{5}{\sqrt{3}}$
145.	Nosinusoidal tok oniy qiymatlari $i=3+4\sqrt{2}\sin\omega t$ bo`lsa, eletromagnit tizimli ampermetr qancha amper ko`rsatadi?	7 A	4 A	3 A	5 A
146.	Agar $i=4+10\sqrt{2}\sin\omega t++3\sqrt{2}\sin3\omega t$ bo`lsa, nosinusoidal tok siljish koeffisienti K_C nimaga teng?	$\frac{\sqrt{3}}{2}$	$\sqrt{\frac{3}{5}}$	$\frac{2\sqrt{2}}{3\sqrt{3}}$	$\frac{2}{\sqrt{5}}$
147.	Ketma-ket sxemada ulangan R,L zanjir parametrlari: R=X_L =10 Om bo`lib, nosinusoidal tok $i=5+5\sqrt{2}\sin\omega t-5\sqrt{2}\sin(2\omega t+45^0)$ ulangan. Zanjir kuchlanishi effektiv qiymati U ni toping.	100 V	$100\sqrt{2}$	$120\sqrt{2}$	$\frac{100}{\sqrt{2}}$
148.	Sxemada kalit uzilganda induktivlikdagi $U_{L(t)}$ o`tkinchi jarayon kuchlanishi qanday o`zgaradi? 	$Ue^{-\frac{R}{L}t}$	$-Ue^{-\frac{2R}{L}t}$	$(U/2)e^{-\frac{R}{L}t}$	$e^{\frac{R}{L}t}$
149.	R,C zanjir o`zgarmas tok kuchlanishga ulanganda o`tkinchi jarayon $U_{C(t)}$ kuchlanish qanday ifodalanadi?	$U(1-e^{-\frac{1}{RC}t})$	$Ue^{-\frac{1}{RC}t}$	$Ue^{\frac{1}{RC}t}$	$IRe^{\frac{1}{RC}t}$
150.	Sxemadagi o`zgarmas tok zanjiri qisqa tutashtirilganda $i_{(t)}$ o`tkinchi jarayon tok ifodasini toping. 	$\frac{U}{R}e^{-\frac{R}{L}t}$	$\frac{U}{2R}e^{-\frac{R}{L}t}$	$\frac{U}{2R}e^{-\frac{2R}{L}t}$	$Ue^{\frac{R}{L}t}$

151.	Sxemada ekvivalent sig'im nimaga teng? 	$C = C_1 + \frac{C_2 \cdot C_3}{C_2 + C_3}$	$C = C_1 + C_2 + C_3$	$C = \frac{C_1(C_2 + C_3)}{C_1 + C_2 + C_3}$	$\frac{1}{C} = \frac{1}{C_1} + \frac{1}{C_2} + \frac{1}{C_3}$
152.	Simmetrik yulduz sxemada U liniya kuchlanishga ulangan C fazadagi qarshilik qisqa tutashayotganda B fazadagi kuchlanish qanday o'zgaradi? 	$\sqrt{3}U$	$\frac{U}{2}$	$\frac{U}{\sqrt{3}}$	U
153.	Parallel sxema ulangan generator parametrlari: E_1=70V, R_1=14 Om, E_2=50 V, R_2=10 Om bo'lsa, U_{ab} potensial kuchlanish qanchaga teng. 	60 V	0	250 V	120 V

ILOVALAR

1-ilova

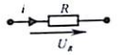
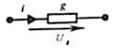
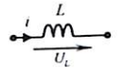
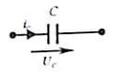
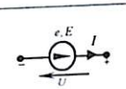
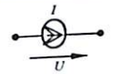
Elektr va magnit kattaliklarning birliklari

Elektromagnit kattaliklar nomi	Kattalik belgisi	Birligi	Birlik nomi	Birlik belgisi
1	2	3	4	5
1-umumiy elektr magnit kattaliklari				
Elektr miqdori (hajmi) zaryadi	Q, q	Amper-sekund	Kulon	K
Elektr maydon kuchlanganligi, potensial gradienti	$E, grad\varphi$	Voltmetr	–	V/m
Elektr zaryad siljishi	D	Kulon taqsim metr KV.	–	Kl/m^2
Elektr doimiyligi	ε_0	Farada taqsim metr		F/m
Elektr sig'im	C	Kulon taqsim metr	Farada	f
Elektr yurituvchi kuch, kuchlanish potensiali	e, U, φ	Volt	Volt	V
Elektr tok, elektr tokning zichligi	I, i δ	Amper Amper taqsim metr kvadrat	Amper -	A A/m^2
Elektr qarshilik	R, r	Volt amper	Om	Om
Elektr o'tkazuvchanlik	G, g	Amper volt	Simens	Sm
Elektr energiya (elektr bajargan ish)	W, A	Amper (vatt-sekund)	Joul	j
Elektr quvvat	P	Volt-amper	Vatt	Vt
Magnit oqimi	ϕ	amper Volt-sekund	Veber	Vb
Ilashgan magnit oqimi	$\psi = w\phi$	Volt-sekund	Veber	Vb
Magnit induksiya	B	Veber taqsim metr kvadrat	Tesla	Tl
Magnit maydon kuchlanganligi	H	Amper taqsim metr	–	A/m
Magnit doimiyligi	μ_0	Genri taqsim metr		G/m
Induktivlik	L	Veber taqsim amper	Genri	G
O'zaro induktivlik	M	Veber taqsim amper	Genri	G
Magnit yurituvchi kuch (magnitlovchi kuch)	$F = Hl$	Amper	Amper	A

2. O‘zgaruvchan (sinusoidal) tokga oid kattaliklar				
Elektr tok: oniy	i	Amper	Amper	A
Amplitudaviy	I_m	Amper	Amper	A
Effektiv (amaliy)	$I = I_m/\sqrt{2}$	Amper	Amper	A
O‘rta	$I_{o'r} = \frac{2}{\pi} I_m$	Amper	Amper	A
Tok davri	T	sekund	sekund	sek
Tok chastotasi	$f = 1/T$	Bir taqsim sekund	Gers	Gs
Burchak chastota	$\omega = 2\pi f$	Radian - sekund		Rad/s
Tokning (EYK ning, kuchlanishning) boshlang‘ich fazasi	ψ_e, ψ_i, ψ_u	Radian (gradus)	–	–
Tok va kuchlanish o‘rtasidagi fazaviy siljish	$\varphi = \psi_u - \psi_i$	Radian (gradus)	–	–
Quvvat: aktiv	$P = UI \cdot \cos\varphi$	Volt-amper	Vatt	Vt
Reaktiv	$Q = UI \cdot \sin\varphi$	Volt-amper	Volt-amper reaktiv	Var
To‘la	$S = UI$	Volt-amper	Volt-amper	VA
Quvvat koeffitsienti	$\cos\varphi$	–	–	–
Rezonans chastota	$\omega = \frac{1}{\sqrt{LC}}$	Radian -sekund		rad/sek

2-ilova

Elektr zanjir elementlarining asosiy tavsifi.

Ele-mentlar	Shartli belgilar	Elektr kuchlanish (V)	Tok (A)	Quvvat yoki energiya (Vt, KVt) (Dj)
Aktiv qarshi-lik (rezistor)		$U_R = iR$	$i = \frac{U_R}{R}$	$P = Ri^2$
O‘tkazuv-chanlik		$U_g = \frac{i}{g}$	$i = U_g g$	$P = gu_g^2 = \frac{I_g^2}{g}$
Induktivlik		$U_L = L\frac{di_L}{dt}$	$i_L = \frac{1}{L}\int U_L\,dt$	$W_L = \frac{Li_g^2}{2}$
Sig‘im		$U_C = \frac{1}{C}\int i_C\,dt$	$i_C = C\frac{du_C}{dt}$	$W_C = \frac{Cu_g^2}{2}$
Elektr yurituvchikuc h		$e = -u$	I–istalgan qiymat	$P_e = EI$
Tok manbai		u–istalgan qiymat	$i = I$	$P_1 = UI$

3-ilova

Test savol javoblari:

Savol	Javob	Savol	Javob	Savol	Javob	Savol	Javob	Savol	Javob	Savol	Javob	Savol	Javob	Savol	Javob
1	B	21	D	41	D	61	B	81	C	101	D	121	A	141	C
2	A	22	A	42	B	62	D	82	B	102	A	122	D	142	D
3	C	23	B	43	A	63	A	83	C	103	A	123	C	143	B
4	A	24	B	44	B	64	C	84	B	104	D	124	B	144	A
5	C	25	A	45	A	65	D	85	A	105	D	125	A	145	D
6	A	26	B	46	C	66	B	86	D	106	C	126	B	146	D
7	D	27	D	47	C	67	A	87	C	107	D	127	A	147	B
8	C	28	D	48	A	68	C	88	A	108	D	128	D	148	B
9	A	29	B	49	C	69	A	89	D	109	B	129	C	149	A
10	A	30	D	50	C	70	C	90	C	110	D	130	A	150	B
11	D	31	B	51	A	71	A	91	B	111	D	131	D	151	C
12	B	32	D	52	C	72	D	92	A	112	B	132	D	152	D
13	C	33	B	53	C	73	D	93	A	113	A	133	B	153	A
14	D	34	A	54	A	74	B	94	A	114	C	134	D		
15	A	35	B	55	C	75	C	95	C	115	A	135	C		
16	D	36	B	56	C	76	D	96	B	116	B	136	B		
17	C	37	C	57	B	77	A	97	C	117	D	137	B		
18	B	38	D	58	A	78	C	98	B	118	D	138	C		
19	A	39	A	59	D	79	C	99	C	119	B	139	B		
20	C	40	A	60	C	80	A	100	B	120	B	140	B		

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M. IBADULLAYEV, A. TOVBOEV, A. YESENBEKOV

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MASALA VA MASHQLAR TO‘PLAMI

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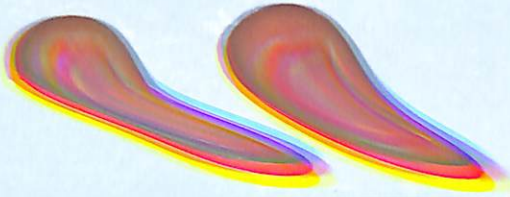

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