

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

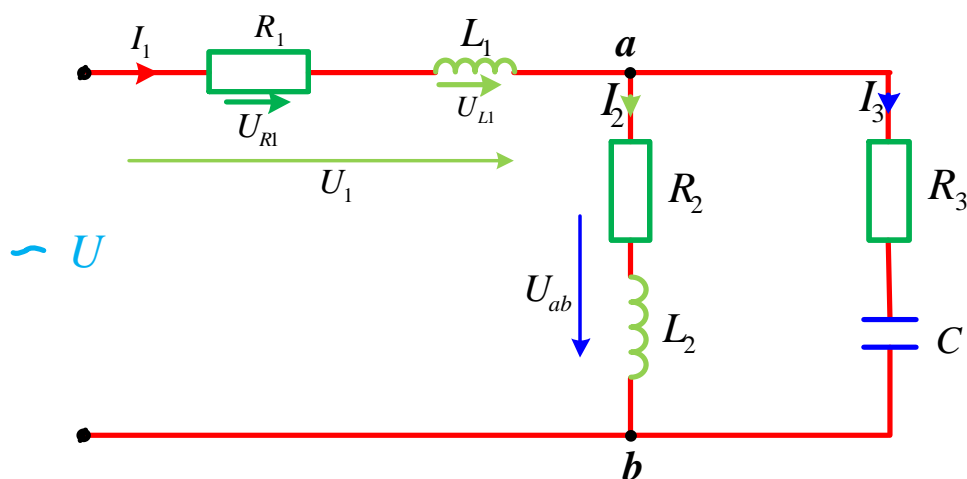
ISLOM KARIMOV NOMIDAGI TOSHKENT
DAVLAT

TEXNIKA UNIVERSITETI

ELEKTROTEXNIKA VA ELEKTRONIKA

amaliy mashg‘ulotlar uchun

USLUBIY QO‘LLANMA



Toshkent-2022

UDK 621.373

Abdullayev B., Abduraimov E.X., Xalmanov D.X., Peysenov M.B. Elektrotexnika va elektronika. Amaliy mashg'ulotlar. Uslubiy qo'llanma. - Toshkent: ToshDTU, 2022. 106 b.

Uslubiy qo'llanma "Elektrotexnika va elektronika" fanining o'quv dasturi asosida tuzilgan bo'lib, unda fan bo'yicha amaliy mashg'ulotlar olib borish uchun masalalar yechish bo'yicha namunalari ko'rsatilgan, shuningdek mustaqil yechish uchun topshiriqlar, hisob grafik ishlari berilgan.

Uslubiy qo'llanma oliy o'quv yurtlarining noenergetik bakalavriat ta'lim yo'nalishlari bo'yicha tahsil olayotgan talabalar uchun mo'ljallangan. Uslubiy qo'llanmadan bakalavriat va magistratura ta'lim yo'nalishlarida tahsil olayotgan talabalar, magistrlar, doktorant va soha mutaxassislari ham foydalanishlari mumkin.

*Islom Karimov nomidagi Toshkent davlat texnika universitetining uslubiy Kengashi qaroriga asosan chop etishga ruxsat etilgan.
(Bayonnoma № _____ 2022 y.)*

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KIRISH

Elektrotexnika — elektr zanjirlarida va elektromagnit maydonlarida elektr shuningdek magnit energiyalarining hosil bo'lish, o'zgarish qonuniyatlarini, hamda elektr energiyasini amaliy maqsadlarda qo'llanilishini o'rganadigan fanidir. Elektrotexnika asosan elektr energetikasi sohasida qo'llanilib bunda, elektr energiyasini ishlab chiqarish, bir joydan ikkinchi joyga uzatish va iste'molchilarga taqsimlash vazifalarini ham o'rganadi.

Elektrotexnika fanining rivojlanishiga buyuk fizik olimlar: G. Om, E. Lens, D. Joul, G. Kirxgof, M. Faradey, J. Maksvell va boshqalar asos solgan bo'lib, 1827-yilda nemis olimi Om tok, kuchlanish va qarshiliklarning orasida o'zaro bog'lanish qonunini yaratdi. 1842-yilda rus olimi E. Lens va ingliz olimi D. Djoullar elektr tok energiyasining issiqlik energiya o'zgartirish qonuniga asos soldi. 1845-yilda G. Kirxgof elektr tok zanjirlarini hisoblash uchun asosiy qonunlarni tatbiq etdi.

Elektr energiyasi boshqa turdagi (mexanik, issiqlik, yorug'lik, kimyoviy va x.k) energiyalardan quyidagi afzalliklarga ega:

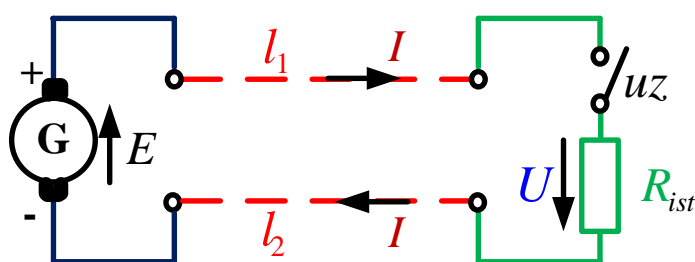
- ❖ elektr energiyasi boshqa turdagi energiyalarga ya'ni, mexanik, issiqlik, yorug'lik, kimyoviy energiyalarga oson aylanadi;
- ❖ elektr energiyasini uzoq masofalarga kam quvvat isrofi bilan uzatish mumkin (foydali ish koeffitsiyenti 85%);
- ❖ elektr energiyasini iste'molchilar orasida quvvatning bir necha ulushidan, bir necha killovattlargacha taqsimlash mumkin;
- ❖ elektr energiyasini ishlatishda elektr qurilmalari oson avtomatlashtiriladi.

Yuqoridagi afzalliklaridan kelib chiqib elektr energiyasidan bugungi kunda xalq xo'jaligining barcha sohalarida keng qo'llanilmoqda. Shuning uchun ham texnika sohasida bakalavr darajasiga ega bo'lgan mutaxassislar ixtisosligidan qat'iy nazar yetarli darajada elektrotexnik bilim va ko'nikmalarga ega bo'lishi kerak.

1. O‘ZGARMAS TOK ELEKTR ZANJIRLARI

1.1. Elektr zanjiri va uning elementlari.

Har qanday elektr zanjiri o‘zaro simlar bilan birlashtirilgan bitta yoki bir nechta elektr energiyasi manbalaridan va iste’molchilaridan iborat bo‘ladi. Shuning uchun *elektr zanjiri* deb, elektr tokini hosil qiluvchi va uning oqib o‘tishini ta’minlash uchun xizmat qiladigan qurilmalar yig‘indisiga aytiladi. Elektr zanjirlarini shartli belgilar yordamida tasvirlash elektrik *sxema* deb ataladi.

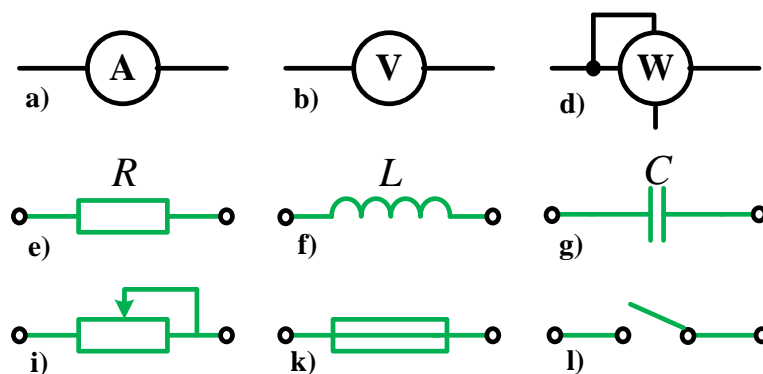


1.1-rasm

Oddiy o‘zgarmas tok elektr zanjirining sxemasi 1.1-rasmda ko‘rsatilgan. Oddiy o‘zgarmas tok elektr zanjiri asosan quyidagi elementlardan tashkil topgan:

- ❖ elektr energiyasining manbai - G - EYuK (o‘zgarmas tok generatori);
- ❖ elektr energiyasining iste’molchisi - R_{ist} (yuklama);
- ❖ birlashtiruvchi simlar - l_1 va l_2 (masalan, elektr uzatish liniyasi);
- ❖ zanjirni ulab-uzish uchun moslama (uzgich) - uz kabi elementlardan tashkil topgan.

O‘lchov asboblari, elektr zanjirining asosiy parametrlari va ayrim elementlarining shartli belgilari 1.2-rasmda keltirilgan. a – ampermetr; b – voltmeter; d – vattmetr; e – rezistor (aktiv qarshilik); f – induktivlik (induktiv g‘altak); g – sig‘im (kondensator); i – reostat (o‘zgaruvchan qarshilik); k – saqlagich (eruvchan); l – uzgich (bir qutbli).



1.2-rasm

Agar tokning qiymati vaqt davomida o'zgarmasa, bunday tok o'zgarmas tok deyiladi:

$$I = \frac{q}{t}. \quad (1.1)$$

EYUK manbai E - EYUK manbaining qutblarida yuklanish (elektr tokini) yetarlicha katta chegarada o'zgartirganda ham kuchlanish o'zgarmaydi:

$$U_{chiq} = E = const.$$

Elektr zanjirida harakatlanayotgan zaryadga o'tkazgich muhiti ma'lum darajada qarshilik ko'rsatadi. Bu qarshilik o'tkazgichning elektr qarshiligi deb atalib, quyidagi ifoda yordamida aniqlanadi:

Qarshilik R - elementning elektr zanjiridan energiya iste'mol qilib, uni boshqa tur energiyaga aylantirish xususiyati. Aylantirilgan energiyaning quvvati qarshilikka to'g'ri proporsional, shuning uchun bu parametarning qiymati o'zgarmas tok zanjiri uchun $R = \frac{P}{I^2}$ ga teng bo'ladi.

$$R = \rho \frac{l}{S} \quad (1.2)$$

bu yerda: ρ - o'tkazgichning solishtirma qarshiligi, $\Omega \cdot m$; l - o'tkazgichning uzunligi, m ; S - o'tkazgichning ko'ndalang kesim yuzasi, m^2 .

Ayrim hollarda elektr qarshiligi o'rniga (qarshiliklari parallel ulangan zanjirlar o'rganilganda) unga teskari bo'lgan kattalik o'tkazuvchanlikdan foydalaniladi, ya'ni

$$G = \frac{1}{R}; \left[\frac{1}{\Omega m} = 1 \text{simens} = 1Sm \right]. \quad (1.3)$$

1.2. Elektr zanjirlarining asosiy qonunlari.

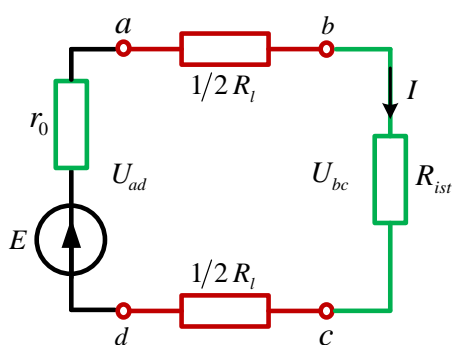
Om qonuni: Elektr zanjiriga oid asosiy qonun bo‘lib, zanjirdagi tok va kuchlanish o‘zaro qanday nisbatda bog‘langanligini ifodalaydi. Bu qonunga ko‘ra tarmoqlanmagan berk zanjirdagi (konturdagi) tok EYuK ga to‘g‘ri proporsional, zanjirning to‘la qarshiligiga teskari proporsionaldir. Mazkur qonunga binoan 1.3-rasmda ko‘rsatilgan elektr zanjirdagi tok quyidagicha ifodalanadi:

$$I = \frac{E}{r_0 + R_l + R_{ist}} = \frac{E}{r_0 + R_T}, \quad (1.4)$$

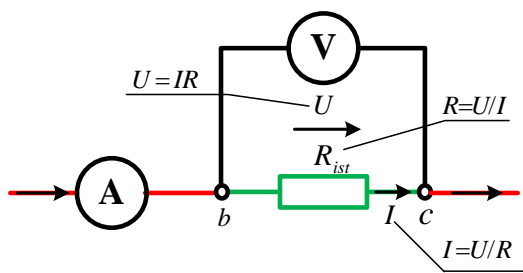
bu yerda r_0 - manbaning ichki qarshiligi; $R_l = \frac{1}{2}R_l + \frac{1}{2}R_l$ - elektr uzatish liniya simining qarshiligi; $r_0 + R_T$ - zanjirning to‘la qarshiligi; $R_T = R_l + R_{ist}$ - tashqi zanjirning qarshiligi:

(1.4) formula berk kontur uchun Om qonunini ifodalaydi. Shuningdek, EYuK manbai bo‘lmagan elektr zanjirining istalgan qismi uchun ham tadbiq etish mumkin. U holda zanjirning qismidagi (1.3 va 1.4-rasmlar) tok:

$$I = \frac{U_{bc}}{R_{ist}} = \frac{\varphi_b - \varphi_c}{R_{ist}}, \quad (1.5)$$



1.3-rasm.



1.4-rasm.

Butun zanjir uchun Om qonuni: Umumiy holda, ya'ni elektr zanjir tarkibida bir nechta EYuK manbai va rezistorlar bo‘lsa, tok quyidagi ifodadan aniqlanadi:

$$I = \frac{\varphi_a - \varphi_d + \sum E}{\sum R_{ekv}}, \quad (1.6)$$

bu formula umumlashgan Om qonuni deyiladi.

Bir konturli elektr zanjiri uchun Om qonuni quyidagicha yoziladi:

$$I = \frac{\sum E}{\sum R} = \frac{\varphi_a - \varphi_d + \sum E}{\sum R_{ekv}}, \quad (1.7)$$

bunda $\sum R$ - ichki va tashqi qarshiliklarning zanjir bo'yicha arifmetik yig'indisi, $\sum E$ - zanjirdagi EYuKlarning algebraik yig'indisi. Agar tok yo'nalishi EYuK yo'nalishi bilan bir xil bo'lsa, u holda EYuK E musbat, qarama-qarshi yo'nalishda bo'lsa, manfiy ishora bilan olinadi.

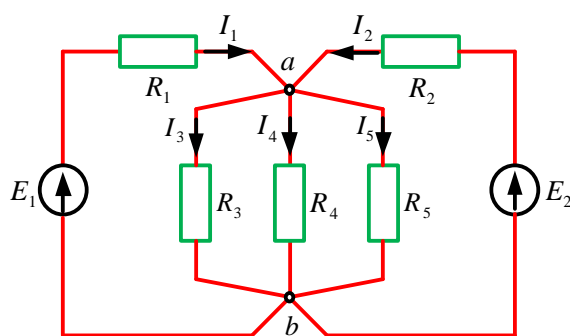
Kirxgof qonunlari murakkab (ikki va undan ortiq konturli) elektr zanjirlarni hisoblash va ularning elektr holatlarini to'la aniqlash uchun xizmat qiladi. Murakkab zanjirlar uchun tarmoq, tugun va kontur tushunchalari qo'llanadi.

❖ **Tarmoq** - elektr zanjirining ma'lum bir qismi bo'lib, ketma-ket birlashtirilgan qarshiliklar (rezistorlar), energiya manbalari va hokazolardan iborat.

❖ **Tugun** - elektr zanjirining uchta va undan ortiq tarmoqlarining birlashgan joyi.

❖ **Kontur** - zanjirining bir necha tarmoqlaridan iborat yopiq yo'l.

Masalan, 1.5-rasmdagi elektr zanjiri beshta tarmoq (bulardan ikkitasining energiya manbai bor) ikkita tugun va to'qqizta konturdan iborat.



1.5-rasm.

Kirxgofning birinchi qonuni (toklar qonuni) Bu qonunga ko'ra, elektr zanjirining tarmoqlanish tuguniga kelayotgan va undan chiqib ketayotgan toklarning algebraik yig'indisi nolga teng. 1.5- rasmdagi elektr zanjirining a tuguni uchun

$$I_1 + I_2 - I_3 - I_4 - I_5 = 0 \quad (1.8)$$

deb yozish mumkin. Bunda tarmoqlanish tuguniga kelayotgan toklarni «+» ishora va undan chiqib ketayotgan toklarni «-» ishora bilan olgan bo‘lamiz. Umumiy holda

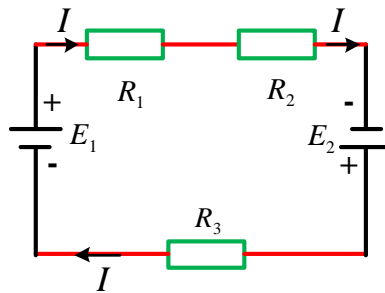
$$\sum_{k=1}^n I_k = 0. \quad (1.9)$$

Kirxgorfning ikkinchi qonuni (kuchlanishlar qonuni) berk konturdagi barcha EYuK larning algebraik yig‘indisi shu konturning barcha qismlaridagi kuchlanishlar pasayishining algebraik yig‘indisiga teng:

$$\sum_{k=1}^n E_k = \sum_{k=1}^n I_k \cdot R_k. \quad (1.10)$$

Kirxgorfning ikkinchi qonuniga binoan. 1.6-rasmda ko‘rsatilgan elektr zanjirida EYuK ning shartli musbat yo‘nalishi bo‘yicha (ya’ni, soat milining harakat yo‘nalishi bo‘yicha) zanjirning elektr muvozanat tenglamasi:

$$E_1 + E_2 = IR_1 + IR_2 + IR_3 \quad (1.11)$$



1.6-rasm.

Joul-Lens qonuni. Elektr tokining ishi deyilganda, elektr maydonida zaryadlangan zarrachalarning potentsiali kichik nuqtadan potentsiali yuqori nuqtaga ko‘chishida bajargan ishi (A) yoki shu ishni bajarish uchun sarflangan energiya (W) tushuniladi, ya’ni

$$A = U \cdot I \cdot t = W \quad (1.12)$$

1.3. Elektr tokining quvvati.

Elektr tokining **quvvati** vaqt birligida bajarilgan ishga yoki shu ishni bajarish uchun sarflangan energiyaga teng, ya'ni

$$P = \frac{A}{t} = U \cdot I. \quad (1.13)$$

Xalqaro SI birliklar sistemasida quvvatning o'lchov birligi sifatida vatt (W) qabul qilingan.

1.4. Elektr zanjirida quvvatlar muvozanati.

Har qanday elektr zanjirida manbaning ishlab chiqargan elektr energiyasi (quvvati) iste'molchida, uzatish liniyasida va manbaning o'zida sarf bo'lgan energiyaga (quvvatiga) tengdir.

$$P_E = \Delta P_0 + \Delta P_l + P_{ist} = \Delta P_0 + \Delta P_T. \quad (1.14)$$

bu yerda $P_E = E \cdot I$ - manba hosil qilgan elektromagnit quvvat. U manbaning o'zida (ichida) $\Delta P_0 = I^2 \cdot r_0$ quvvatga uzatish liniyasi ma'lum qarshilik (R_l) ga ega bo'lgani sababli uzatilayotgan quvvatning $\Delta P_l = I^2 \cdot R_l$ qismi issiqlik energiyasiga, qolgan qismi $P_{ist} = I^2 \cdot R_{ist}$ (yuklamaga) sarflanadi.

1.1-masala. Ichki qarshilik $0,5 \Omega$, elektr yurituvchi kuchi $150 V$ bo'lgan o'zgarmas tok generatorining qismlariga ikki simli uzatish liniyasi orqali qarshiligi $11,56 \Omega$ bo'lgan yuklama ulangan (1.3-rasm). Uzatish liniyasi alyuminiy simlardan iborat bo'lib, uning parametrlari quyidagicha: uzunligi $l = 200 m$, ko'ndalang kesimi $S = 4 mm^2$, solishtirma qarshiligi $\rho = 0,0294 \frac{\Omega \cdot mm^2}{m}$. Berilgan kattaliklar asosida quyidagilar aniqlansin:

- 1)zanjirdagi tok - I ;
- 2)generator qismlaridagi kuchlanish - U ;
- 3)yuklama qismlaridagi kuchlanish - U_{ist} ;
- 4)generatorning elektromagnit quvvati - P_E ;
- 5)generatorning ichida sarflanayotgan quvvatning isrofi - ΔP_0 ;
- 6)uzatish liniyasidagi quvvatning isrofi - ΔP_l ;
- 7)yuklama iste'mol qilayotgan quvvat - P_{ist} ;
- 8)zanjirning quvvatlar muvozanati.

Yechilishi:

- ❖ uzatish liniyasining qarshiligi:

$$R_l = \rho \frac{2l}{S} = 0,0294 \frac{2 \cdot 200}{4} = 2,94 \text{ } \Omega;$$

- ❖ zanjirning umumiy qarshiligi:

$$R = r_0 + R_l + R_{ist} = 0,5 + 2,94 + 11,56 = 15 \text{ } \Omega;$$

- ❖ Om qonuniga binoan zanjirdagi tok:

$$I = \frac{E}{R} = \frac{150}{15} = 10 \text{ A}$$

- ❖ generator qismlaridagi kuchlanish:

$$U_G = E - I \cdot r_0 = 150 - 10 \cdot 0,5 = 145 \text{ V.}$$

- ❖ yuklama qismlaridagi kuchlanish:

$$U_{ist} = U_G - I \cdot R_l = 145 - 10 \cdot 2,94 = 115,6 \text{ V.}$$

- ❖ generatorning elektromagnit quvvati:

$$P_E = E \cdot I = 150 \cdot 10 = 1500 \text{ W} = 1,5 \text{ kW}$$

- ❖ generatorning ichida sarflanayotgan quvvatning isrofi:

$$\Delta P_0 = I^2 \cdot r_0 = 10 \cdot 0,5 = 50 \text{ W.}$$

- ❖ uzatish liniyasidagi quvvatning isrofi:

$$\Delta P_l = I^2 \cdot R_l = 10^2 \cdot 2,94 = 294 \text{ W.}$$

- ❖ yuklama iste'mol qilayotgan quvvat:

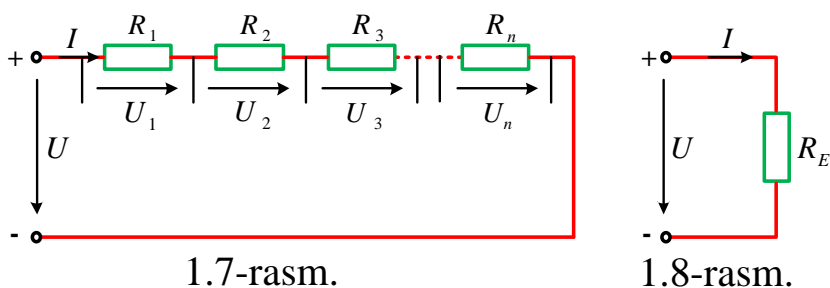
$$P_{ist} = U_{ist} \cdot I = 115,6 \cdot 10 = 1156 \text{ W} = 1,156 \text{ kW.}$$

- ❖ zanjirdagi quvvatlar muvozanati:

$$P_E = \Delta P_0 + \Delta P_l + P_{ist} = 50 + 294 + 1156 = 1500 \text{ W} = 1,5 \text{ kW.}$$

1.5. Elektr zanjiridagi qarshiliklarni ulash sxemalari.

Elektr iste'molchilarni zanjirga ketma-ket, parallel va aralash ulash sxemalari mavjud.



1.7-rasm.

1.8-rasm.

Qarshiliklarni (iste'molchilarni) ketma-ket ulash (1.7-rasm).

Qarshiliklari ketma-ket birlashtirilgan, ya'ni **tarmoqlanmagan elektr zanjirining** o'ziga xos xususiyati shundaki, unda tok o'tkazadigan bitta yopiq kontur bo'lib, konturning barcha qismlaridan bir xil qiymatga ega bo'lgan tok o'tadi. Bunday zanjirda unga berilgan kuchlanish – U zanjirning ayrim qismlaridagi kuchlanishlar pasayishining algebraik yig'indisiga teng.

$$I = I_1 = I_2 = I_3 = \dots = I_n$$

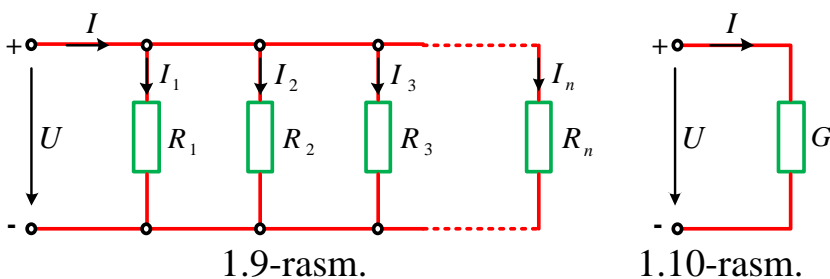
$$U = U_1 + U_2 + U_3 + \dots + U_n \quad \text{yoki} \quad U = I \cdot R_1 + I \cdot R_2 + I \cdot R_3 + \dots + I \cdot R_n,$$

$$R_E = R_1 + R_2 + R_3 + \dots + R_n \quad (1.15)$$

U holda 1.7-rasmdagi sxemaning ekvivalent elektr zanjiri 1.8-rasmdagi ko'rinishga ega bo'ladi. Bunday zanjirdagi tok Om qonuniga binoan quyidagicha ifodalanadi:

$$I = \frac{U}{R_E} \quad (1.16)$$

Qarshiliklarni (iste'molchilarni) parallel ulash deb, $R_1, R_2, R_3, \dots, R_n$ va hokazo qarshiliklarning bosh uchlarini bir tugunga va ana shu qarshiliklarning oxirgi uchlarini ikkinchi tugunga birlashtirishga aytiladi (1.9-rasm).



1.9-rasm.

1.10-rasm.

Qarshiliklari parallel ulangan elektr zanjirining o‘ziga xos xususiyati zanjirga ulangan barcha qarshiliklar qismlaridagi kuchlanishning bir xil qiymatga ega bo‘lishidir.

$R_1, R_2, R_3, \dots, R_n$ qarshiliklar bosh uchlarining ulanish nuqtalariga keluvchi tok (I) shu nuqtalardan (tugunlardan) tarqaluvchi $I_1, I_2, I_3, \dots, I_n$ toklarning yig‘indisiga teng.

$$U = U_1 = U_2 = U_3 = \dots = U_n$$

$$I = I_1 + I_2 + I_3 + \dots + I_n$$

yoki

$$I = \frac{U}{R_1} + \frac{U}{R_2} + \frac{U}{R_3} + \dots + \frac{U}{R_n} = U \cdot \left(\frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3} + \dots + \frac{1}{R_n} \right) \quad (1.17)$$

Agar

$$\frac{1}{R_1} = G_1; \frac{1}{R_2} = G_2; \frac{1}{R_3} = G_3; \frac{1}{R_n} = G_n; \quad \text{va} \quad \frac{1}{R_E} = G_E;$$

bo‘lsa, u holda

$$I = U \cdot (G_1 + G_2 + G_3 + \dots + G_n)$$

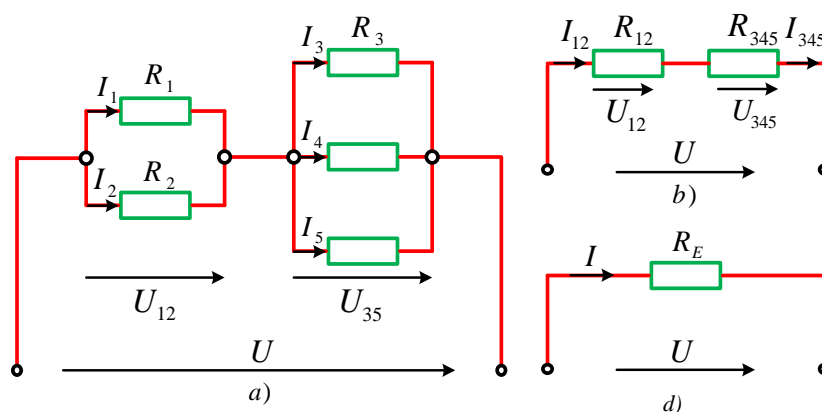
Agar $G_E = G_1 + G_2 + G_3 + \dots + G_n$ bo‘lsa, zanjirdagi tok quyidagicha ifodalanadi:

$$I = U \cdot G_E. \quad (1.18)$$

Bu yerda: $G_1, G_2, G_3, \dots, G_n$ - parallel tarmoqlarning o‘tkazuvchanliklari, Sm;

G_E - parallel tarmoqlarning ekvivalent o‘tkazuvchanligi Sm.

Qarshiliklarni aralash ulash ketma-ket va parallel ulashlarning birgalikda qo‘llanilishidir (1.11-rasm)



1.11-rasm.

Qarshiliklari aralash ulangan zanjirlarning ekvivalent qarshiligini hisoblash zanjirning oxirgi qismidan manba tomon olib boriladi

1.2-masala. 1.11-rasm, a da ko'rsatilgan murakkab elektr zanjiri uchun quyidagilar: $U = 36 V$, $R_1 = 8 \Omega$, $R_2 = 2 \Omega$, $R_3 = R_4 = 5 \Omega$, $R_5 = 10 \Omega$, ma'lum bo'lsa, zanjirning tarmoqlaridagi I_1, I_2, I_3, I_4, I_5 toklarining qiymati aniqlansin.

Yechilishi. Zanjirdagi R_1 va R_2 qarshiliklari o'zaro parallel ulangani uchun ularning ekvivalent qarshiligi.

$$R_{1,2} = \frac{R_1 \cdot R_2}{R_1 + R_2} = \frac{8 \cdot 2}{8 + 2} = \frac{16}{10} = 1,6 \Omega.$$

R_3, R_4, R_5 qarshiliklar o'zaro parallel ulangani uchun ularning ekvivalent o'tkazuvchanligi.

$$G_E = \frac{1}{R_{3,4,5}} = \frac{1}{R_3} + \frac{1}{R_4} + \frac{1}{R_5} + \frac{1}{5} + \frac{1}{5} + \frac{1}{10} + \frac{5}{10} = 0,5 Sm.$$

Bunda

$$R_{3,4,5} = \frac{1}{G_E} = \frac{1}{0,5} = 2 \Omega.$$

Qarshiliklar $R_{1,2}$ va $R_{3,4,5}$ o'zaro ketma-ket ulangani uchun (1.11 b-rasm,) zanjirning ekvivalent qarshiligi (1.11 c-rasm,):

$$R_E = R_{1,2} + R_{3,4,5} = 1,6 + 2 = 3,6 \Omega.$$

U holda zanjirdagi tok.

$$I = \frac{U}{R_E} = \frac{36}{3,6} = 10 \text{ A.}$$

Zanjirning qismlaridagi kuchlanishlar esa

$$U_{1,2} = I \cdot R_{1,2} = 10 \cdot 1,6 = 16 \text{ V};$$

$$U_{3,4,5} = I \cdot R_{3,4,5} = 10 \cdot 2 = 20 \text{ V.}$$

U holda tarmoqdagi toklarning qiymati:

$$I_1 = \frac{U_{1,2}}{R_1} = \frac{16}{8} = 2 \text{ A}; \quad I_2 = \frac{U_{1,2}}{R_2} = \frac{16}{2} = 8 \text{ A};$$

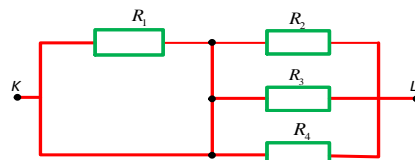
$$I_3 = I_4 = \frac{U_{3,4,5}}{R_3} = \frac{20}{5} = 4 \text{ A}; \quad I_5 = \frac{U_{3,4,5}}{R_5} = \frac{20}{10} = 2 \text{ A.}$$

Kirxgofning birinchi qonuniga binoan

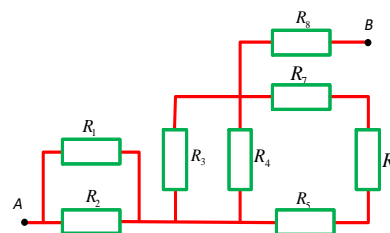
$$I_1 + I_2 = I_3 + I_4 + I_5; \quad 2 + 8 = 4 + 4 + 2 \Rightarrow 10 \text{ A} = 10 \text{ A.}$$

1.6. Amaliy mashg'ulotlar uchun masalalar va hisob grafik ishlari.

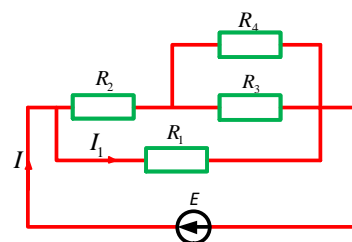
1.1-masala: Rasmdagi $R_1 = 4 \Omega$, $R_2 = 3 \Omega$, $R_3 = R_4 = 6 \Omega$ K va L nuqtalar orasidagi umumiy qarshilikni toping (Ω)?



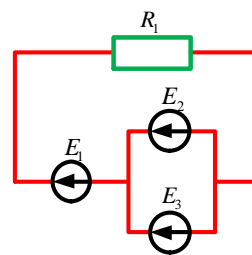
1.2-masala: $R_1 = R_2 = R_8 = 4 \Omega$, $R_3 = R_4 = 6 \Omega$, $R_7 = R_6 = R_5 = 2 \Omega$, A va B nuqtalar orasidagi R_e toping (Ω)?



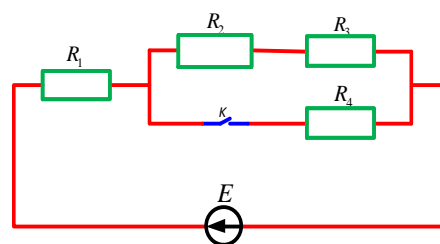
1.3-masala: Elektr zanjir $I = 6 \text{ A}$, $I_1 = 4 \text{ A}$, $R_1 = 8 \Omega$, $R_2 = R_3 = 12 \Omega$ ma'lumotlardan foydalanib, R_4 ni aniqlang (Ω)?



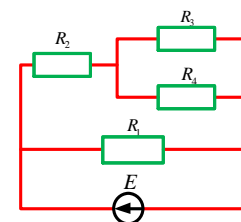
1.4-masala: Tok manbalarining har birining EYuK.i 40 V va ichki qarshiligi 2 Ω boʻlsa, $R_1 = 7 \Omega$ rezistordan oʻtayotgan tok kuchi necha Amper?



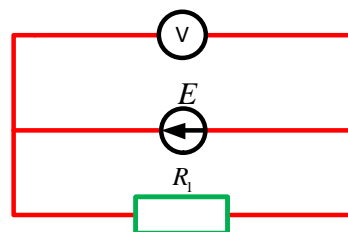
1.5-masala: Rasmdagi elektr zanjiriga $E = 60 V$ kuchlanish berilgan, zanjirning qarshiliklari: $R_1 = 4\Omega$; $R_2 = 3\Omega$; $R_3 = 5\Omega$; $R_4 = 8\Omega$ dan iborat. K kalit ulanganda va uzilganda $t = 30$ sekund t vaqtda butun zanjirdan ajralib chiqqan issiqlik miqdorini toping.



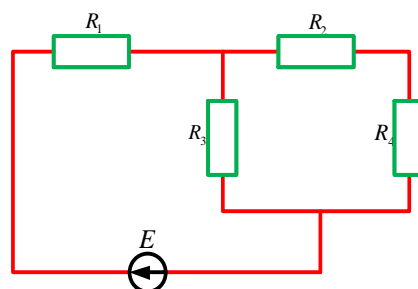
1.6-masala: Elektr zanjiridan oqib oʻtayotgan tok $I = 4 A$ boʻlsa, $R_1 = 4 \Omega$, $R_2 = 2 \Omega$, $R_3 = 6 \Omega$, $R_4 = 3 \Omega$, $r = 1 \Omega$ manbaning EYuK i necha Volt?



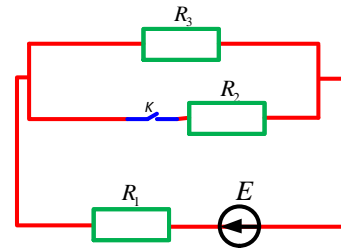
1.7-masala: Agar elektr zanjirida $E = 100 V$ $R_1 = 10\Omega$ boʻlsa, K kalit ulanganda voltmetrning koʻrsatishi necha Volt boʻladi?



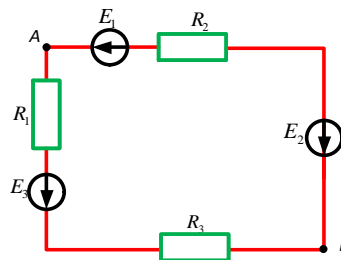
1.8-masala: Rasmdagi elektr zanjirda $R_1 = 6 \Omega$; $R_2 = 3 \Omega$; $R_3 = 4 \Omega$; boʻlib, R_2 va R_3 qarshiliklardan oʻtayotgan tok kuchi teng boʻlsa, R_4 qarshiliga necha Ω ga teng?



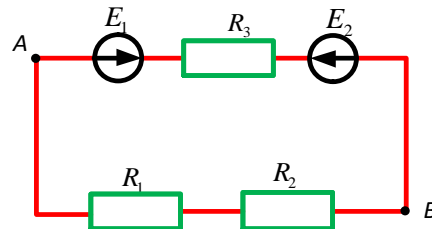
1.9-masala: Agar elektr zanjirida $E = 60 V$; $r_0 = 2 \Omega$; $R_1 = 6 \Omega$; $R_2 = R_3 = 4 \Omega$; bo'lib K kalit ochiq holda elektr zanjiridan oqib o'tayotgan tok 5 A bo'lsa, kalitning yopiq holda zanjiridan oqib o'tayotgan tok necha Amper bo'ladi?



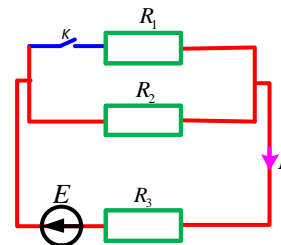
1.10-masala: Agar elektr zanjiridagi $E_1 = 5 V$; $E_2 = 30 V$; $E_3 = 5 V$; $R_1 = R_2 = 2 \Omega$; $R_3 = 3 \Omega$ bo'lsa A va B nuqtalar orasidagi potentsiallar ayirmasini aniqlang (V)?



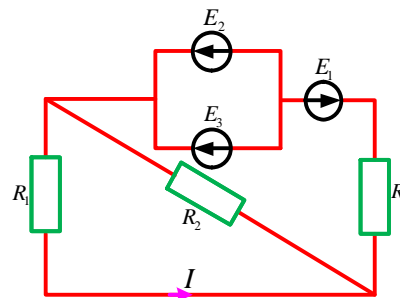
1.11-masala: Quyidagi elektr zanjirda EYuK manbalari $E_1 = 80 V$; $E_2 = 40 V$; ularning ichki qarshiliklari $r_1 = r_2 = 3 \Omega$; zanjir qarshiliklari $R_1 = R_3 = 4 \Omega$; $R_2 = 6 \Omega$ bo'lsa A va B nuqtalar orasidagi potentsiallarning farqi necha Volt?



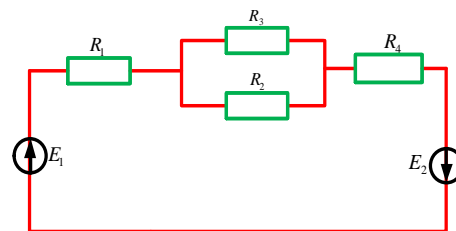
1.12-masala: Agar elektr zanjirining parametrlari $E = 28 V$; $R_1 = 4 \Omega$; $R_2 = 12 \Omega$ bo'lib, zanjirdan oqib o'tayotgan tok K kalit ochiq holda 2A bo'lsa, kalit ulangan holda qancha tok oqib o'tishi va R_3 qarshiligini aniqlansin.



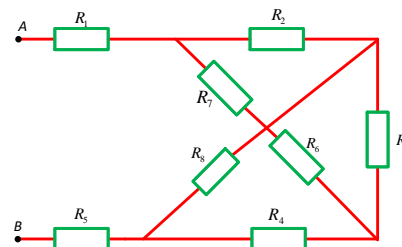
1.13-masala: Elektr zanjiridagi $E_1 = 6V$; $E_2 = E_3 = 18V$; $R_1 = 6 \Omega$; $R_2 = 3 \Omega$ bo'lib, R_1 qarshilikdan 1 A tok oqib o'tayotgan bo'lsa, R_3 ning qiymatini aniqlansin.



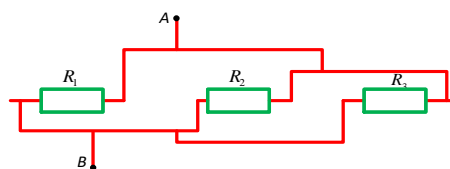
1.14-masala: Ushbu elektr zanjirida EYuK manbalari $E_1 = 12 V$; $E_2 = 24 V$; manbalarning ichki qarshiliklari $r_1 = r_2 = 1 \Omega$; zanjir qarshiliklari $R_1 = 2 \Omega$; $R_2 = 3 \Omega$; $R_3 = R_4 = 6 \Omega$; bo'lsa, elektr zanjirining R_2 qarshiligidan 1 minutda ajralib chiqayotgan issiqlik miqdorini toping.



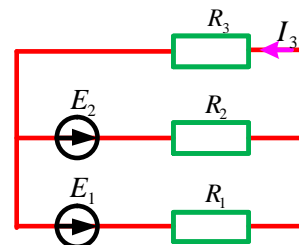
1.15-masala: Agar $R_1 = R_4 = R_5 = 2 \Omega$; $R_2 = R_3 = R_6 = R_7 = R_8 = 4 \Omega$ bo'lsa, A va B nuqtalar orasidagi umumiy qarshilik aniqlansin.



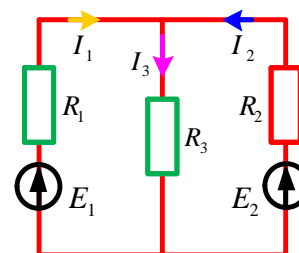
1.16-masala: Agar elektr zanjirining A va B nuqtalari orasidagi umumiy qarshilik 1Ω bo'lib, $R_1 = R_2 = 3 \Omega$ bo'lsa, R_3 ni qiymatini aniqlang.



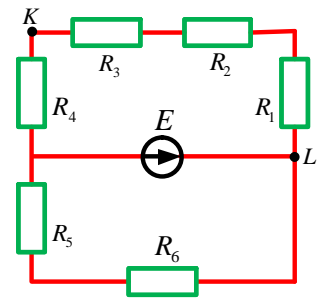
1.17-masala: Agar elektr zanjirining parametrlari $E_2 = 10 V$; $R_1 = 3 \Omega$; $R_2 = 2 \Omega$; $R_3 = 5 \Omega$ bo'lib, zanjirdan $1 A$ tok oqib o'tayotgan bo'lsa E_1 ning qiymati qancha?



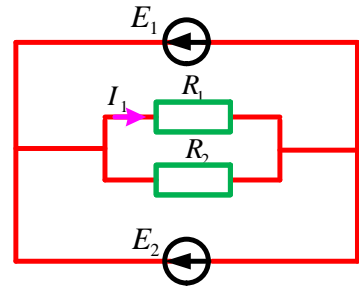
1.18-masala: Elektr zanjiridagi ma'lumotlardan foydalanib qarshiligi $R_3 = 2 \Omega$ bo'lgan rezistordan oqayotgan tok kuchini aniqlang. $E_1 = E_2 = 4 V$; $R_1 = 1 \Omega$; $R_2 = 6 \Omega$.



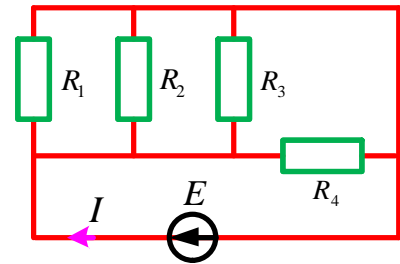
1.19-masala: Agar elektr zanjirining barcha qarshiliklari $R_1 = R_2 = R_3 = R_4 = R_5 = R_6 = 6 \Omega$ bo'lib, EYuK manбайдan zanjirga berilayotgan kuchlanish $E = 24 V$ bo'lsa K va L nuqtalar orasidagi potentsiallar farqi necha Voltga teng?



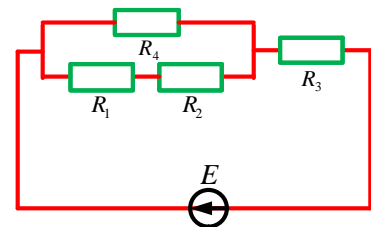
1.20-masala: Elektr zanjiridagi EYuK lar $E_1 = E_2 = 15 V$; ichki qarshiliklari $r_1 = r_2 = 2 \Omega$; parallel ulangan $R_1 = R_2 = 4 \Omega$ rezistorlarning har biridan o'tayotgan tok necha Amper ?



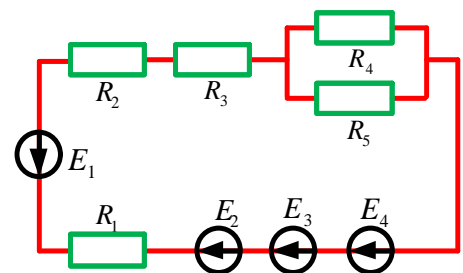
1.21-masala: Quyida berilgan ma'lumotlardan foydalanib manбайдan o'tayotgan tok kuchini aniqlang. $E = 6 V$; $r_0 = 0$; $R_1 = 12 \Omega$; $R_2 = 2 \Omega$; $R_3 = 4 \Omega$; $R_4 = 6 \Omega$.



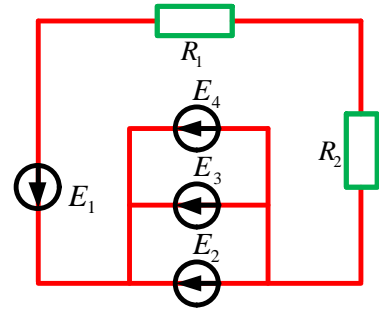
1.22-masala: Elektr zanjirida $E = 24 V$; $R_1 = 4 \Omega$; $R_2 = R_3 = 2 \Omega$; bo'lib, R_1 rezistordan $2 A$ tok oqib o'tayotgan bo'lsa, R_4 rezistorning qarshiligi qancha?



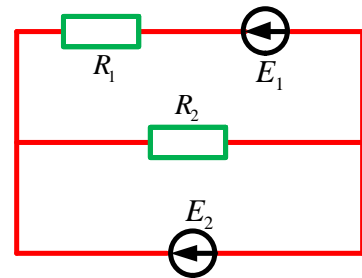
1.23-masala: Agar EYuK manbalarining qiymatlari $E_1 = 6 V$; $E_2 = E_3 = E_4 = 4 V$; manbalarining ichki qarshiliklari $r_1 = r_2 = r_3 = r_4 = 0$; rezistorlarning qarshiliklari $R_1 = R_2 = R_3 = 2 \Omega$; $R_4 = 6 \Omega$; $R_5 = 12 \Omega$ bo'lsa, 6Ω qarshilikka ega rezistor uchlaridagi potentsiallarning farqi necha Volt?



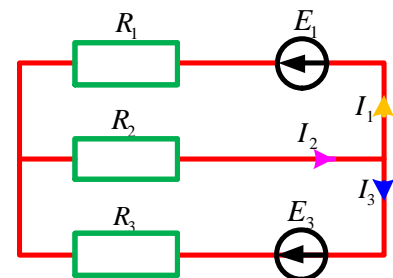
1.24-masala: Berilgan ma'lumotlardan foydalanib rezistor R_1 iste'mol qilayotgan quvvatni aniqlang. EYuK manbalarining qiymatlari $E_1 = E_2 = E_3 = E_4 = 10 V$; manbalarining ichki qarshiliklari $r_2 = r_3 = r_4 = 3 \Omega$; $r_1 = 2 \Omega$; ketme ket ulangan rezistorlarning qiymatlari $R_1 = 3 \Omega$; $R_2 = 14 \Omega$.



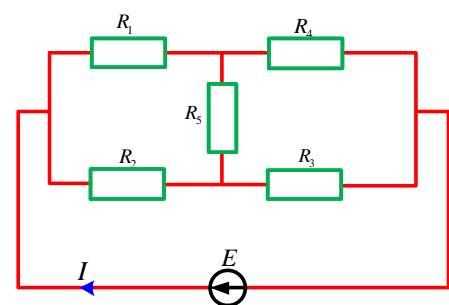
1.25-masala: Agar elektr zanjiridagi EYuK larning qiymatlari $E_1 = 40 V$; $E_2 = 120 V$; manbalarining ichki qarshiliklari $r_1 = r_2 = 0$; rezistorlarning qarshiliklari $R_1 = 40 \Omega$; $R_2 = 60 \Omega$ bo'lsa, elektr zanjirining E_2 ulangan tarmog'idan o'tayotgan tok necha Amper?



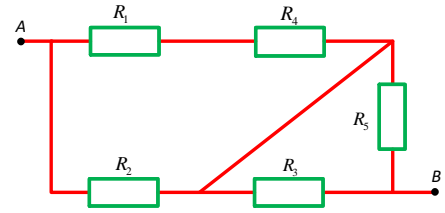
1.26-masala: Berilgan ma'lumotlardan foydalanib R_1 rezistorning qarshiligini aniqlang. EYuK manbalarining qiymati $E_1 = E_2 = 30 V$; manbalarining ichki qarshiliklari $r_1 = r_2 = 0$; ikkinchi tarmoqdan o'tayotgan tok $I_2 = 6 A$; birinchi va ikkinchi tarmoqlarning qarshiliklari $R_2 = 4 \Omega$; $R_3 = 3 \Omega$.



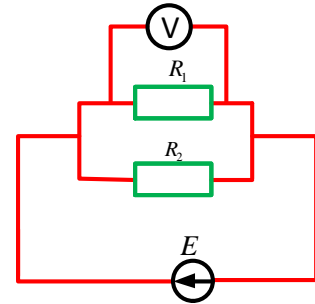
1.27-masala: Agar elektr zanjiridagi EYuK manbai $E = 48 V$; manbaning ichki qarshiligi $r_0 = 0$; aralash sxemada ulangan qarshiliklar $R_1 = 6 \Omega$; $R_2 = 9 \Omega$; $R_3 = 3 \Omega$; $R_4 = 2 \Omega$; $R_5 = 4 \Omega$; dan iborat. Ushbu elektr zanjirda manbadan o'tayotgan tok necha Amper?



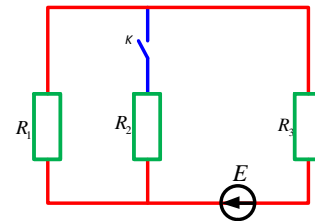
1.28-masala: Agar elektr zanjirining barcha qarshiliklari 6Ω dan, ya'ni $R_1 = R_2 = R_3 = R_4 = R_5 = 6 \Omega$ bo'lsa, elektr zanjirining A va B nuqtalar orasidagi umumiy qarshilik qancha (Ω)?



1.29-masala: Agar $R_1 = 4 \Omega$, $R_2 = 12 \Omega$ bo'lib, Voltmetrning ko'rsatishi $12V$ bo'lsa, elektr zanjiriga EYuK manbaidan necha Volt kuchlanish berilayapti?



1.30-masala: Elektr zanjirining parametrlari $E = 60 V$; $r_0 = 1 \Omega$; $R_1 = 6 \Omega$; $R_2 = 3 \Omega$; bo'lib, K kalitning ochiq holida R_3 dan $6A$ tok o'tayotgan bo'lsa, kalit ulanganda undan necha Amper tok o'tadi?

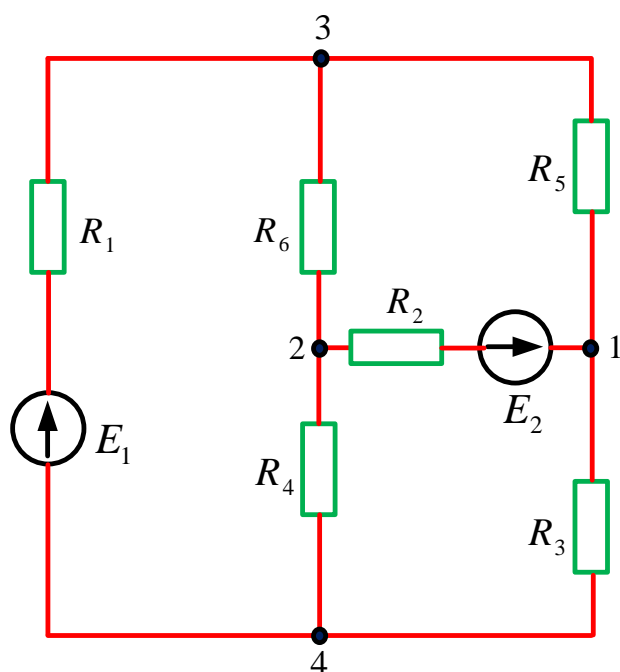


HISOB-GRAFIK ISHI

Berilgan sxema uchun elektr zanjirini hisoblashda quyidagilar bajariladi:

1. Kirxgofning birinchi va ikkinchi qonuni bo'yicha tenglama tuziladi.
2. Kontur toklar usuli bo'yicha tenglamalar sistemasini tuzish bilan tarmoqdagi toklarini topish.
3. Tugun potentsiallar usuli bo'yicha tenglamalar sistemasini tuzish bilan tarmoqdagi toklarini topish.
4. Topilgan tarmoqdagi toklarni Kirxgofning I va II qonunlari asosida tekshiramiz.
5. Ekvivalent generator usuli yordamida birorta tarmoqdagi tok qiymatini aniqlaymiz.
6. Quvvat muvozanati tenglamasini tuzamiz va hisoblash xatoligini aniqlaymiz. Eslatma: Chizmada berilgan sxemalar variantlariga mos parametrlar va EYuKlar qiymatlari jadval 1.1.da keltirilgan.

HISOB-GRAFIK ISHINI BAJARISHGA NA'MUNA



1.12-rasm

1.12- rasmda berilgan murakkab elektr zanjiri tarmoqlaridagi qarshiliklarning qiymatlari $R_1 = 9 \Omega$, $R_2 = 12 \Omega$, $R_3 = 4 \Omega$, $R_4 = 8 \Omega$, $R_5 = 10 \Omega$, $R_6 = 7 \Omega$ ga va elektr yurituvchi kuchlarining qiymatlari $E_1 = 40 V$, $E_2 = 120 V$ ga teng. Elektr yurituvchi kuch manbalarining va qarshiliklarning qiymatlaridan foydalanib, barcha tarmoq (shaxobcha) lardagi toklarning qiymatlari murakkab

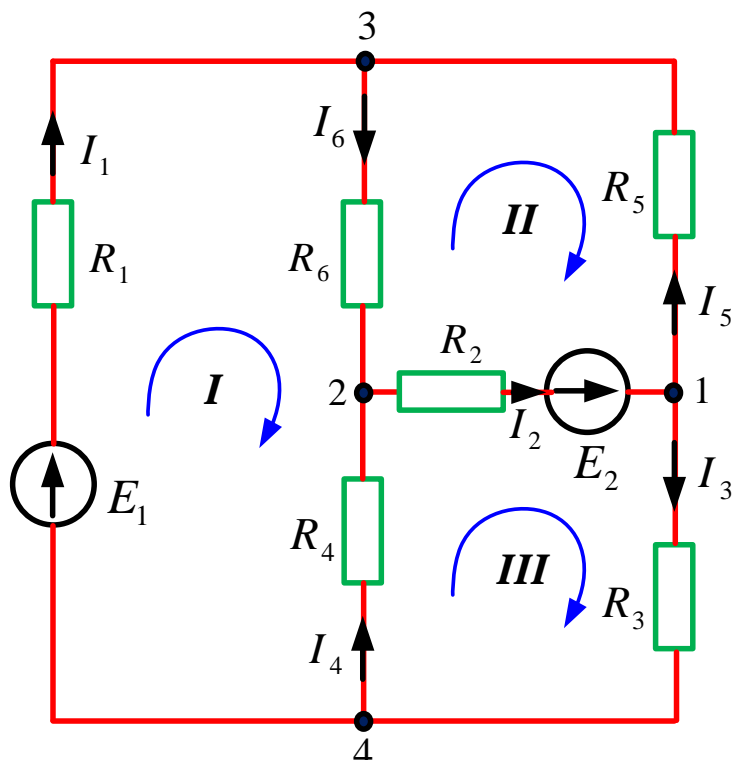
elektr zanjirlarini hisoblash usullari yordamida aniqlansin, shuningdek ko‘rilayotgan elektr zanjiri uchun quvvatlar muvozanati tenglamasi tuzilib qiymatlar taqqoslansin.

Yechilishi. 1. Kirxgofning qonunlarini bevosita qo‘llash usuli.

Dastlab berilgan murakkab elektr zanjirining sxemasi tarmoqlaridan oqib o‘tayotga barcha tarmoqdagi toklarning shartli musbat yo‘nalishini aniqlaymiz va belgilaymiz¹. Keyingi navbatda ko‘rilayotgan elektr zanjirining sxemasini mustaqil konturlarga ajratamiz va konturlarning ham shartli musbat yo‘nalishlarini belgilab olamiz² (1.13-rasm).

So‘ngra, barcha tarmoqlardagi toklarni aniqlash uchun Kirxgofning qonunlariga asosan tugun va konturlar uchun tenglamalar tuzamiz.

Kirxgofning I - qonuniga asosan o‘zaro bog‘liq bo‘lmagan $n - 1$ tenglama tuzamiz, bu yerda n tugunlar soni. Sxemada tugunlar soni $n = 4$ ta bo‘lgani uchun $n - 1 = 3$ tuzilayotgan tenglamalar soni 3 ta bo‘ladi.



1.13-rasm

1- tugun uchun $I_2 - I_3 - I_5 = 0$

2- tugun uchun $-I_2 + I_4 + I_6 = 0$

3- tugun uchun $I_1 + I_5 - I_6 = 0$

4- tugun uchun $-I_1 + I_3 - I_4 = 0$

¹ Toklarning yo‘nalishini tanlash ixtiyoriy, biroq biron bir tugunga tegishli tarmoqlarning toklarini barchasi shu tugunga kiruvchi yoki tugundan chiquvchi bo‘lib qolishiga yo‘l qo‘yilmasligi kerak.

² Konturlar yo‘nalishini tanlash ham ixtiyoriy, faqat birinchi kontur yo‘nalishi qanday bo‘lsa, qolgan konturlarning yo‘nalishi ham shu yo‘nalishda bo‘lishi maqsadga muvofiqdir.

Kirxgofning II - qonuniga asosan $m - n + 1 = 6 - 4 + 1 = 3$ o‘zaro bog‘liq bo‘lmagan tenglama tuzamiz, bu yerda m - tarmoqlar soni. Kirxgofning ikkinchi qonuniga asosan tenglamalar tuzilayotganda³. sxemaning barcha tarmoqlari ishtirok etishi shart.

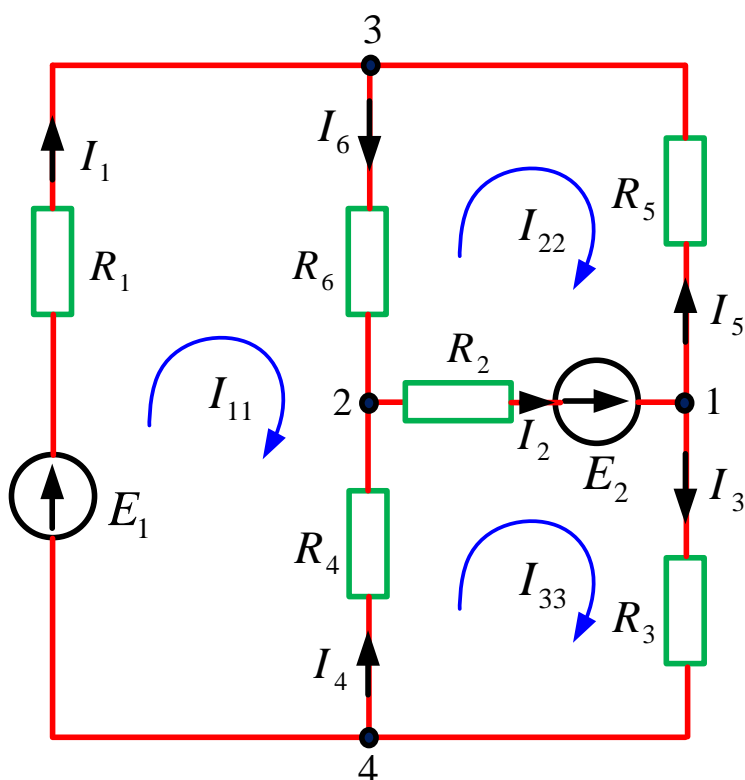
$$I\text{-kontur uchun} \quad I_1 \cdot R_1 - I_4 \cdot R_4 + 6 \cdot R_6 = E_1$$

$$II\text{-kontur uchun} \quad -I_2 \cdot R_2 - I_5 \cdot R_5 - I_6 \cdot R_6 = -E_2$$

$$III\text{-kontur uchun} \quad I_2 \cdot R_2 + I_3 \cdot R_3 + I_4 \cdot R_4 = E_2$$

Kirxgofning qonunlariga asosan tuzilgan tenglamalarning birgalikdagi yechimi elektr zanjirining barcha tarmoqlaridagi toklarning qiymatini aniqlash imkonini beradi.

2. Kontur toklar usuli bo‘yicha hisoblaymiz. Bu usulning avvalgi



1.14-rasm

usulga qaraganda afzalligi shundaki, tuzilishi kerak bo‘lgan tenglamalar soni teng yarmiga qisqaradi, ya‘ni mustaqil konturlar soniga teng bo‘lgan tenglama tuzilsa yetarli bo‘ladi.

Berilgan murakkab elektr zanjiri sxemasining xar bir mustaqil konturida uchtadan tarmoq toki oqib o‘tayapdi, bu tarmoq toklarining o‘rnida xar bir mustaqil konturida bittadan

kontur toki (I_{11}, I_{22}, I_{33}) oqib o‘tayapdi deb faraz qilamiz⁴ (1.14-rasm).

³ Yo‘nalishi kontur yo‘nalishiga mos yo‘nalgan EYuK lar musbat (+) ishora bilan, qarama-qarshi yo‘nalganlari esa manfiy (-) ishora bilan olinadi. Shuningdek, yo‘nalishi kontur yo‘nalishiga mos bo‘lgan toklar hosil qilgan kuchlanishlar pasayuvi (+) ishora bilan, qarama-qarshi bo‘lganlari esa manfiy (-) ishora bilan olinadi.

⁴ Aslida kontur toki degan kattalik mavjud emas, hisoblashlarni soddalashtirish uchngina ushbu tushunch qabul qilinadi.

1.14-rasmdagi elektr zanjirini hisoblash uchun tenglamalar sistemasi quyidagicha ko‘rinishga ega bo‘ladi:

$$\begin{cases} I_{11}R_{11} + I_{22}R_{12} + I_{33}R_{13} = E_{11} \\ I_{11}R_{21} + I_{22}R_{22} + I_{33}R_{23} = E_{22} \\ I_{11}R_{31} + I_{22}R_{32} + I_{33}R_{33} = E_{33}. \end{cases}$$

Bunda, I kontur tarmoqlaridagi qarshiliklar yig‘indisi:

$$R_{11} = R_1 + R_6 + R_4 = 9 + 7 + 8 = 24 \Omega.$$

II kontur tarmoqlaridagi qarshiliklar yig‘indisi:

$$R_{22} = R_1 + R_6 + R_4 = 2 + 7 + 10 = 29 \Omega.$$

III kontur tarmoqlaridagi qarshiliklar yig‘indisi:

$$R_{33} = R_1 + R_6 + R_4 = 12 + 4 + 8 = 24 \Omega.$$

I va II konturlarga tegishli (umumiy) bo‘lgan tarmoq (bu yerda kontur yo‘nalishi va tok yo‘nalishiga qaraymiz):

$$R_{12} = R_{21} = -R_6 = -7 \Omega.$$

I va III konturlarga tegishli (umumiy) bo‘lgan tarmoq:

$$R_{13} = R_{31} = -R_4 = -8 \Omega.$$

II va III konturlarga tegishli (umumiy) bo‘lgan tarmoq:

$$R_{23} = R_{32} = -R_2 = -12 \Omega.$$

I,II,III konturlardagi EYuK manbalari:

$$E_{11} = E_1 = 40 V$$

$$E_{22} = -E_2 = 120 V$$

$$E_{33} = E_2 = 120 V$$

Kontur toklari I_{11}, I_{22}, I_{33} ko‘rinishida belgilangan bo‘lib, ularning yo‘nalishi bir-biriga mos yo‘naltirilgan. Kirxgofning ikkinchi qonuniga asosan tenglama tuzamiz⁵:

$$\begin{cases} I_{11}(R_1 + R_6 + R_4) - I_{22}R_6 - I_{33}R_4 = E_1 \\ -I_{11}R_6 + I_{22}(R_1 + R_6 + R_4) - I_{33}R_2 = -E_2 \\ -I_{11}R_4 - I_{22}R_2 + I_{33}(R_1 + R_6 + R_4) = E_2. \end{cases}$$

Qarshiliklar va EYuK manbalarining son qiymatini tenglamalar sistemasiga qo‘yib I_{11}, I_{22}, I_{33} kontur toklarini aniqlaymiz:

$$\begin{cases} I_{11}(9 + 7 + 8) - I_{22}7 - I_{33}8 = 40 \\ -I_{11}7 + I_{22}(12 + 7 + 10) - I_{33}12 = -120 \\ -I_{11}8 - I_{22}12 + I_{33}(12 + 4 + 8) = 120 \end{cases}$$

yoki:

$$\begin{cases} I_{11}24 - I_{22}7 - I_{33}8 = 40 \\ -I_{11}7 + I_{22}29 - I_{33}12 = -120 \\ -I_{11}8 - I_{22}12 + I_{33}24 = 120. \end{cases}$$

Kramer usulidan foydalanib tenglamalar sistemasini yechamiz.

Determinant:

$$\begin{aligned} \Delta &= \begin{vmatrix} 24 & -7 & -8 \\ -7 & 29 & -12 \\ -8 & -12 & 24 \end{vmatrix} = \\ &= (24 \cdot 29 \cdot 24 + (-7) \cdot (-12) \cdot (-8) + (-7) \cdot (-12) \cdot (-8)) - \\ &- ((-8) \cdot 29 \cdot (-8) + (-12) \cdot (-12) \cdot 24 + (-7) \cdot (-7) \cdot 24) = 8872 \end{aligned}$$

$$\begin{aligned} \Delta_{11} &= \begin{vmatrix} 40 & -7 & -8 \\ -120 & 29 & -12 \\ 120 & -12 & 24 \end{vmatrix} = \\ &= (40 \cdot 29 \cdot 24 + (-7) \cdot (-12) \cdot 120 + (-120) \cdot (-12) \cdot (-8)) - \\ &- ((-8) \cdot 29 \cdot 120 + (-12) \cdot (-12) \cdot 40 + (-7) \cdot (-120) \cdot 24) = 28320 \end{aligned}$$

$$\begin{aligned} \Delta_{22} &= \begin{vmatrix} 24 & 40 & -8 \\ -7 & -120 & -12 \\ -8 & 120 & 24 \end{vmatrix} = \\ &= (24 \cdot (-120) \cdot 24 + 40 \cdot (-12) \cdot (-8) + (-7) \cdot 120 \cdot (-8)) - \end{aligned}$$

⁵ Xar ikkala konturga tegishli bo‘lgan tarmoqdan kontur toklari bir-biriga qarama-qarshi tomonga oqib o‘tayotganligi uchun manfiy (-) ishora bilan olingan.

$$-((-8) \cdot (-120) \cdot (-8) + (-12) \cdot 24 \cdot 120 + (-7) \cdot 40 \cdot 24) = -9600$$

$$\Delta_{33} = \begin{vmatrix} 24 & -7 & 40 \\ -7 & 29 & -120 \\ -8 & -12 & 120 \end{vmatrix} =$$

$$= (24 \cdot 29 \cdot 120 + (-7) \cdot (-120) \cdot (-8) + (-7) \cdot (-12) \cdot 40) - \\ - (40 \cdot 29 \cdot (-8) + (-120) \cdot (-12) \cdot 24 + (-7) \cdot (-7) \cdot 120) = 49000$$

Kontur toklari

$$I_{11} = \frac{\Delta_{11}}{\Delta} = \frac{28320}{8872} = 3,192 \text{ A.}$$

$$I_{22} = \frac{\Delta_{22}}{\Delta} = \frac{-9600}{8872} = -1,082 \text{ A.}$$

$$I_{33} = \frac{\Delta_{33}}{\Delta} = \frac{49000}{8872} = 5,523 \text{ A.}$$

Kontur toklarining qiymatlari asosida tarmoqlardagi haqiqiy toklarning qiymatini aniqlaymiz.

Qarshiligi R_1 bo'lgan tarmoqdagi, birinchi tarmoq tokining haqiqiy qiymati I_{11} kontur tokiga teng bo'ladi:

$$I_1 = I_{11} = 3,192 \text{ A.}$$

Qarshiligi R_2 bo'lgan tarmoqdagi, ikkinchi tarmoq tokining haqiqiy qiymati I_{22} va I_{33} kontur toklaridan aniqlanadi:

$$I_2 = I_{22} + I_{33} = (-1,082) + 5,523 = 6,605 \text{ A.}$$

Qarshiligi R_3 bo'lgan tarmoqdagi, uchinchi tarmoq tokining haqiqiy qiymati I_{33} kontur tokiga teng bo'ladi:

$$I_3 = I_{33} = 5,523 \text{ A.}$$

Qarshiligi R_4 bo'lgan tarmoqdagi, to'rtinchi tarmoq tokining haqiqiy qiymati I_{11} va I_{33} kontur toklaridan aniqlanadi:

$$I_4 = I_{11} + I_{33} = 3,192 + 5,523 = 8,715 \text{ A.}$$

Qarshiligi R_5 bo'lgan tarmoqdagi, beshinchi tarmoq tokining haqiqiy qiymati I_{22} kontur tokidan aniqlanadi:

$$I_5 = I_{22} = -(-1,082) = 1,082 \text{ A.}$$

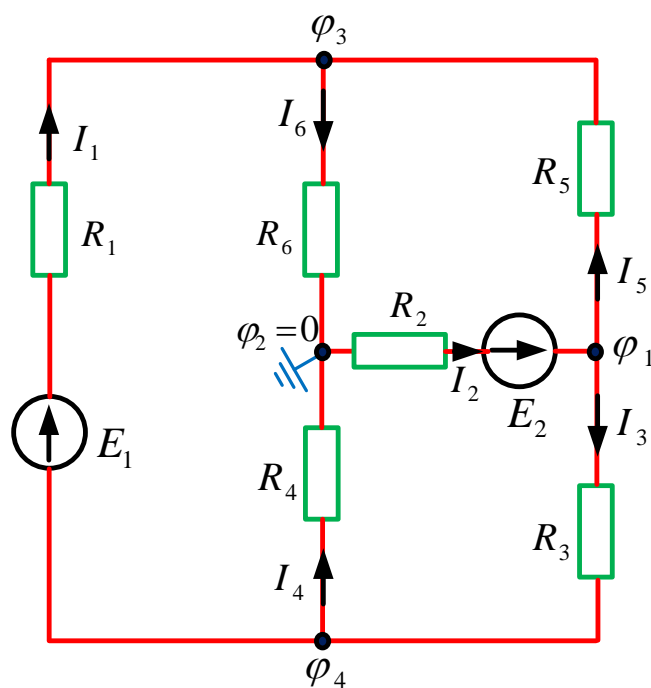
Qarshiligi R_6 bo'lgan tarmoqdagi, oltinchi tarmoq tokining haqiqiy qiymati I_{11} va I_{22} kontur toklaridan aniqlanadi:

$$I_6 = I_{11} - I_{22} = 3,192 - (-1,082) = 4,274 \text{ A.}$$

Izox: I_3 tokning manfiy ishorali bo'lishi, ularning zanjirdagi haqiqiy yo'nalishi, biz qabul qilganga nisbatan qarama-qarshi ekanligini ifodalaydi.

3. Tugun potensial usuliga asosan hisoblash: Murakkab elektr zanjirlarini hisoblaganda, bog'liq bo'lmagan konturlar soni tugunlar sonidan bittaga kamaytirilganda, tugun potentsiali usulidan foydalanish maqsadga muvofiq bo'ladi.

Bu usulda noma'lum deb berilgan elektr zanjiri sxemasining tugunlar potentsiali qabul qilinadi. Tugunlarni bog'lovchi tarmoqdagi toklar Om qonuni yordamida aniqlanadi.



1.15-rasm

Tugunlar potentsiali usuli bo'yicha tenglamalar tuzilganda biror bir tugunning potentsiali nolga teng deb qabul qilinadi va uni tayanch deyiladi. Tugunlar potentsiali usulida noma'lumlar soni tenglamalar soniga teng va sxema uchun bu tenglamalarni Kirxgofning birinchi qonuniga asosan tuzish kerak. "2" tugunning potentsialini nolga teng deb qabul qilamiz, ya'ni $\varphi_2 = 0$. Endi faqat 3 ta tugunning potentsiallari $\varphi_1, \varphi_3, \varphi_4$ ni aniqlashimiz kerak. Qarshilikka teskari bo'lgan kattalik o'tkazuvchanlik deb ataladi. g tugunga kiruvchi tarmoqning o'tkazuvchanligi.

$$g = \frac{1}{R} [\text{Sm}]$$

Tarmoqdagi toklarni Om qonuni yordamida aniqlaymiz:

- ❖ birinchi tarmoqdan o'tayotgan tok $I_1 = \frac{\varphi_4 - \varphi_3 + E_1}{R_1} = (\varphi_4 - \varphi_3 + E_1)g_1;$
- ❖ ikkinchi tarmoqdan o'tayotgan tok $I_2 = \frac{\varphi_2 - \varphi_1 + E_2}{R_2} = (E_2 - \varphi_1)g_2;$
- ❖ uchinchi tarmoqdan o'tayotgan tok $I_3 = \frac{\varphi_1 - \varphi_4}{R_3} = (\varphi_1 - \varphi_4)g_3;$
- ❖ to'rtinchi tarmoqdan o'tayotgan tok $I_4 = \frac{\varphi_4 - \varphi_2}{R_4} = \varphi_4 g_4;$
- ❖ beshinchi tarmoqdan o'tayotgan tok $I_5 = \frac{\varphi_1 - \varphi_3}{R_5} = (\varphi_1 - \varphi_3)g_5;$
- ❖ oltinchi tarmoqdan o'tayotgan tok $I_6 = \frac{\varphi_3 - \varphi_2}{R_6} = \varphi_3 g_6.$

Tarmoqdagi toklarni Kirxgofning 1 qonuniga nisbatan tuzilgan tenglamaga oborib qoyamiz.

$$\varphi_1 \text{ tugun uchun} \quad I_2 - I_3 - I_5 = 0$$

$$\varphi_3 \text{ tugun uchun} \quad I_1 + I_5 - I_6 = 0$$

$$\varphi_4 \text{ tugun uchun} \quad -I_1 + I_3 - I_4 = 0$$

$$\left\{ \begin{array}{l} \frac{-\varphi_1 + E_2}{R_2} - \frac{\varphi_1 - \varphi_4}{R_3} - \frac{\varphi_1 - \varphi_3}{R_5} = 0 \\ \frac{\varphi_4 - \varphi_3 + E_1}{R_1} + \frac{\varphi_1 - \varphi_3}{R_5} - \frac{\varphi_3}{R_6} = 0 \\ -\frac{\varphi_4 - \varphi_3 + E_1}{R_1} + \frac{\varphi_1 - \varphi_4}{R_3} - \frac{\varphi_4}{R_4} = 0 \end{array} \right.$$

Ushbu ifodadagi qiymati noma'lum kattaliklarni tenglamaning bir tomoniga, qiymati ma'lum kattaliklarni esa tenglamaning ikkinchi tomoniga o'tkazib qayta yozamiz.

$$\begin{cases} \varphi_1 \left(\frac{1}{R_2} + \frac{1}{R_3} + \frac{1}{R_5} \right) - \varphi_3 \left(\frac{1}{R_5} \right) - \varphi_4 \left(\frac{1}{R_3} \right) = \frac{E_2}{R_2} \\ -\varphi_1 \left(\frac{1}{R_5} \right) + \varphi_3 \left(\frac{1}{R_1} + \frac{1}{R_5} + \frac{1}{R_6} \right) - \varphi_4 \left(\frac{1}{R_1} \right) = \frac{E_1}{R_1} \\ -\varphi_1 \left(\frac{1}{R_3} \right) - \varphi_3 \left(\frac{1}{R_1} \right) + \varphi_4 \left(\frac{1}{R_1} + \frac{1}{R_3} + \frac{1}{R_4} \right) = -\frac{E_1}{R_1} \end{cases}$$

O'tkazuvchanliklar va EYuK manbalarining son qiymatini tenglamalar sistemasiga qo'yib $\varphi_1, \varphi_3, \varphi_4$ tugun potentsiallarini aniqlaymiz:

$$\begin{cases} (g_2 + g_3 + g_5)\varphi_1 - g_5\varphi_3 - g_3\varphi_4 = g_2E_2 \\ -g_5\varphi_1 + (g_1 + g_5 + g_6)\varphi_3 - g_1\varphi_4 = g_1E_1 \\ -g_3\varphi_1 - g_1\varphi_3 + (g_1 + g_3 + g_4)\varphi_4 = -g_1E_1 \end{cases}$$

$$\begin{aligned} \varphi_a 0,433 - \varphi_c 0,1 - \varphi_d 0,25 &= 10 \\ -\varphi_a 0,1 + \varphi_c 0,354 - \varphi_d 0,111 &= 4,44 \\ -\varphi_a 0,25 - \varphi_c 0,111 + \varphi_d 0,486 &= -4,44 \end{aligned}$$

yoki

$$\begin{aligned} 0,433\varphi_1 - 0,1\varphi_3 - 0,25\varphi_4 &= 10 \\ -0,1\varphi_1 + 0,354\varphi_3 - 0,111\varphi_4 &= 4,44 \\ -0,25\varphi_1 - 0,111\varphi_3 + 0,486\varphi_4 &= -4,44 \end{aligned}$$

Kramer usulidan foydalanib tenglamalar sistemasini yechamiz.

Determinant:

$$\Delta = \begin{vmatrix} 0,433 & -0,1 & -0,25 \\ -0,1 & 0,354 & -0,111 \\ -0,25 & -0,111 & 0,486 \end{vmatrix} = 0,03667$$

$$\Delta_{11} = \begin{vmatrix} 10 & -0,1 & -0,25 \\ 4,44 & 0,354 & -0,111 \\ -4,44 & -0,111 & 0,486 \end{vmatrix} = 1,494$$

$$\Delta_{22} = \begin{vmatrix} 0,433 & 10 & -0,25 \\ -0,1 & 4,44 & -0,111 \\ -0,25 & -4,44 & 0,486 \end{vmatrix} = 1,097$$

$$\Delta_{33} = \begin{vmatrix} 0,433 & -0,1 & 10 \\ -0,1 & 0,354 & 4,44 \\ -0,25 & -0,111 & -4,44 \end{vmatrix} = 0,68386$$

Tugundagi potentsiallar farqi:

$$\varphi_1 = \frac{\Delta_{11}}{\Delta} = \frac{1,494}{0,03667} = 40,74 \text{ V};$$

$$\varphi_2 = 0 \text{ V};$$

$$\varphi_3 = \frac{\Delta_{22}}{\Delta} = \frac{1,097}{0,03667} = 29,92 \text{ V};$$

$$\varphi_4 = \frac{\Delta_{33}}{\Delta} = \frac{0,68386}{0,03667} = 18,674 \text{ V}.$$

Tugundagi kuchlanishlar bo'yicha tarmoqdagi toklarni aniqlaymiz:
birinchi tarmoqdan o'tayotgan tok

$$I_1 = \frac{\varphi_4 - \varphi_3 + E_1}{R_1} = \frac{18,674 - 29,92 + 40}{9} = 3,192 \text{ A};$$

ikkinchi tarmoqdan o'tayotgan tok

$$I_2 = \frac{\varphi_2 - \varphi_1 + E_2}{R_2} = \frac{0 - 40,74 + 120}{12} = 6,605 \text{ A};$$

uchinchi tarmoqdan o'tayotgan tok

$$I_3 = \frac{\varphi_1 - \varphi_4}{R_3} = \frac{40,74 - 18,67}{4} = 5,523 \text{ A};$$

to'rtinchi tarmoqdan o'tayotgan tok

$$I_4 = \frac{\varphi_4 - \varphi_2}{R_4} = \frac{18,64 - 0}{8} = 2,331 \text{ A};$$

beshinchi tarmoqdan o'tayotgan tok

$$I_5 = \frac{\varphi_1 - \varphi_3}{R_5} = \frac{40,74 - 29,92}{10} = 1,082 \text{ A};$$

oltinchi tarmoqdan o'tayotgan tok

$$I_6 = \frac{\varphi_3 - \varphi_2}{R_6} = \frac{29,92 - 0}{7} = 4,274 \text{ A}.$$

4. Aniqlangan tarmoqdagi toklarning to'g'riligini Kirxgofning birinchi va ikkinchi qonunlari yordamida tekshiramiz.

1- tugun uchun $I_2 - I_3 - I_5 = 0$

$$6,605 - 5,523 - 1,082 = 0;$$

2- tugun uchun $-I_2 + I_4 + I_6 = 0$

$$-6,605 + 2,331 + 4,274 = 0;$$

3- tugun uchun $I_1 + I_5 - I_6 = 0$

$$3,192 + 1,082 - 4,274 = 0;$$

4- tugun uchun $-I_1 + I_3 - I_4 = 0$

$$-3,192 + 5,523 - 2,331 = 0.$$

I- kontur uchun. $I_1 \cdot R_1 - I_4 \cdot R_4 + I_6 \cdot R_6 = E_1;$

$$3,192 \cdot 9 - 2,331 \cdot 8 + 4,274 \cdot 7 = 40;$$

$$39,998 = 40$$

II- kontur uchun. $-I_2 \cdot R_2 - I_5 \cdot R_5 - I_6 \cdot R_6 = -E_2;$

$$-6,605 \cdot 12 - 1,082 \cdot 10 - 4,274 \cdot 7 = -120;$$

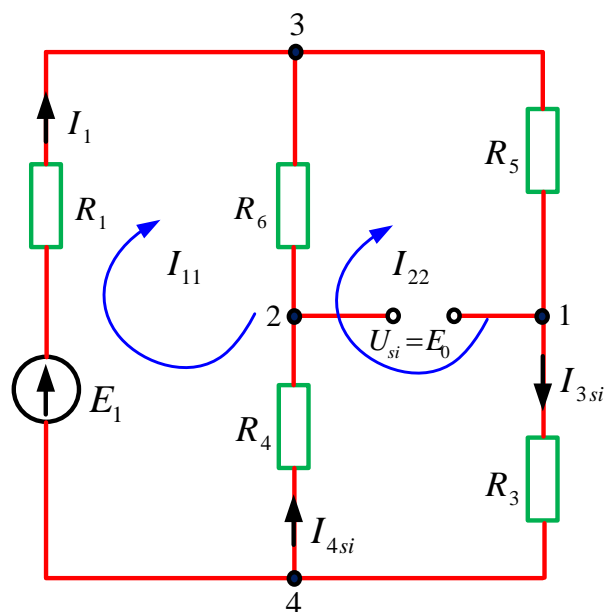
$$-119,998 = -120$$

III- kontur uchun. $I_2 \cdot R_2 + I_3 \cdot R_3 + I_4 \cdot R_4 = E_2;$

$$6.605 \cdot 12 + 5,523 \cdot 4 + 2,331 \cdot 8 = 120;$$

$$120 = 120;$$

5. Ekvivalent generator usuli yordamida ikkinchi tarmoqdagi tok kuchi I_2 ni aniqlaymiz.



1.16-rasm

Ekvivalent generator usuli yordamida ikkinchi tarmoqdagi tokni aniqlash uchun, 1.16-rasmda ko‘rsatilgan salt holat tokini aniqlaymiz:

$$I_2 = \frac{U_0 + E_1}{R_2 + R_{um}}$$

Kontur toklar usuli yordamida tenglamalar sistemasini tuzamiz:

$$\begin{cases} I_{11}(R_1 + R_6 + R_4) - I_{22}(R_6 + R_4) = E_1 \\ -I_{11}(R_6 + R_4) + I_{22}(R_6 + R_4 + R_3 + R_5) = 0 \end{cases}$$

Son qiymatlarini qo‘ysak:

$$I_{11} \cdot 24 - I_{22} \cdot 15 = 40$$

$$-15 \cdot I_{11} + 29 \cdot I_{22} = 0$$

bu yerda,

$$\Delta = \begin{vmatrix} 24 & -15 \\ -15 & 29 \end{vmatrix} = 24 \cdot 29 - (-15) \cdot (-15) = 471$$

$$\Delta_{11} = \begin{vmatrix} 40 & -15 \\ 0 & 29 \end{vmatrix} = 24 \cdot 29 - 15 \cdot 0 = 696$$

$$\Delta_{22} = \begin{vmatrix} 24 & 40 \\ -15 & 0 \end{vmatrix} = 24 \cdot 0 - (-15) \cdot 40 = 600$$

$$I_{11} = \frac{\Delta_{11}}{\Delta} = \frac{696}{471} = 1,47 \text{ A};$$

$$I_{22} = \frac{\Delta_{22}}{\Delta} = \frac{600}{471} = 1,27 \text{ A};$$

$$I_{3si} = I_{22} = 1,27 \text{ A}$$

$$I_{4si} = I_{11} - I_{22} = 1,47 - 1,27 = 0,2 \text{ A}$$

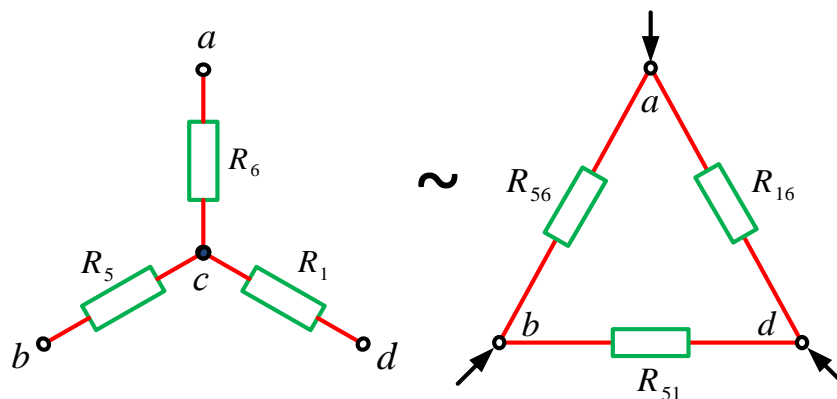
Salt holat kuchlanishini U_0 ni Kirxgofning ikkinchi qonuniga asosan aniqlaymiz:

$$U_0 + I_{3s.i.}R_3 - I_{4s.i.}R_4 = 0$$

yoki,

$$U_0 = -5,08 - 9,52 = 4,44 \text{ B}$$

Zanjirning qarshiligi R_{um} ni aniqlaymiz. Buning uchun “c” tugunga yulduz ulangan “a”, “b”, “d” tugunlarni, ekvivalent uchburchakka almashtiramiz (1.17-rasm):



1.17-rasm

Ekvivalent sxemaning qiymatlarini quyidagi tenglamadan topamiz:

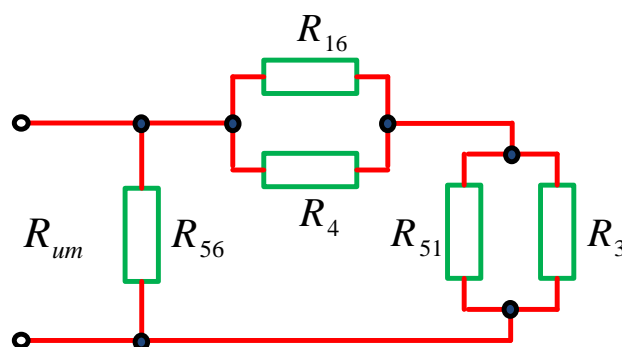
$$R_{56} = R_5 + R_6 + \frac{R_5 \cdot R_6}{R_1} = 17 + \frac{170}{9} = 36 \Omega$$

$$R_{51} = R_5 + R_1 + \frac{R_5 \cdot R_1}{R_6} = 19 + \frac{190}{7} = 46 \Omega$$

$$R_{16} = R_6 + R_1 + \frac{R_6 \cdot R_1}{R_5} = 16 + \frac{63}{10} = 17 \Omega.$$

Ekvivalent almashtirilgandan keyin ekvivalent sxema quyidagi ko‘rinishda bo‘ladi (1.18-rasm):

Demak, Ekvivalent qarshilik R_{um} quyidagiga teng:



1.18-rasm

$$R_{um} = \frac{\left(\frac{R_{16}R_4}{R_{16} + R_4} + \frac{R_{51}R_3}{R_{51} + R_3} \right) R_{56}}{\left(\frac{R_{16}R_4}{R_{16} + R_4} + \frac{R_{51}R_3}{R_{51} + R_3} \right) + R_{56}} = \frac{(5,44 + 3,68) \cdot 36}{5,44 + 3,68 + 36} = \frac{328,32}{45,12} = 7,28 \Omega$$

Endi I_2 tokni aniqlaymiz.

$$I_2 = \frac{U_0 + E_2}{R_2 + R_{um}} = \frac{4,44 + 120}{12 + 7,28} = 6,45 \text{ A}$$

Kontur toklar usulida topilgan I_2 toki bilan solishtirsak xatolik quyidagiga teng:

$$\gamma = \frac{6,6 - 6,45}{6,6} \cdot 100\% = \frac{0,15}{6,6} \cdot 100\% = 0,0227 \cdot 100\% = 2,3 \%$$

6. Quvvat muvozanati tenglamasini tuzamiz va hisoblash xatoligini aniqlaymiz.

Quvvat muvozanati tenglamasini tuzamiz:

$$P_m = E_1 \cdot I_1 + E_2 \cdot I_2 = 40 \cdot 3,19 + 120 \cdot 6,6 = 919,6 \text{ W}$$

$$P_{is} = I_1^2 \cdot R_1 + I_2^2 \cdot R_2 + I_3^2 \cdot R_3 + I_4^2 \cdot R_4 + I_5^2 \cdot R_5 + I_6^2 \cdot R_6 =$$

$$= 3,19^2 \cdot 9 + 6,6^2 \cdot 12 + 5,52^2 \cdot 4 + 2,33^2 \cdot 8 + 1,68^2 \cdot 10 + 4,27^2 \cdot 7$$

$$= 918,91 \text{ W.}$$

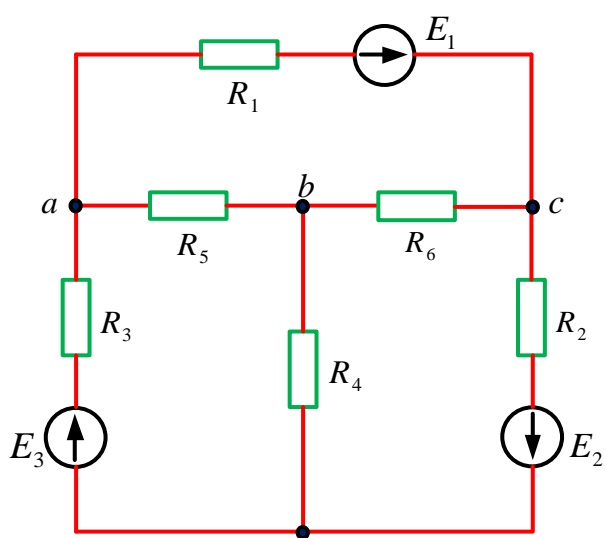
Hisoblashning xatoligi: $\gamma = \frac{919,6-918,91}{919,255} \cdot 100\% = 0,07 \%$.

1.1-jadval

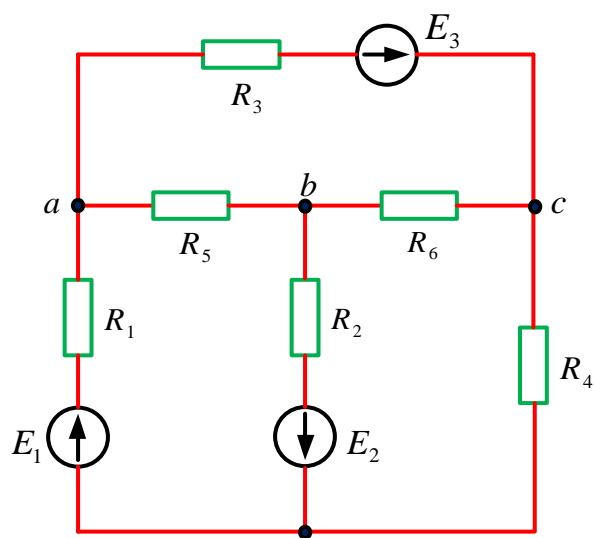
№	E ₁	E ₂	E ₃	R ₁	R ₂	R ₃	R ₄	R ₅	R ₆
	Volt			Ω					
1	60	40	20	5	8	6	10	12	4
2	70	110	40	4	5	8	6	10	12
3	80	90	100	12	4	5	8	6	10
4	90	100	80	10	12	4	5	8	6
5	100	80	60	6	10	12	4	5	8
6	110	70	90	8	6	10	12	4	5
7	120	60	80	12	4	8	10	7	9
8	40	120	60	9	12	4	8	10	7
9	50	110	80	7	9	12	4	8	10
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11	70	90	60	8	10	7	9	12	4
12	80	100	90	4	8	10	7	9	12
13	90	110	80	12	4	8	10	7	9
14	100	120	110	15	6	5	3	4	2
15	110	100	90	3	15	6	5	2	4
16	120	80	100	4	3	15	6	5	7
17	30	60	80	2	4	3	15	6	5
18	100	50	75	6	2	4	3	15	5
19	60	40	20	5	8	6	10	12	4
20	70	110	40	4	5	7	9	11	6
21	80	90	50	12	4	8	5	14	10
22	90	80	100	12	8	10	4	6	2
23	100	80	60	6	10	12	5	4	8
24	110	70	40	8	6	10	4	7	5
25	120	60	35	12	10	8	4	6	9

26	40	80	60	9	11	13	15	17	7
27	50	70	90	7	9	12	4	8	10
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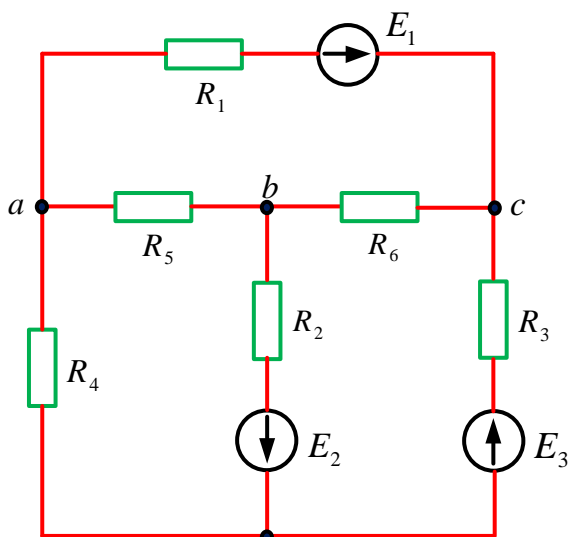
HISOB-GRAFIK ISHI SXEMALARI



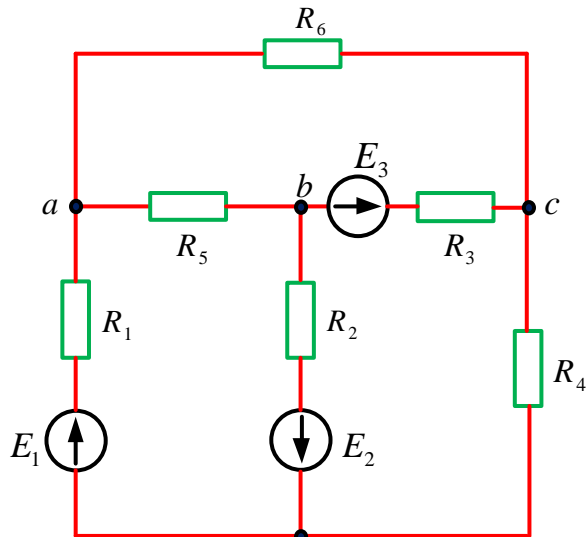
1-sxema



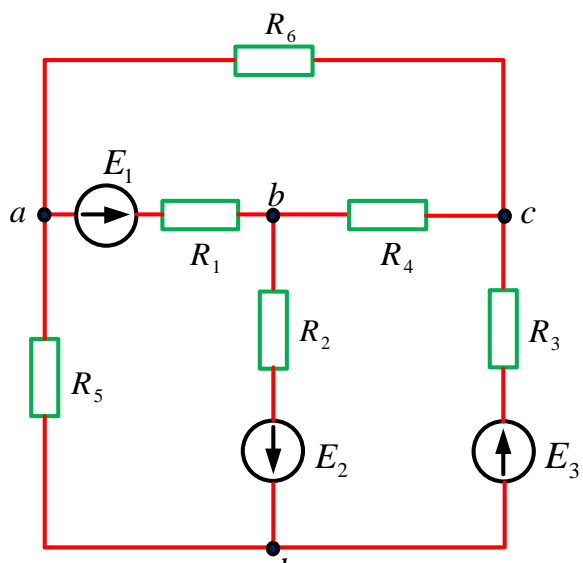
2-sxema



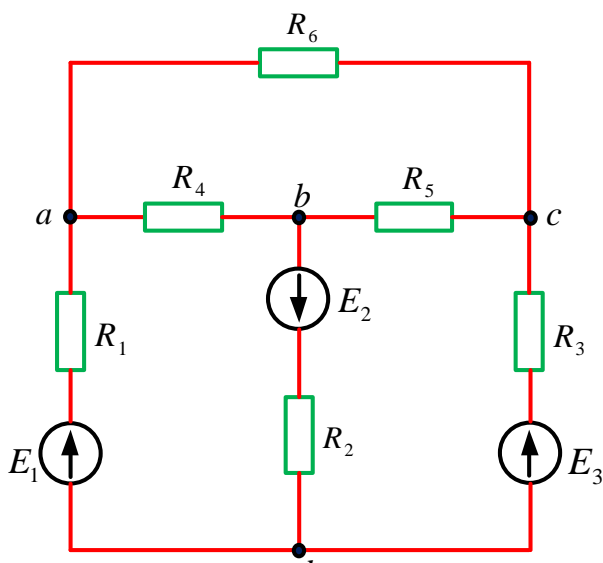
3-sxema



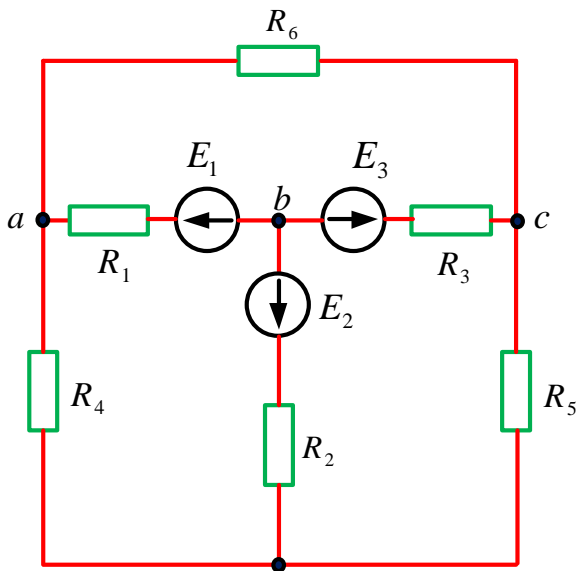
4-sxema



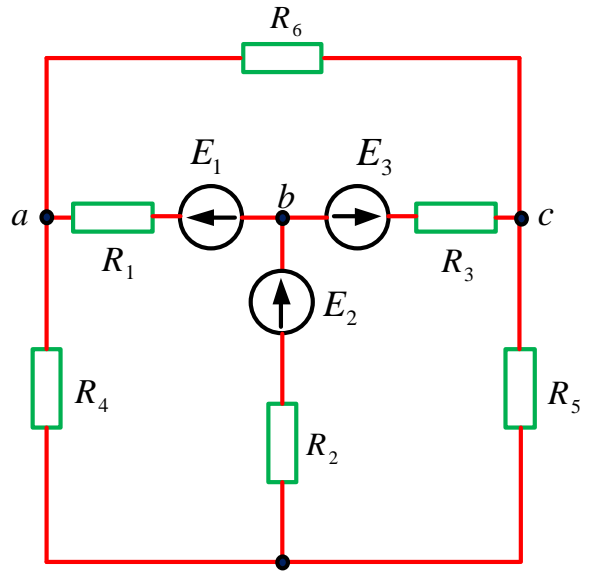
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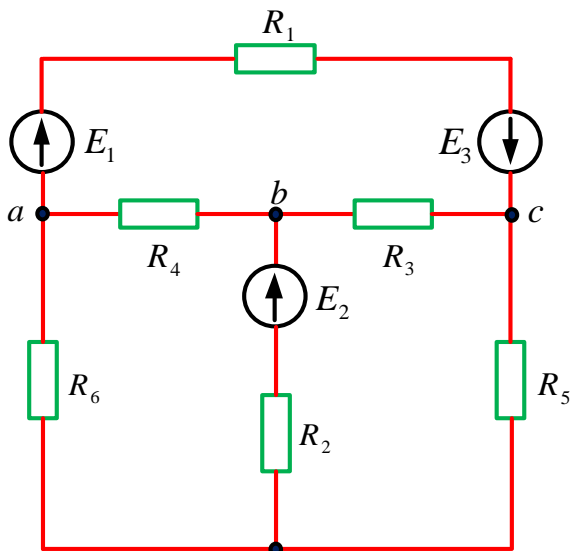
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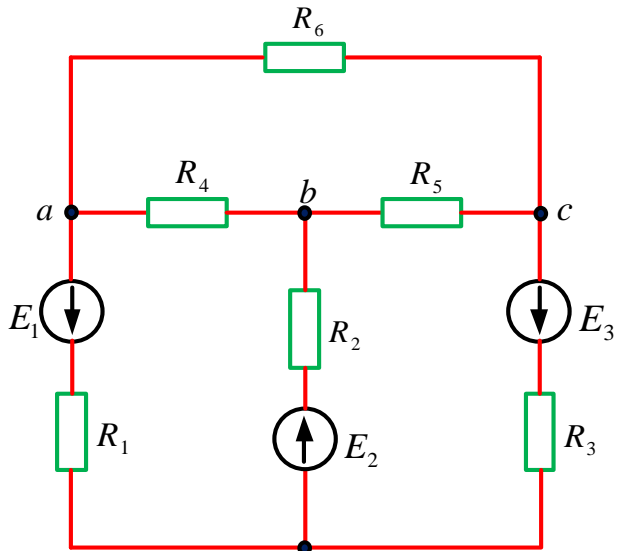
7-sxema



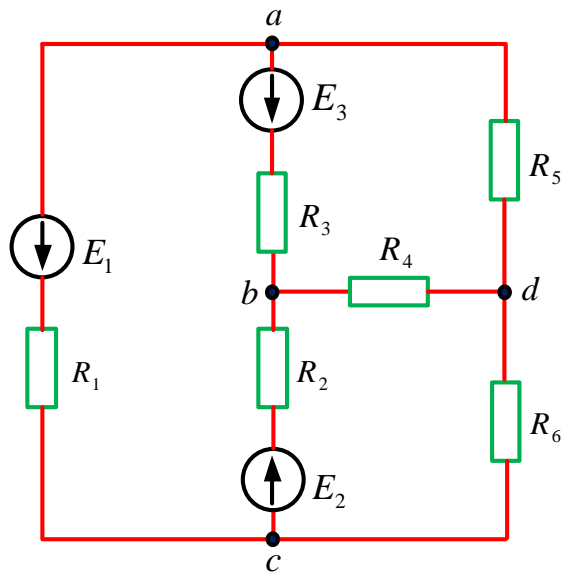
8-sxema



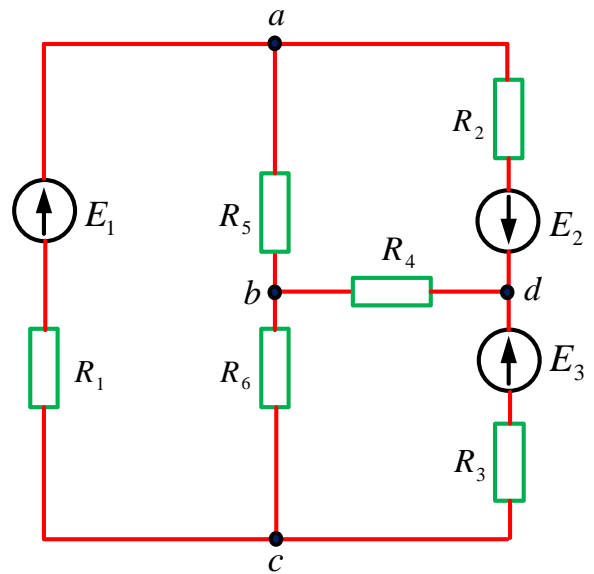
9-sxema



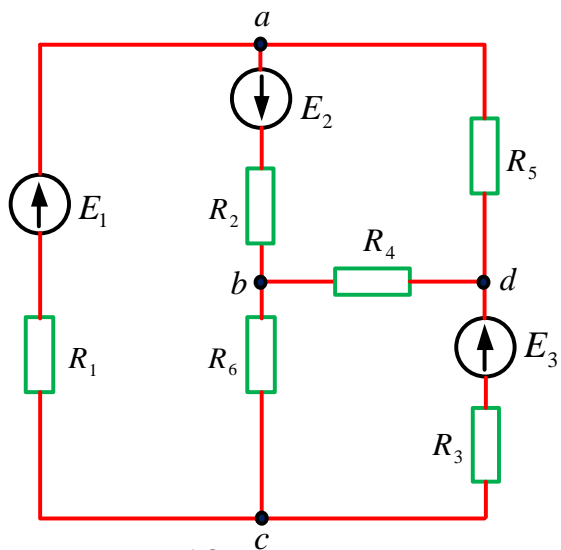
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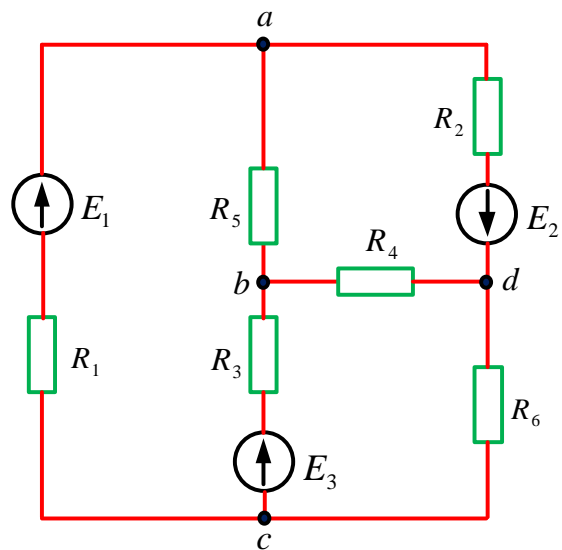
11-sxema



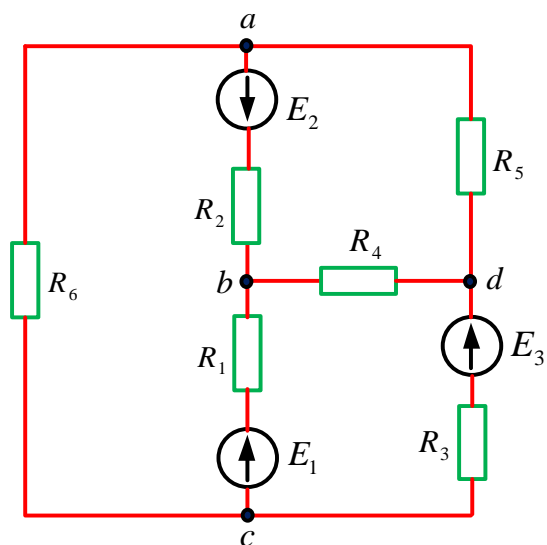
12-sxema



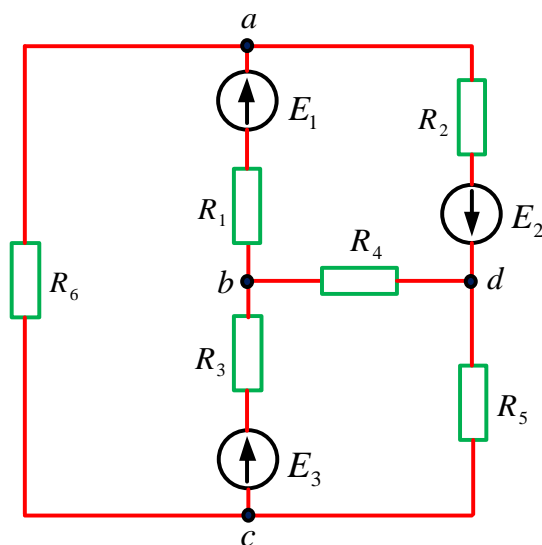
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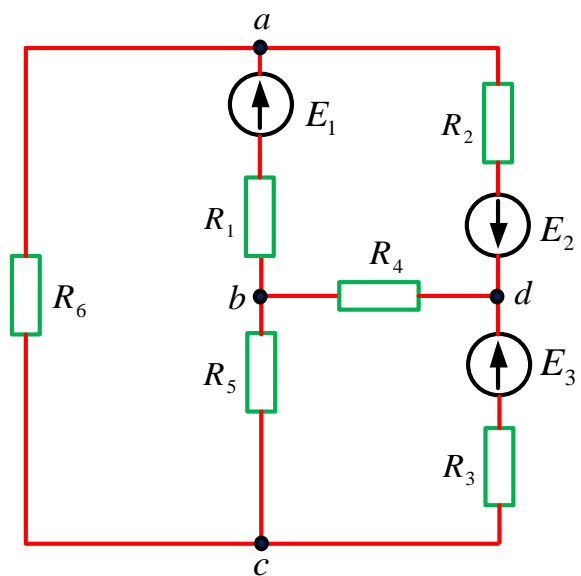
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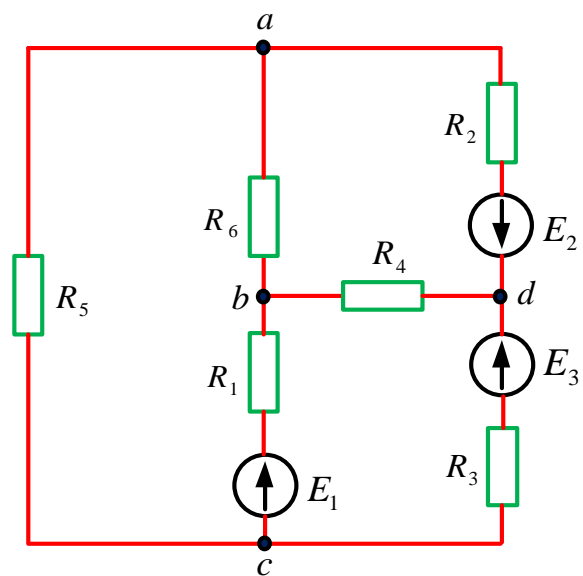
15-sxema



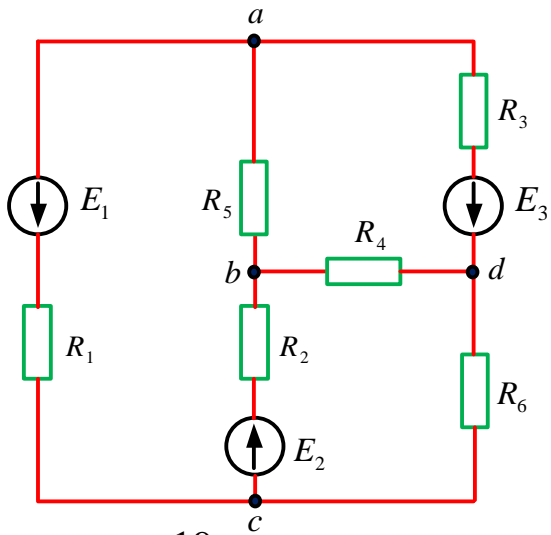
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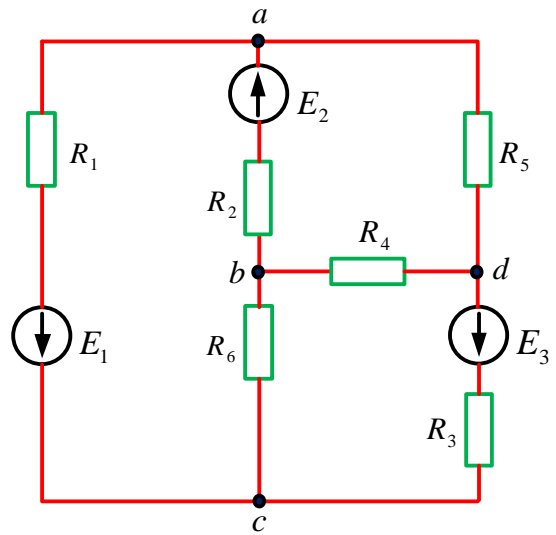
17-sxema



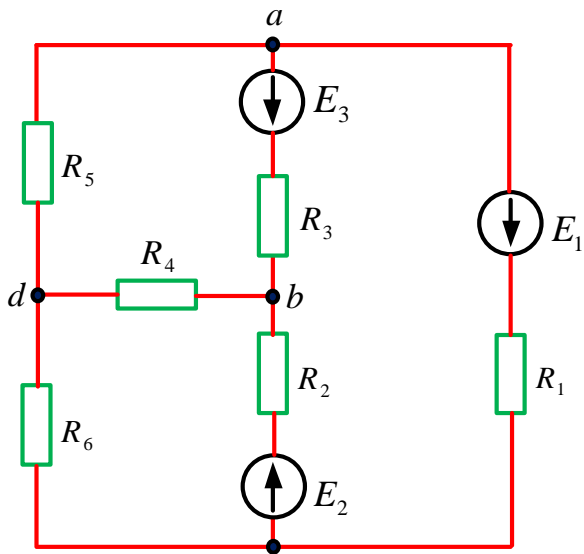
18-sxema



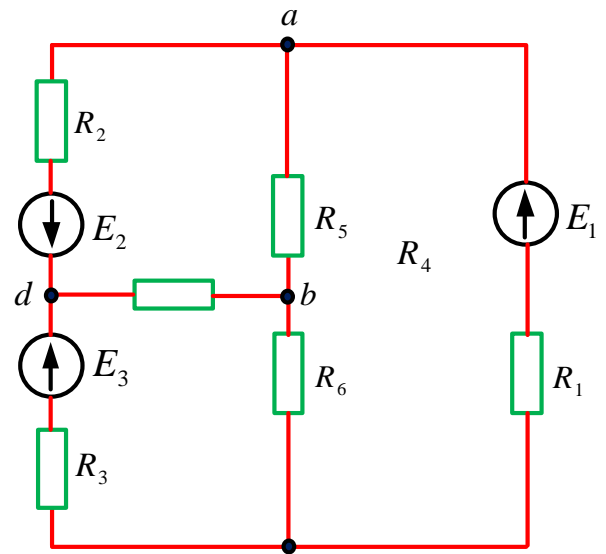
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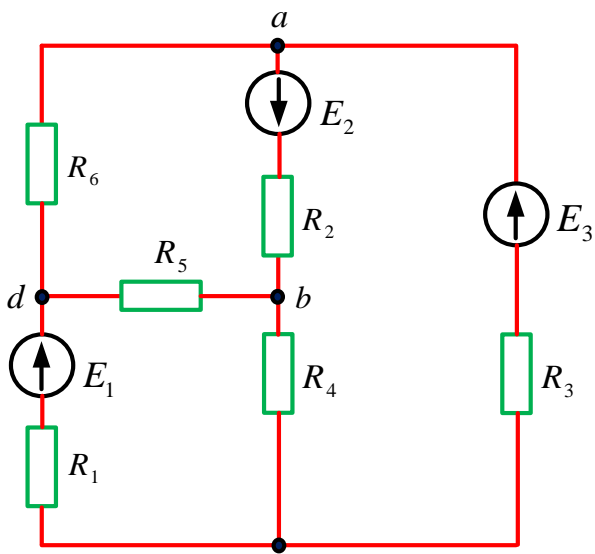
20-sxema



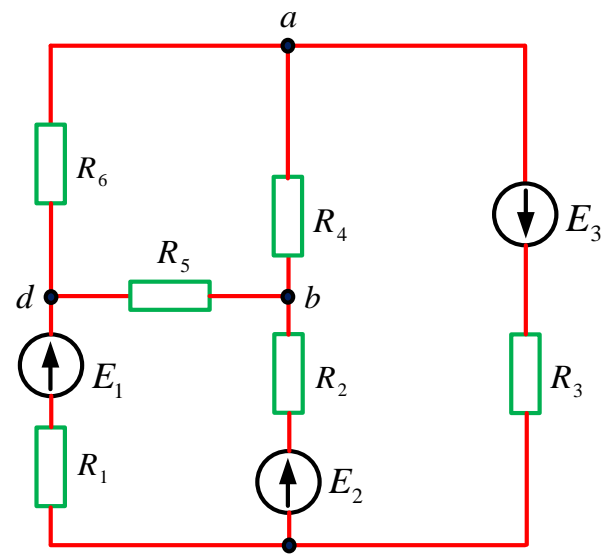
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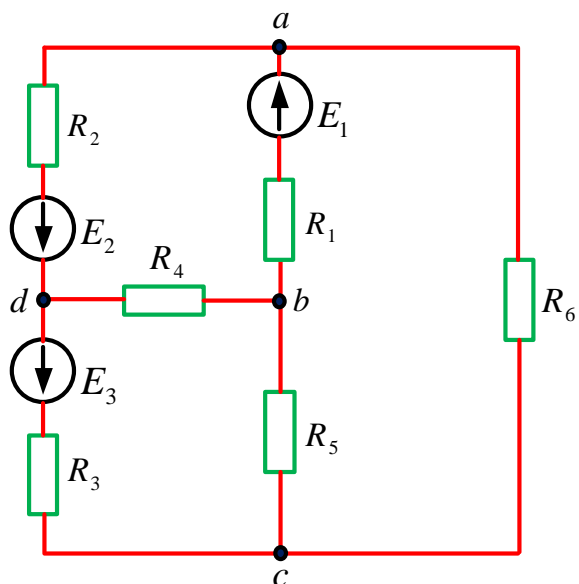
22-sxema



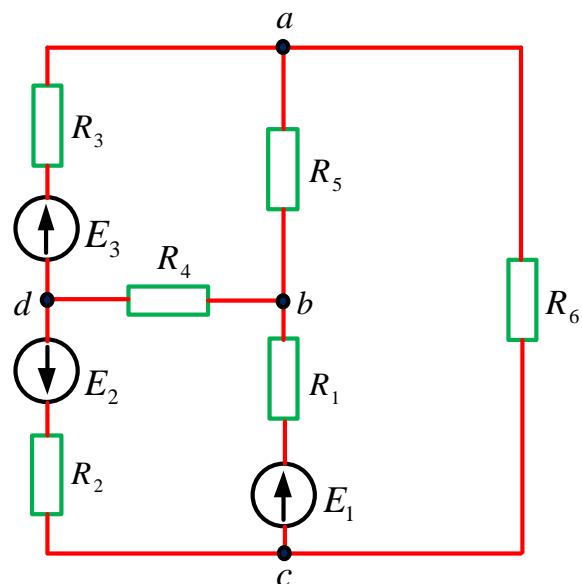
23-sxema



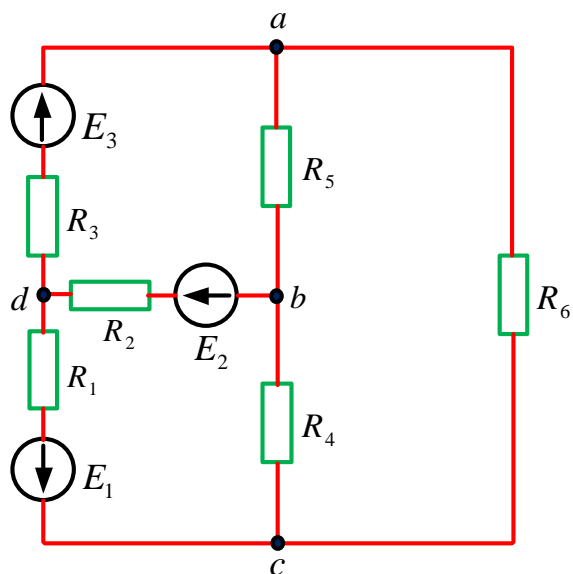
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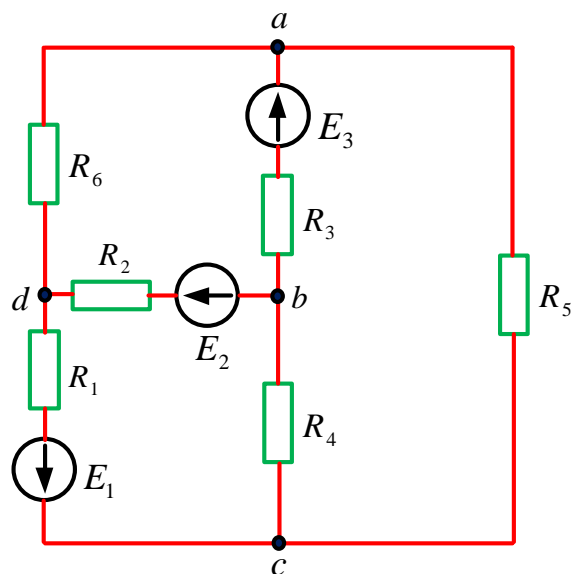
25-sxema



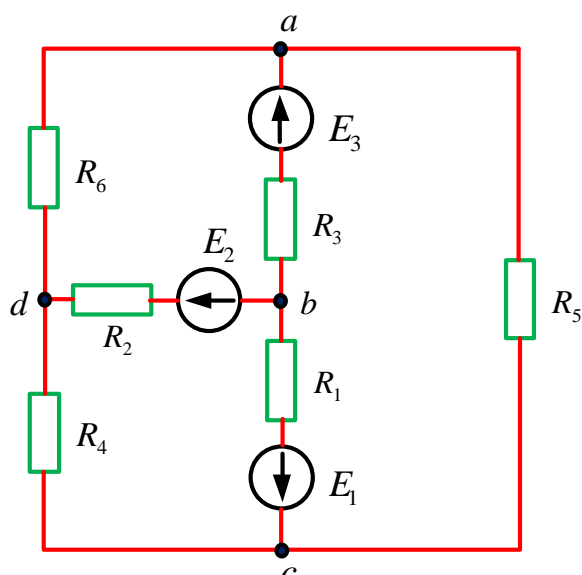
26-sxema



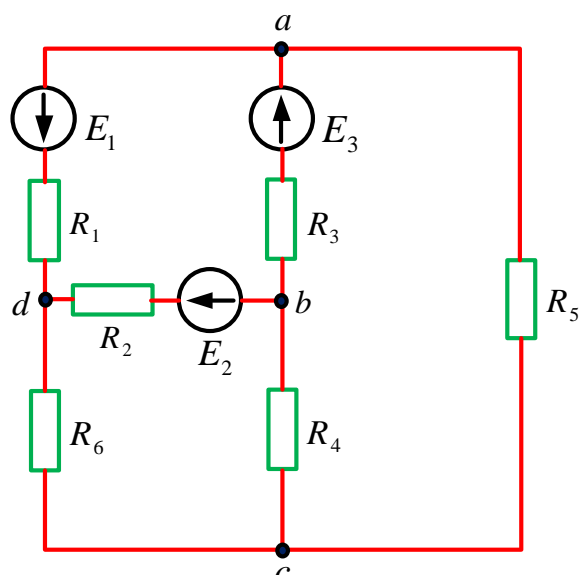
27-sxema



28-sxema



29-sxema



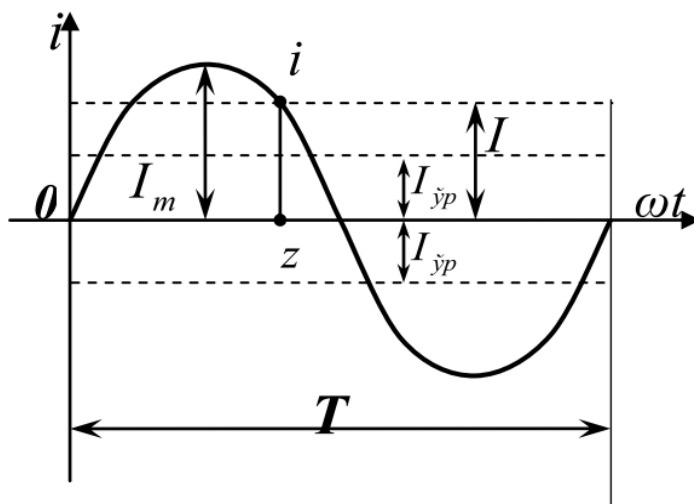
30-sxema

2. BIR FAZALI O‘ZGARUVCHAN TOK ELEKTR ZANJIRLARI

2.1. O‘zgaruvchan tok.

Yo‘nalishi va qiymati davriy ravishda o‘zgarib turadigan har qanday tok *o‘zgaruvchan tok* deyiladi.

Sinusoidal qonun bo‘yicha o‘zgaradigan EYuK, kuchlanish va toklar *sinusoidal o‘zgaruvchan kattaliklar* hisoblanadi.



2.1-rasm

$$i = I_m \sin(\omega t + \varphi_i), u = U_m \sin(\omega t + \varphi_u), e = E_m \sin(\omega t + \varphi_e)$$

i - sinusoid o‘zgaruvchan tokning oniy qiymati;

I_m - amplituda yoki maksimal qiymat;

U_m - amplituda yoki maksimal qiymat;

ω - burchak chastota – (*rad/sek*);

φ_i – tokning boshlangich fazasi – (*grad*);

φ_u – kuchlanishning boshlangich fazasi – (*grad*);

f – chastota – (*Hz*);

T – davr – (*sek*);

Davr T – bu muayyan vaqt oralig‘i bo‘lib, tokning o‘zgarishi takrorlanadi, ya’ni to‘liq bitta to‘lqin o‘zgarishi kuzatiladi. Bir sekunddagi davrlar soni chastota f deb ataladi. $f = \frac{1}{T}$

$\omega = 2\pi f = \frac{2\pi}{T}$ -o‘zgaruvchan tokning burchak chastotasi. Sinusning argumenti, ya'ni $(\omega t + \varphi_i)$ kattalik faza deb ataladi.

2.2. Sinusoidal o'zgaruvchan funksiyaning ta'sir etuvchi va o'rtacha qiymatlari.

Sinusoidal o'zgaruvchan tokning ta'sir etuvchi qiymati uning maksimal qiymatidan $\sqrt{2}$ marta kichikdir.

$$I = \frac{I_m}{\sqrt{2}} \quad (2.1)$$

Yuqoridagi o'xshash yo'l bilan sinusoidal o'zgaruvchan EYuK va kuchlanishlarning ham ta'sir etuvchi qiymatlarini yoza olamiz:

$$E = \frac{E_m}{\sqrt{2}} \quad (2.2)$$

$$U = \frac{U_m}{\sqrt{2}}. \quad (2.3)$$

Sinusoidal tokning o'rtacha qiymati musbat yarim davrdagi oniy toklar yig'indisining o'rtacha arifmetik qiymatiga teng.

$$E_{o'r} = \frac{2E_2}{\pi} = 0,636E_m; \quad (2.4)$$

$$U_{o'r} = \frac{U_m}{\pi} = 0,636U_m. \quad (2.5)$$

Sinusoidal miqdor amplitudasining uning effektiv qiymatiga nisbati *amplituda koeffitsiyenti* deb ataladi.

$$k_a = \frac{I_m}{I} = \sqrt{2} \quad (2.6)$$

Tokning effektiv qiymatini o'rtacha qiymatiga nisbati $\frac{I}{I_{o'r}}$ sinusoidal shaklining egriligi, ya'ni *shakl(forma) koeffitsiyenti* k_f ni ifodalaydi:

$$k_f = \frac{I}{I_{o'r}} = \frac{\pi}{2\sqrt{2}} = 1,11 \quad (2.7)$$

2.3. Sinusoidal o'zgaruvchan kattaliklarni aylanuvchan vektorlar yordamida ifodalash.

Vektorlar diagrammalarni tuzishda va unga o'tishda quyidagilarga rioya qilinishi kerak:

1)vektorlarga faqat bir xil ω chastotali sinusoidal kattaliklar bo'lgandagina o'tish mumkin;

2)vektorli ifodaga vaqt $t = 0$ da o'tiladi, barcha tegishli hisoblashlarni ω chastotani hisobga olmasdan bajarish mumkin, chunki vektorlar aylanganda ularning o'zaro joylashishi o'zgarmaydi;

3) sinusoidal kattaliklarning soni birdan ortiq bo'lganda ulardan qaysi birini boshlang'ich vektor (yoki faza) uchun qabul qilish ixtiyoriy, ammo qolgan vektorlar boshlang'ich vektorga nisbatan fazalar farqiga ko'ra joylashish kerak;

4) sinusoidal kattaliklar vektorlari yo'nalishlarining o'zgarishi nazariy mexanikadagi kabi fazoviy bo'lmasdan, vaqtga qarab o'zgaradi. Ammo ularni qo'shish va ayirish oddiy vektorlar kabi bajariladi. Ularning modullari tegishli amplituda qiymatlarni ifodalasa, yo'nalishlari orasidagi burchaklar esa berilgan sinusoidal kattaliklarning (vaqt bo'yicha) faza siljishini ifodalaydi;

5) boshlang'ich fazasi musbat bo'lgan vektor koordinata boshida soat mili harakatiga teskari yo'nalishda, manfiysi esa soat milining harakati yo'nalishida qo'yilishi kerak;

Umuman, vektor diagramma, deb to'g'ri burchakli koordinatalar sistemasida bir-birlariga nisbatan to'g'ri oriyentatsiyalarda qurilgan, turli amplituda va boshlang'ich fazaga ega bo'lgan bir xil chastotadagi sinusoidal miqdorlarni xarakterlovchi vektorlar yig'indisiga aytiladi.

2.1-masala. Sinusoidal bo'lgan $u_1 = 30 \sin \omega t$, $u_2 = 40 \sin(\omega t + 90^\circ)$ va $u_3 = 20 \sin(\omega t - 45^\circ)$ kuchlanishlarning berilgan qiymatlari bo'yicha vektor diagrammasini tuzib, zanjirdagi umumiy kuchlanishning o'zgarish qonuniyati aniqlansin.

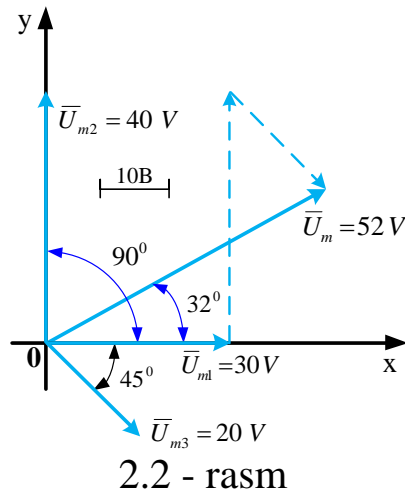
Yechilishi: $u_1 = 30 \sin \omega t$ ning boshlang'ich fazasi $\Psi_1 = 0$ bo'lgani uchun uning yo'nalishi absissalar o'qining musbat yo'nalishiga mos bo'lib, vektor diagrammada U_{m_1} bilan ifodalangan (2.2-rasm).

Kuchlanish $u_2 = 40 \sin(\omega t + 90^\circ)$ ning boshlang'ich fazasi $\Psi_2 = 90^\circ$ bo'lgani uchun u kuchlanish u_1 dan faza bo'yicha 90° ilgari keladi. Shuning uchun vektor U_{m_2} vektor U_{m_1} ga nisbatan soat milining harakatiga teskari yo'nalishda 90° ga burilgan bo'ladi. $u_3 = 20 \sin(\omega t - 45^\circ)$ ning boshlang'ich fazasi $\Psi_3 = -45^\circ$ bo'lgani uchun u u_1 dan faza bo'yicha 45° kechikadi. Shuning uchun vektor U_{m_3} vektor U_{m_1} ga nisbatan soat milining harakat yo'nalishi bo'yicha 45° ga burilgan bo'ladi.

Endi uchala vektorni o'zaro qo'shib umumiy kuchlanishning amplituda qiymati $U_m = U_{m_1} + U_{m_2} + U_{m_3}$ ni aniqlaymiz.

U_m ning vektor diagrammadagi uzunligini tanlangan masshtab ($m_U = 1V/mm$) ga ko‘paytirish orqali uning qiymatini aniqlaymiz:

$$U_m = l_{U_m} \cdot m_U = 52mm \cdot \frac{1V}{mm} = 5V.$$



Endi transportir yordamida U_m absissalar o‘qi orasidagi burchakni o‘lchaymiz. Mazkur burchak zanjirdagi umumiy kuchlanishning faza siljishi burchagi bo‘lib, $\Psi + 32^\circ$ ga teng. U holda zanjirda umumiy kuchlanishning o‘zgarish qonuniyati quyidagicha ifodalanadi:

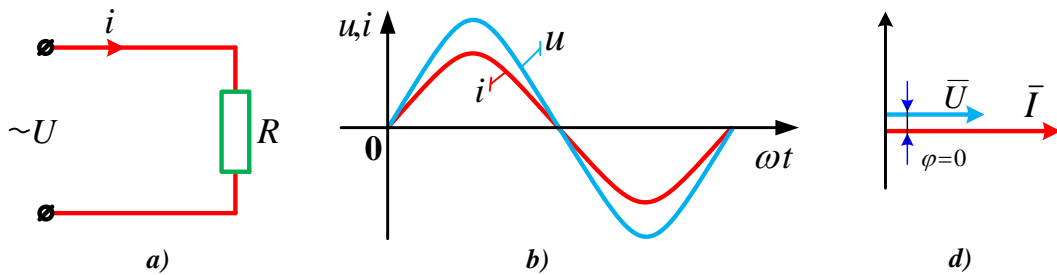
$$u = 52 \sin(\omega t + 32^\circ) V.$$

2.4. Aktiv qarshilik, induktiv g‘altak va kondensator ulangan o‘zgaruvchan tok zanjirlari.

Umumiy tushunchalar. Elektr manбайдan iste‘mol qilinayotgan energiya issiqlik energiyasiga aylanadigan zanjir elementi aktiv element, uning qarshiligi aktiv qarshilik (R), undagi quvvat esa aktiv quvvat (P) deyiladi. Reaktiv qarshiliklar (induktiv- X_L , sig‘imi- X_C), ulardagi quvvatlar esa reaktiv quvvatlar (induktiv- Q_L , sig‘imi- Q_C) deyiladi.

R, L, C parametrlarning har biri o‘zgaruvchan tok zanjiriga yakka holda qanday ta’sir etishini ko‘rib chiqamiz.

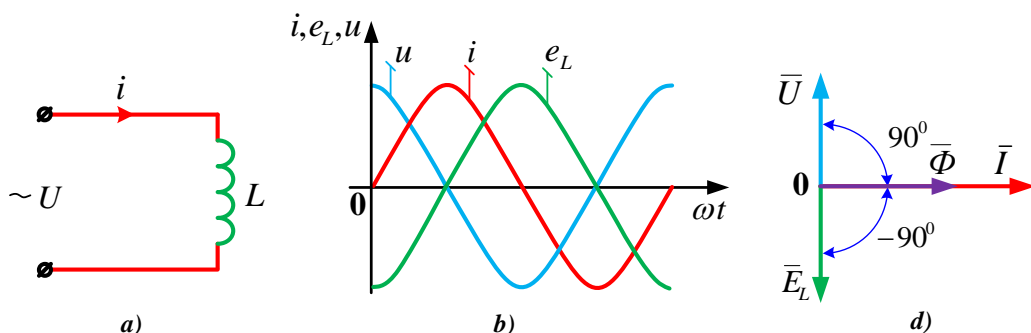
Aktiv qarshilik ulangan o‘zgaruvchan tok zanjiri



2.3 – rasm.

$$i = \frac{u}{R} = \frac{U_m \sin \omega t}{R} = I_m \sin \omega t \quad (2.8)$$

Induktiv g'altak ulangan o'zgaruvchan tok zanjiri.



2.4 – rasm.

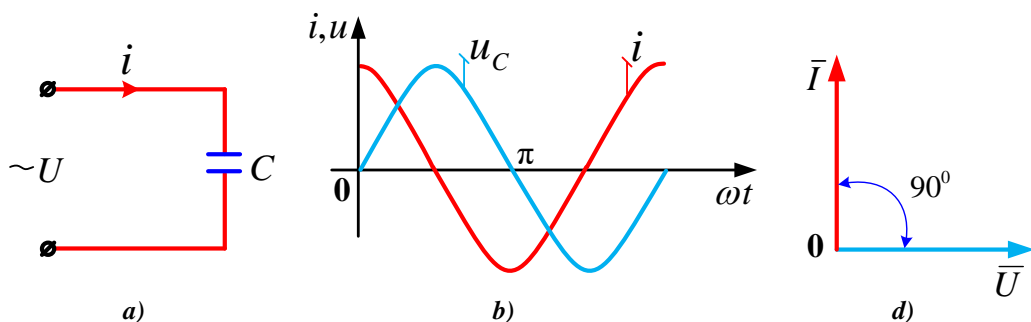
$$i = I_m \sin \omega t$$

$$e_L = -L \frac{di}{dt} = -\omega L I_m \cos \omega t = -E_m \sin(\omega t + 90^\circ).$$

$$u_L = -e_L = \omega L I_m \sin(\omega t + 90^\circ) = U_m \sin(\omega t + 90^\circ).$$

$$X_L = \omega L = 2\pi f L [\Omega]. \quad (2.9)$$

Kondensator ulangan o'zgaruvchan tok zanjiri.



2.5 - rasm

$$i = \frac{dq}{dt} = \frac{d}{dt}(CU_m \sin \omega t) = I_m \sin(\omega t + 90^\circ)$$

$$u = U_m \sin \omega t$$

$$X_C = \frac{1}{\omega C} = \frac{1}{2\pi f C} \quad (2.10)$$

2.5. Aktiv va reaktiv qarshiliklari o‘zaro ketma-ket ulangan zanjir.

Elementlari (R, L, C) o‘zaro ketma-ket ulangan zanjirga (2.6 a -rasm) berilgan kuchlanish uchta tashkil etuvchidan iborat:

Kirxgofning ikkinchi qonuniga binoan quyidagicha ifodalanadi:

$$u = u_R + u_L + u_C. \quad (2.11)$$

(2.11) ifodaga binoan zanjirdagi kuchlanishning o‘zgarishi:

$$u = U_{R_m} \sin \omega t + U_{L_m} \sin(\omega t + 90^\circ) + U_{C_m} \sin(\omega t - 90^\circ) =$$

$$= U_m \sin(\omega t \pm \varphi). \quad (2.12)$$

Aktiv va reaktiv qarshiliklari o‘zaro ketma-ket ulangan zanjirning vektor diagrammasi 2.6-rasm, b va d da ko‘rsatilgan.

Mazkur vektorlar diagrammasidan ko‘rinadiki, zanjirga berilgan kuchlanishning qiymati uning ayrim qismlaridagi kuchlanishlarning geometrik yig‘indisiga teng, ya’ni:

$$\bar{U} = \bar{U}_R + \bar{U}_L + \bar{U}_C. \quad (2.13)$$

Vektor diagramma qurish natijasida hosil bo‘lgan kuchlanishlar uchburchagi OAB dan esa kuchlanishlarning absolyut qiymatlarini aniqlanish mumkin:

$$U = \sqrt{U_R^2 + (U_L - U_C)^2} = I\sqrt{R^2 + (X_L - X_C)^2}. \quad (2.14)$$

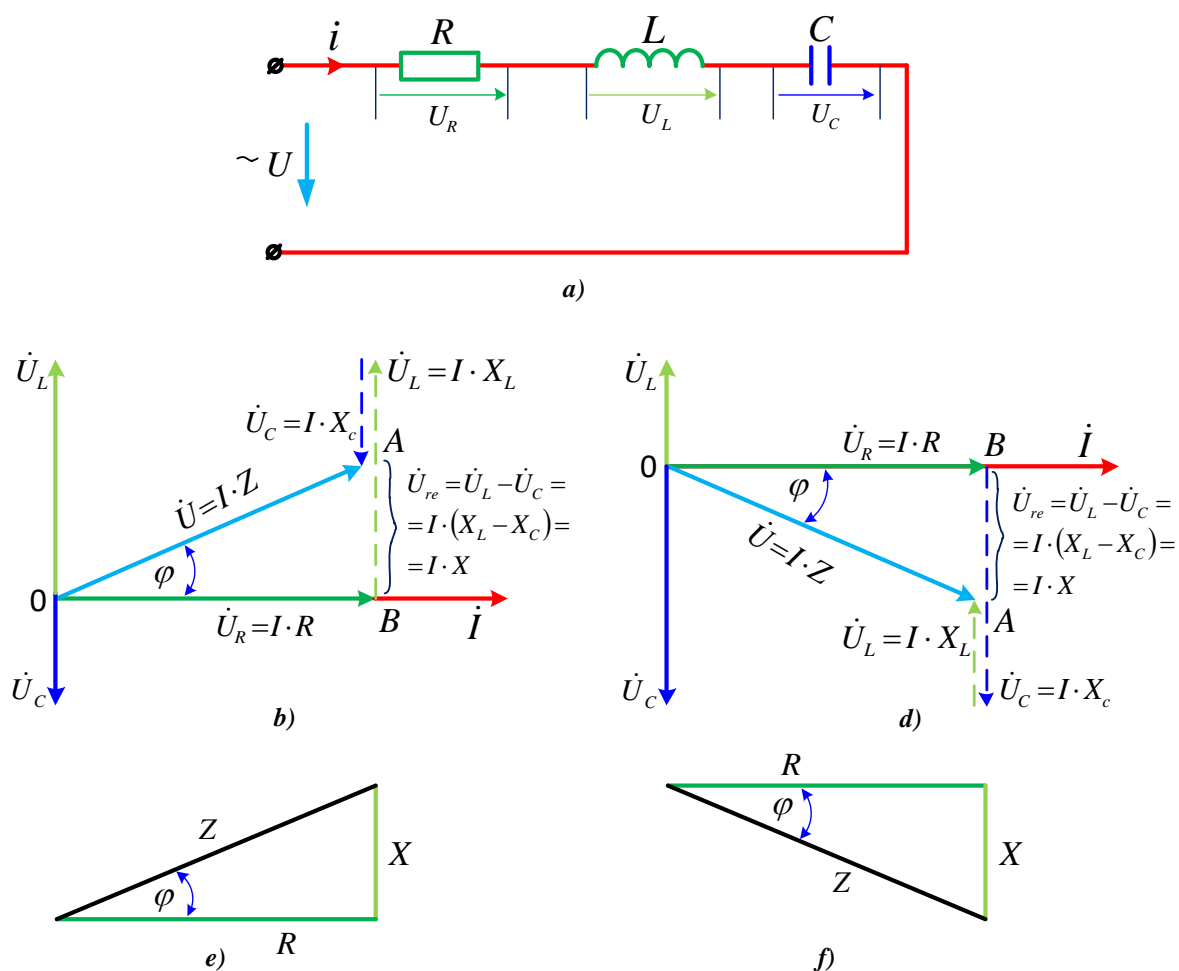
Shunday qilib, berilgan zanjir uchun Om qonunining ifodasi:

$$I = \frac{U}{\sqrt{R^2 + (X_L + X_C)^2}} = \frac{U}{\sqrt{R^2 + X^2}} = \frac{U}{Z}, \quad (2.15)$$

Bu yerda Z - zanjirning to‘la qarshiligi, Ω , X - zanjirning reaktiv qarshiligi, Ω .

Kuchlanishlar uchburchagining uchala tomonini tok I ga bo‘lib, qarshiliklar uchburchagini hosil qilamiz (2.6 e va f-rasm). Bu uchburchakdan foydalanib, quyidagi nisbatlarni yozish mumkin:

$$R = Z \cdot \cos \varphi, X = Z \cdot \sin \varphi, \tan \varphi = \frac{X}{R}, \varphi = \arctg \frac{X}{R}.$$



2.6 – rasm.

2.6. Aktiv va reaktiv qarshiliklari o‘zaro parallel ulangan zanjir.

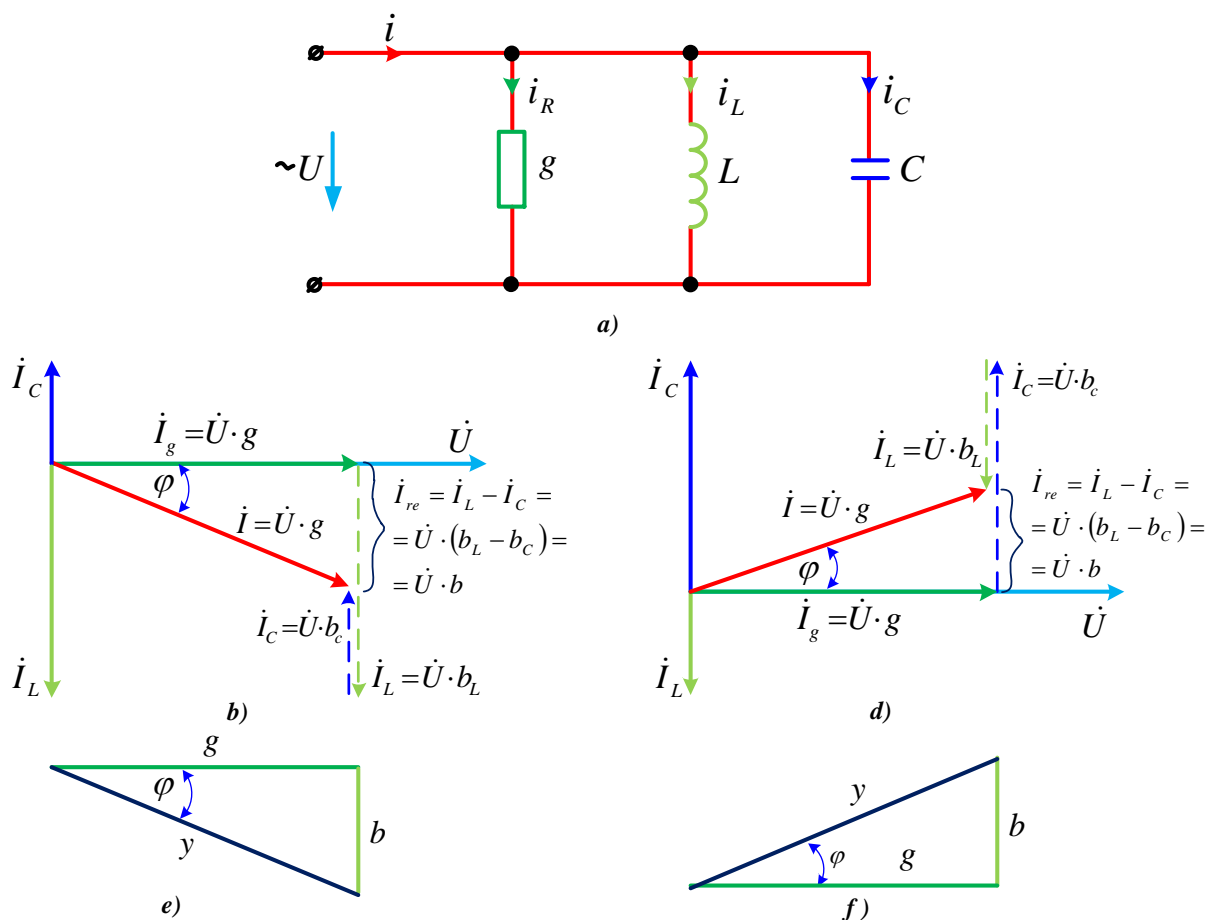
Elementlari (R, L, C) o‘zaro parallel ulangan zanjirga, tarmoqlangan o‘zgaruvchan tok zanjirida (2.7 a -rasm) o‘tkazuvchanlik uch turga bo‘linadi: aktiv o‘tkazuvchanlik $g = \frac{1}{R}$; reaktiv o‘tkazuvchanlik $b = b_L - b_C$ (bu yerda $b_L = \frac{1}{\omega L}$ induktiv, $b_C = \omega C$ sig‘im o‘tkazuvchanligi); to‘la o‘tkazuvchanlik $Y = \sqrt{b^2 + g^2}$. Barcha o‘tkazuvchanliklar simensda o‘lchanadi va qisqacha [sm] deb belgilanadi.

Kirxgofning birinchi qonuniga binoan zanjirdagi tok (yoki umumiy tok):

$$i = i_g + i_L + i_C. \quad (2.16)$$

U holda elementlari parallel ulangan zanjirdagi umumiy tokning o‘zgarishi:

$$\begin{aligned}
 i &= i_g + i_L + i_C = gu + \frac{1}{L} \int u dt + C \frac{du}{dt} = \\
 &= gU_m \sin \omega t - \frac{U_m}{\omega L} \cos \omega t + \omega C U_m \cos \omega t = I_{gm} \sin \omega t - \\
 &- I_{Lm} \sin(\omega t - 90^\circ) + I_{Cm} \sin(\omega t + 90^\circ) = I_m \sin(\omega t - \varphi), \quad (2.17)
 \end{aligned}$$



2.7 – rasm.

Aktiv va reaktiv qarshiliklari o‘zaro parallel ulangan zanjirning vektor diagrammasi 2.7 b va d -rasmida ko‘rsatilgan.

Mazkur vektorlar diagrammasidan ko‘rinadiki, zanjirdagi umumiy tok parallel shoxobchalardagi toklarning geometrik yig‘indisiga teng:

$$I = I_g + I_L + I_C. \quad (2.18)$$

Vektor diagrammani qurish natijasida hosil bo‘lgan toklar uchburchagidan

$$I = \sqrt{I_g^2 + (I_L - I_C)^2} = U \sqrt{g^2 + (b_L - b_C)^2}. \quad (2.19)$$

Berilgan zanjir uchun Om qonunining ifodasi:

$$I = U \sqrt{g^2 + (b_L - b_C)^2} = U \sqrt{g^2 + b^2} = U \cdot Y. \quad (2.20)$$

Toklar uchburchagining uchala tomonining kuchlanishi U ga bo‘lib, o‘tkazuvchanliklar uchburchagini hosil qilamiz (2.7 e va f-rasm). O‘tkazuvchanliklar uchburchagidan quyidagi nisbatlarni yozish mumkin:

$$g = Y \cdot \cos \varphi; \quad b = Y \cdot \sin \varphi; \quad \tan \varphi = \frac{b}{g_n}$$

2.7. O‘zgaruvchan tok zanjirining quvvati va quvvat koeffitsiyenti.

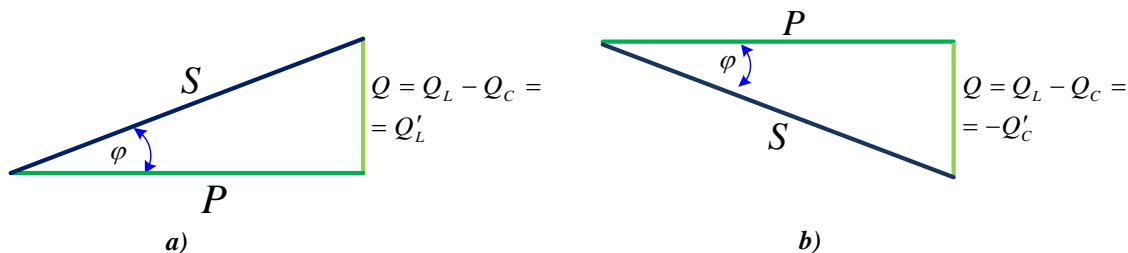
Quvvatlar uchburchagi (2.8 a va b -rasm). Mazkur uchburchakning tomonlari esa quyidagilarni bildiradi:

$$P = U_k \cdot I = I^2 \cdot R - \text{zanjirning aktiv quvvati};$$

$$Q = U_x \cdot I = I^2 \cdot X - \text{zanjirning reaktiv quvvati};$$

$$S = U \cdot I = I^2 \cdot Z - \text{zanjirning to‘la quvvati};$$

$$\cos \varphi = P/S - \text{zanjirning quvvat koeffitsiyenti.}$$



2.8 – rasm.

Shuningdek, quvvatlar uchburchagidan foydalanib, va ular o‘rtasidagi bog‘lanishlarni aniqlash mumkin:

$$P = S \cdot \cos \varphi = UI \cos \varphi; \quad (2.21)$$

$$Q = S \cdot \sin \varphi = UI \sin \varphi; \quad (2.22)$$

$$S = \sqrt{P^2 + Q^2} = U \cdot I. \quad (2.23)$$

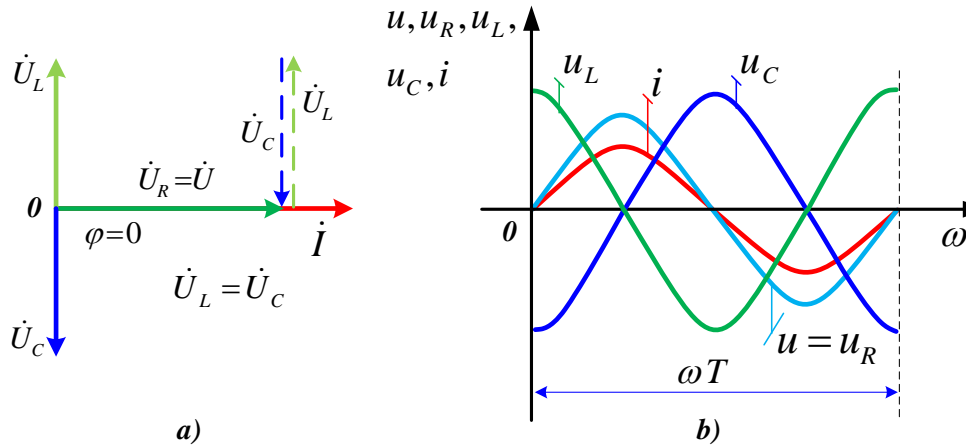
SI sistemasida aktiv quvvat vatt (W) yoki kilovatt (kW), reaktiv quvvat volt-amper reaktiv (VAr) yoki kilovolt-amper reaktiv ($kVAr$), to‘la quvvat volt-amper (VA) yoki kilovolt-amper (kVA) birliklarda ulanadi.

Aktiv quvvat ifodasidan ko‘paytiruvchi $\cos \varphi$ **quvvat koeffitsiyenti** deb ataladi.

$$\cos \varphi = \frac{P}{UI} = \frac{P}{S} \quad (2.24)$$

2.8. Kuchlanishlar rezonansi.

Kuchlanishlar rezonansi xodisasi R, L, C elementlari o`zaro ketma-ket ulangan o`zgaruvchan tok zanjirida xosil bo`lishi mumkin (2.6 a- rasm). Bunda reaktiv elementlar qarshiliklarining o`zaro teng ($X_L = X_C$) bo`lishi rezonans sharti hisoblanadi.



2.9 – rasm.

Rezonans paytida zanjirning reaktiv quvvati nolga teng, ya'ni $Q = Q_L - Q_C = U_L \cdot I - U_C \cdot I = 0$ bo'ladi, chunki $U_L = U_C$.

$$X_L = \omega L = 2\pi f L \text{ va } X_C = \frac{1}{\omega C} = \frac{1}{2\pi f C} \quad (2.25)$$

Kuchlanishlar rezonansi shartiga ko'ra:

$X = \omega L - \frac{1}{\omega C} = 0$ yoki $\omega L = \frac{1}{\omega C}$ ya'ni, reaktiv elementlarning qarshiliklari o'zaro teng ($x_L = x_C$) bo'ladi.

Bunda $\omega = \frac{1}{\sqrt{LC}}$ chastota **rezonans chastotasi** deyiladi.

Rezonans rejimida zanjirning to'la qarshiligi minimal bo'lib, aktiv qarshilikka teng bo'ladi:

$$Z = \sqrt{r^2 + (x_L - x_C)^2} = r. \quad (2.26)$$

Zanjirdagi tok bu paytda maksimal qiymatga erishadi:

$$I = \frac{U}{Z} = \frac{U}{r}. \quad (2.27)$$

r qarshilikdagi kuchlanish pasayishi manba kuchlanishiga teng bo'ladi:

$$U_r = Ir = U. \quad (2.28)$$

ρ - rezonansli ketma-ket ulangan zanjirning (tebranish konturining) to'liq qarshiligi deyiladi

$$\rho = \sqrt{\frac{L}{C}} \quad (2.29)$$

Q – rezonansli ketma-ket ulangan zanjirning asillik koeffitsiyenti deyiladi

$$Q = \frac{\rho}{R} \quad (2.30)$$

d – rezonansli ketma-ket ulangan zanjirning asillik koeffitsiyenti deyiladi

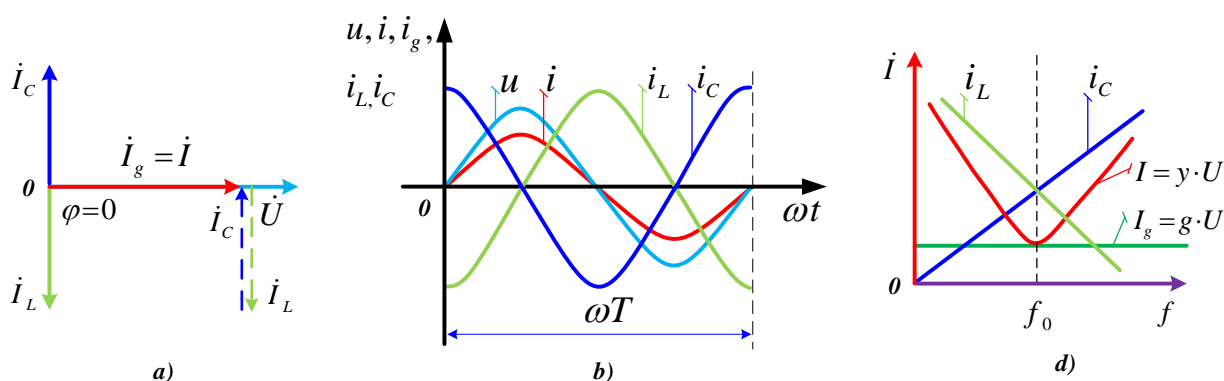
$$d = \frac{1}{Q} \quad (2.31)$$

2.9. Toklar rezonansi.

Toklar rezonansi hodisasi R (g), L , C elementlari o‘zaro parallel ulangan o‘zgaruvchan tok zanjirida yuzaga keladi (2.7 a - rasm). Bu faqat g‘altak va sig‘imning reaktiv o‘tkazuvchanliklari teng ($b_L = b_C$) bo‘lganda, ya‘ni $b = b_L - b_C = \frac{1}{\omega L} - \omega C = 0$ da mumkin bo‘ladi.

Rezonans paytida reaktiv toklar I_L va I_C zanjirdagi umumiy tok I dan ($\bar{I} = \bar{I}_g + \bar{I}_L + \bar{I}_C$) bir qancha katta bo‘lishi mumkin. Shuning uchun ham bu hodisa toklar rezonansi deb ataladi.

Bunda $|I_L| = |I_C|$ toklar manba tokidan bir necha marotaba ortib ketishi mumkin. Shuning uchun ham bu zanjirdagi rezonans **toklar rezonansi** deb ataladi (2.10 d -rasm).



2.10 – rasm.

Reaktiv o‘tkazuvchanlik b_L va b_C lar qanchalik katta bo‘lsa, I_L va I_C toklar ham shunchalik katta bo‘ladi:

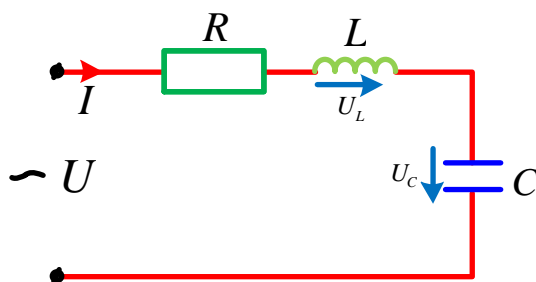
$$b_L = b_C = \frac{1}{\omega L} = \omega C = \sqrt{\frac{C}{L}} = \gamma \left[\frac{1}{\Omega} \right] \quad (2.32)$$

bunda γ – rezonansli parallel ulangan zanjirning (tebranish konturining) to‘lqin o‘tkazuvchanligi deyiladi.

Q – rezonansli parallel ulangan zanjirning (tebranish konturining) kontur asilligi deyiladi.

$$Q = \frac{\gamma}{g} \quad (2.33)$$

Masala: Ketma–ket ulangan tok zanjirining qiymatlari $R = 5 \Omega$, $L = 150 \text{ mkH}$, $C = 470 \text{ mkF}$ bo‘lib, $U = 10 \text{ V}$ kuchlanishga ulangan. Rezonans chastotasi f_0 , reaktiv elementlardagi kuchlanish U_L, U_C , to‘lqin qarshiligi ρ , kontur asilligi Q va so‘nish koeffitsiyenti d aniqlansin.



Yechilishi:

$$\text{Rezonans chastota: } \omega_0 = \frac{1}{\sqrt{LC}} = \frac{1}{\sqrt{150 \cdot 10^{-6} \cdot 470 \cdot 10^{-6}}} = 3766,2 \left(\frac{\text{rad}}{\text{sek}} \right)$$

$$\text{Bundan: } f_0 = \frac{\omega_0}{2\pi} = \frac{3766,2}{2 \cdot 3,14} = 599,7 \text{ (Hz)}$$

$$\text{Rezonans holat toki: } I_0 = \frac{U}{R} = \frac{10}{5} = 2 \text{ (A)}$$

$$\text{Reaktiv qarshiliklari: } x_L = \omega_0 L = 3766,2 \cdot 150 \cdot 10^{-6} = 0,564 \text{ (\Omega)}$$

$$x_C = \frac{1}{\omega_0 C} = \frac{1}{3766,2 \cdot 470 \cdot 10^{-6}} = 0,564 \text{ (\Omega)}$$

Reaktiv qarshiliklardagi kuchlanishlar:

$$U_L = I \cdot x_L = 2 \cdot 0,564 = 1,128 \text{ (V)}$$

$$U_C = I \cdot x_C = 2 \cdot 0,564 = 1,128 \text{ (V)}$$

ρ – rezonansli ketma-ket ulangan zanjirning (tebranish konturining) to‘lqin qarshiligi:

$$\rho = \sqrt{\frac{L}{C}} = \sqrt{\frac{150 \cdot 10^{-6}}{470 \cdot 10^{-6}}} = 0,564.$$

Q– rezonansli ketma-ket ulangan zanjirning asillik koeffitsiyenti:

$$Q = \frac{\rho}{R} = \frac{0,564}{5} = 0,113.$$

d – rezonansli ketma-ket ulangan zanjirning asillik koeffitsiyenti deyiladi

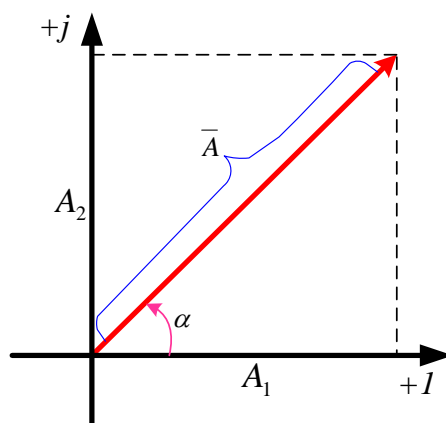
$$d = \frac{1}{Q} = \frac{1}{0,113} = 8,85.$$

2.10. Sinusoidal kattaliklarni kompleks tekislikda vektorlar bilan tasvirlash.

1-ta’rif. Kvadrati -1 ga teng ifodani mavhum birlik deb ataladi va u j orqali belgilanadi. Shunday qilib, $j^2 = -1$ yoki $j = \sqrt{-1}$.

2-ta’rif. z kompleks son deb $z = r + jx$ ko‘rinishdagi ifodaga aytiladi, bunda r va jx ni z kompleks sonning mos ravishda haqiqiy va mavhum qismlari deyiladi va $R_{ez} = r, J_{mz} = x$ kabi belgilanadi. (j -mavhum birlik)

Ma’lumki har qanday kompleks son haqiqiy va mavhum qismlardan iborat. 2.16-rasmda kompleks tekislik keltirilgan. Abtsissa (ox) o‘qi haqiqiy sonlar $+1$, ordinata (oy) o‘qi esa mavhum sonlar $+j$ hisoblanadi.



2.11-rasm.

Bu vektorlar 3 xil ko‘rinishda berilishi mumkin:

- 1) algebraik shaklida: $Z = R + jX$;
- 2) ko‘rsatkichli shaklda: $Z = Ae^{j\varphi}$;
- 3) trigonometrik shaklda: $Z = A(\cos\varphi + j\sin\varphi)$.

Algebraik shakldan ko'rsatkichli va trigonometrik shaklga o'tadigan bo'lsak quyidagicha hisoblaymiz. $A = \sqrt{R^2 + X^2}$, $\varphi = \arctg \frac{X}{R}$.

Demak sinusoidal o'zgaruvchan $I = I_m \sin(\omega t + \varphi_i)$ tokka kompleks tekislikda I_m amplituda va φ_i -argument bilan aniqlanadigan quyidagi vektor mos keladi:

$$I_m = I_m e^{j\varphi_i} \quad (2.34)$$

Haqiqiy hisoblashlarda toklar, eyuk. va kuchlanishlarning effektiv qiymatlari beriladi, u xolda tegishli komplekslarni quyidagicha ko'rinishda yozish mumkin:

$$\underline{I}_m = I_m e^{j\varphi_i}, \underline{U}_m = U_m e^{j\varphi_u}, \underline{E}_m = E_m e^{j\varphi_E} \quad (2.35)$$

2.10.1. Om va Kirxgof qonunlarining kompleks shakli.

Kuchlanish va tokning effektiv qiymatlarining komplekslari:

$$\underline{U} = U e^{j\varphi_u}, \underline{I} = I e^{j\varphi_i} \quad (2.36)$$

Om qonuniga binoan, bu zanjirning to'la qarshiligi kompleks shaklda quyidagicha yoziladi:

$$\begin{aligned} \underline{Z} &= \frac{\underline{U}}{\underline{I}} = \frac{U e^{j\varphi_u}}{I e^{j\varphi_i}} = Z e^{j\varphi} = R + jX = R + j\left(\frac{1}{\omega L} - \omega C\right) = R + j(X_L - X_C), \\ \underline{Z} &= Z e^{j\varphi} = \sqrt{R^2 + X^2} e^{j\varphi} = Z(\cos\varphi + j\sin\varphi). \\ \underline{I} &= \frac{\underline{U}}{\underline{Z}} \end{aligned} \quad (2.37)$$

Oxirgi tenglik Om qonunining kompleks shakli deb ataladi.

$\underline{Z} = Z e^{j\varphi} = R + jX$ -zanjirning **kompleks qarshiligi** deb ataladi.

Zanjirning kompleks o'tkazuvchanligi ham shunday aniqlanadi: To'la kompleks qarshilikka teskari bo'lgan kattalik to'la **kompleks o'tkazuvchanlik** deb ataladi:

$$\underline{Y} = \frac{1}{\underline{Z}} = \frac{1}{Z e^{j\varphi}} = y e^{-j\varphi} = y \cos\varphi - j y \sin\varphi = g - jb,$$

bunda, $y = \sqrt{g^2 + b^2}$, $\varphi = \arctg \frac{b}{g}$ mos ravishda to'la kompleks o'tkazuvchanlikning moduli va argumenti.

Sinusoidal tok zanjirlari uchun Kirxgof qonunlari kompleks tok va kuchlanishlar orqali quyidagicha ifodalanadi:

Zanjirning istalgan tugunidagi kompleks toklarning algebraik yig'indisi nolga teng (Kirxgofning 1-qonuni):

$$\sum_{k=1}^n \dot{I}_k = 0 \quad (2.38)$$

Zanjirning istalgan berk konturida kompleks EYuK larning algebraik yig'indisi shu konturning kompleks qarshiliklaridagi kompleks kuchlanishlar pasayishlarining algebraik yig'indisiga teng (Kirxgofning 2-qonuni):

$$\sum_{k=1}^n \dot{E}_k = \sum_{k=1}^m \dot{I}_k \cdot \underline{Z}_k \quad (2.39)$$

2.11. Quvvat kompleksi va sinusoidal tok zanjirlarida quvvatlar balansi.

2.11.1. Quvvat kompleksi.

Agar $S = UI$ ko'paytmaning komplekslari (\dot{U} yoki \dot{I}) dan birortasining argumenti teskari ishorali qilib olinsa, ko'paytma vektorining argumenti $\pm\varphi$ ga teng bo'ladi, ya'ni:

$$\dot{S} = \underline{\dot{I}}\dot{U} = UIe^{\pm j\varphi} = UI\cos\varphi \pm jUI\sin\varphi = P \pm jQ, \quad (2.40)$$

bu yerda $\underline{\dot{I}}$ -qo'shma kompleks tok.

Masalan, agar $\dot{I} = I_m e^{+j\varphi}$ bo'lsa, u holda bu tokning qo'shmasi $\underline{\dot{I}} = I_m e^{-j\varphi}$ ga teng bo'ladi.

\bar{S} -kompleks to'la quvvat deb ataladi.

2.11.2. Sinusoidal tok zanjirlarida quvvatlar balansi.

Energiya saqlanish qonunidan ma'lumki, har qanday zanjirda quvvatlar balansi saqlanadi:

$$\sum_{k=1}^n P_{kn} = \sum_{k=1}^m I_k^2 \cdot r_k, \quad (2.41)$$

bu yerda, n -manbalar soni, m -iste'molchilar soni.

$$\sum_{k=1}^n Q_{kn} = \sum_{k=1}^m I_k^2 \cdot x_k. \quad (2.42)$$

Kompleks quvvatlar balansi:

$$\sum_{k=1}^n \bar{S}_{kn} = \sum_{k=1}^m \bar{S}_k. \quad (2.43)$$

2.2-masala: Iste`molchidagi tok va kuchlanishlarning kompleks qiymatlari $\dot{I} = 16 + j12$ va $\dot{U} = j100$ ga teng bo`lsa, aktiv va reaktiv qarshiliklarni hamda aktiv, reaktiv va to`la quvvatlarni hisoblang.

Yechilishi:

(Eslatma: $i^2 = -1$, $Z = R + jX$, \dot{I} -qo`shma kompleks tok.)

To`la qarshilikni hisoblaymiz:

$$a) \underline{Z} = \frac{\dot{U}}{\dot{I}} = \frac{j100}{16+j12} = \frac{j100 \cdot (16-j12)}{(16+j12) \cdot (16-j12)} = \frac{1200+j1600}{256+144} = \frac{1200+j1600}{400} = 3 + j4 (\Omega)$$

a usulda hisoblaganimizda kasrning surat va mahrajini berilgan ifodaning qo`shmasiga ko`paytiramiz.

$$b) \underline{Z} = \frac{\dot{U}}{\dot{I}} = \frac{j100}{16+j12} = \frac{\sqrt{100^2} e^{j \arctg \frac{100}{0}}}{\sqrt{16^2+12^2} e^{j \arctg \frac{12}{16}}} = \frac{100 e^{j90^\circ}}{20 e^{j36,87^\circ}} = 5 e^{j53,13^\circ} = 5 \cos 53,13^\circ + j \sin 53,13^\circ = 3 + j4 (\Omega)$$

b usulda hisoblaganimizda kasrning surat va mahrajini ko`rsatkichli ko`rinishga keltiramiz.

Kompleks to`la qarshilikning haqiqiy qismi aktiv qarshilikka, mavxum qismi esa reaktiv qarshilikka teng bo`lganligi uchun:

$$Z = R + jX \text{ bundan } R=3 (\Omega), X=4 (\Omega)$$

$$\text{To`la qarshilk: } Z = Z \cdot e^{j\varphi^0} = 5 \cdot e^{j53,13^\circ} \text{ bundan } Z = 5 (\Omega).$$

Kompleks quvvatni topish uchun tok kuchining mavxum qismidagi ishorasini qarama-qarshisiga o`zgartirib kompleks kuchlanishga ko`paytiramiz:

$$\bar{S} = \dot{U} \cdot \dot{I} = j100 \cdot (16 - j12) = 2000 e^{j53,13^\circ} = 1200 + j1600 (VA).$$

Bunda aktiv, reaktiv va to`la quvvatlarning qiymatlari:

$$\bar{S} = P + jQ, \quad \bar{S} = S \cdot e^{j\varphi^0}$$

$$P = 1200 W, Q = 1600 VA, S = 2000 VA \text{ ga teng bo`ladi.}$$

2.3-masala: Agar tok va kuchlanishning oniy qiymatlari ifodalari mos ravishda, $i = 12,6 \sin(314t - 30^\circ) (A)$, $u = 120 \sin(314t + 45^\circ) (V)$ ko`rinishida berilgan bo`lsa, aktiv, reaktiv va to`la quvvatlar aniqlansin.

Yechilishi:

Tok va kuchlanishning kompleks ta'sir etuvchi qiymatlarini hisoblaymiz.

$$\dot{U} = \frac{120}{\sqrt{2}} e^{j45^\circ} = 84,9 \cdot e^{j45^\circ} \text{ (V)}$$

$$\dot{i} = \frac{12,6}{\sqrt{2}} e^{-j30^\circ} = 8,9 \cdot e^{-j30^\circ} \text{ (A)}$$

Kompleks to'la quvvat:

$$\bar{S} = \dot{U} \cdot \underline{\dot{i}} = 84,9 \cdot e^{j45^\circ} \cdot 8,9 \cdot e^{j30^\circ} = 755,61 \cdot e^{j75^\circ}$$

$$= 755,61 \cos 75^\circ + j755,61 \sin 75^\circ = 195,57 + j729,86$$

yani aktiv, reaktiv va to'la quvvatlar,

$$P = 195,57 \text{ W}, Q = 729,86 \text{ VAr}, S = 755,61 \text{ VA ga teng bo'ladi.}$$

2.12. Amaliy mashg'otlar uchun masalalar va hisob grafik ishlari.

2.1-masala: Kuchlanishi $U = 220 \text{ V}$, chastotasi $f = 60 \text{ Gs}$ bo'lgan manbaga induktiv g'altak va kondensator galma-galdan ulanganda zanjirdan oqib o'tgan tok bir xil, ya'ni $I = 10 \text{ A}$. G'altakning induktivligi va kondensatorning sig'imi aniqlansin.

2.2-masala: Zanjirga berilgan kuchlanishning va undagi tokning oniy qiymatlari $u = 280 \sin \omega t$ va $i = 12,7 \sin(\omega t - 45^\circ)$ ma'lum bo'lsa, zanjirning aktiv, reaktiv va to'la quvvatlari va qarshiliklari topilsin.

2.3-masala: Agar zanjirga ulangan ampermetr 2 A ni, voltmeter esa 220 V ni ko'rsatayotgan bo'lsa, zanjirdagi tok kuchining va kuchlanishning amplituda qiymatlarini toping?

2.4-masala: Effektiv kuchlanishi $U = 120 \text{ V}$ va chastotasi $f = 1 \text{ kHz}$ bo'lgan o'zgaruvchan tokka ulanganda g'altakning induktiv qarshiligi $X_L = 250 \Omega$ bo'lsa undan o'tayotgan tok kuchining amplituda qiymatini, uning induktivligini toping?

2.5-masala: Sigimi 600 mkF bo'lgan kondensator qismlaridagi kuchlanish $u = 141 \sin(100t + 60^\circ)$ qonuniyat bilan o'zgaradi. Kondensatorda jamlangan elektr maydon energiyasining effektiv qiymati, hamda kondensator toki aniqlansin.

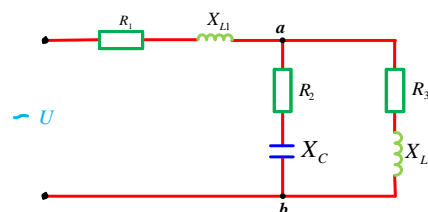
2.6-masala: Qarshiligi 10Ω li rezistordan o'tayotgan tokning oniy

qiymati ifodasi $i = 15\sin(314t - 30^\circ)$ A. Kuchlanish va tokning oniy qiymati topilsin.

2.7-masala: Rezistordan iborat zanjirdagi tok va kuchlanishning oniy qiymati ifodalari mos ravishda $i = 14,1\sin\left(314t + \frac{\pi}{3}\right)$ A va $u = 51\sin\left(314t + \frac{\pi}{3}\right)$ V ga teng. Rezistor qarshiligi, tok va kuchlanishning ta'sir etuvchi qiymatlari aniqlansin.

2.8-masala: O'zgaruvchan kuchlanishi 220 V, chastotasi 400 Hz bo'lgan manbaga induktivligi $L_1 = 5\text{ mH}$, $L_2 = 10\text{ mH}$ va aktiv qarshiliklari mos ravishda $R_1 = 2\ \Omega$, $R_2 = 5\ \Omega$ bo'lgan ikkita g'altak parallel ulangan. Zanjirning toki, to'la, aktiv va reaktiv quvvati aniqlansin.

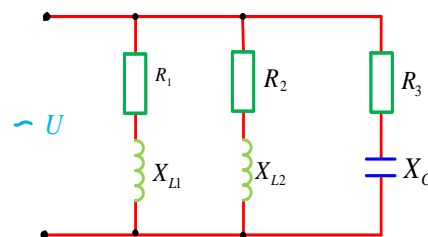
2.9-masala: Quyidagi rasmda elektr zanjirning parametrlari: $R_1 = 3\ \Omega$, $X_{L1} = 20\ \Omega$, $R_2 = 50\ \Omega$, $X_C = -100\ \Omega$, $R_3 = 100\ \Omega$, $X_{L2} = 50\ \Omega$ teng. Zanjirning ekvivalent aktiv va reaktiv qarshiligi qiymatlari aniqlansin.



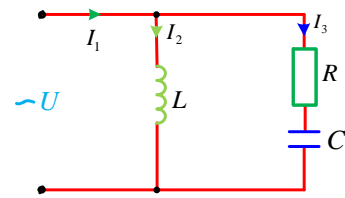
2.10-masala: Kuchlanish va tokning oniy qiymatlari $i = 10\sin(\omega t - 45^\circ)$ A va $u = 170\sin(\omega t + 45^\circ)$ V bo'lganda bular orasidagi burchak φ topilib, $t = 0$ bo'lganda oniy qiymatlari aniqlansin.

2.11-masala: Qarshilikning parametrlari $R = 20\ \Omega$, $X_L = 10\ \Omega$ bo'lgan induktiv g'altak chastotasi $f = 50\text{ Hz}$ bo'lgan $U = 100\sin(\varphi t + 45^\circ)$ V kuchlanish ulangan. Chastota ikki martagacha ko'paygan holat uchun kompleks to'la qarshiligi, tok va to'la quvvati aniqlansin.

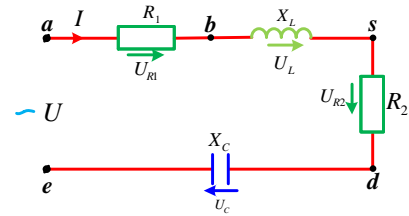
2.12-masala: Paralell sxemada ulangan uchta istemolchining parametrlari: $R_1 = 5\ \Omega$, $X_{L1} = 2\ \Omega$, $R_2 = 2,5\ \Omega$, $X_{L2} = 5\ \Omega$, $R_3 = 1,25\ \Omega$, $X_C = -2,5\ \Omega$ teng. Ekvivalent kompleks to'la o'tqazuvchanlik va umumiy zanjir uchun burchak $\cos\varphi$ aniqlansin.



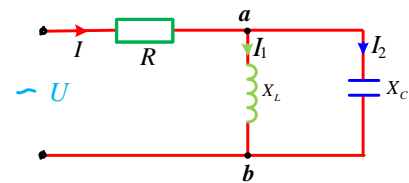
2.13-masala: Keltirilgan sxemada rezonans holatda tarmoqning toklari $I_1 = 4 A$, $I_2 = 3A$ teng bo‘lib, I_3 tok aniqlansin.



2.14-masala: Keltirilgan sxemada $U = 100 V$, $R_1 = 30 \Omega$, $R_2 = 50 \Omega$, $X_L = 90 \Omega$ va $X_C = 30 \Omega$. c va e nuqtalar orasidagi kuchlanishni toping.

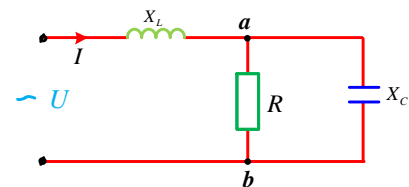


2.15-masala: Keltirilgan sxemada $R = 16 \Omega$, $X_L = 7,5\Omega$, $X_C = 20 \Omega$, $I = 5 A$. zanjirning kirishdagi kuchlanishini, aktiv va reaktiv quvvati aniqlansin.

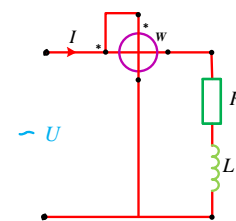


2.16-masala: Kuchlanishi $U = 220 V$ va chastotasi $f = 50 Hz$ bo‘lgan o‘zgaruvchan tok tarmog‘iga sig‘imi $C = 5 mkF$ bo‘lgan kondensator ulangan. Zanjirdagi tok va kondensatorning elektr maydonida yig‘ilgan energiyani maksimal qiymati aniqlansin.

2.17-masala. Quyidagi zanjirda $R = X_L = X_C = 20 \Omega$. zanjirning to‘la qarshiligi kompleks ko‘rinishida aniqlansin.

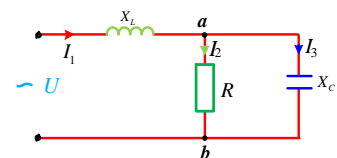


2.18-masala: Berilgan sxemasida $f = 50 Hz$ chastotadagi asboblarning ko‘rsatkichlari $U = 220 V$, $I = 5 A$, $P = 600 W$. $U = 220 V$ va $f = 200 Hz$ chastotada ampermetr va vattmetrning ko‘rsatkichlari qanday o‘zgaradi?



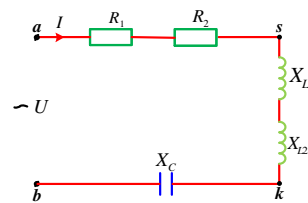
2.19-masala: kuchlanish va tokning effektiv kompleks qiymatlari $\dot{U} = 100 V$ va $\dot{I} = 16 + j12 A$. Aktiv va reaktiv qarshiliklarning kompleks qiymatlarini toping.

2.20-masala: Quyidagi sxemada aktiv quvvat $P = 120 W$, to‘la quvvat $S = 150 VA$, $U_{ab} = 120 V$ va $I_3 = 1 A$.



Induktiv qarshilikni aniqlang X_L .

2.21-masala: Quyidagi berilgan zanjirning qiymatlari $R_1 = 1 \Omega$, $R_2 = 2 \Omega$, $X_{L1} = 6 \Omega$, $X_{L2} = 2 \Omega$, $X_C = 4 \Omega$. Zanjirning umumiy qarshiligi aniqlansin.

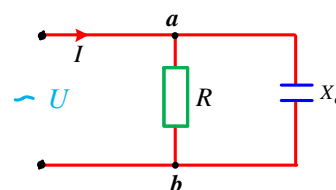


2.22-masala: Chastotasi 400 Hz li tarmoqqa aslligi $Q_L = 8$ bo'lgan real g'altak ulangan. To'la quvvat $S = 100 \text{ VA}$ Agar g'altakning aktiv qarshiligi $R_a = 0,5 \Omega$ bo'lsa, chulg'amni qizdirishga ketayotgan quvvat isrofi va g'altakning induktivligi aniqlansin.

2.23-masala: Ta'sir etuvchi qiymati 10 A bo'lgan sinusoidal tokning maksimal va o'rtacha qiymatlarini aniqlang.

2.24-masala: Ketma-ket ulangan R, L, C zanjir chastotasi 400 Hz manbaga ulangan. Rezonans holatida sig'imi 10 mkF li kondensatordagi kuchlanish pasayishi 60 V . Agar $R = 10 \Omega$ bo'lsa, g'altak induktivligi aniqlansin.

2.25-masala: Agar berilgan sxemada $R = X_C = 100 \Omega$ va kuchlanish $U = 200 \text{ V}$ bo'lsa, zanjirdagi tok, aktiv va reaktiv quvvat aniqlansin.



2.26-masala: Aktiv qarshiligi juda kichik bo'lgan g'altak standart chastotali o'zgaruvchan tok tarmog'iga ulangan. G'altak uchlarida ulangan voltmetr $U = 120 \text{ V}$ kuchlanishni ampermetr esa $I = 2,4 \text{ A}$ ni ko'rsatsa, g'altakning induktivligini toping?

2.27-masala: $R = X_L = 15 \Omega$, $I = 8 \text{ A}$, bo'lsa elektr zanjirining kirish qismidagi kuchlanish, elektr zanjirining to'la qarshiligi tok va kuchlanish orasidagi faza siljish burchagi aniqlansin. Elektr zanjirining vektor diagrammasini quring.

2.28-masala: Agar $u = 100\sqrt{2} \sin(314t + 30^\circ) \text{ V}$ va $i = 10\sqrt{2} \sin(314t - 15^\circ) \text{ A}$ bo'lsa, u holda ularning ta'sir etuvchi va o'rtacha qiymatlari, boshlang'ich fazalari, fazalar siljishi, chastotasi va davri aniqlansin.

2.29-masala: Aktiv qarshiligi $r = 10 \Omega$ va induktiv qarshiligi $x_L = 50 \Omega$ bo'lgan g'altak chastotasi $f = 50 \text{ H}$ va kuchlanishi $U =$

220 V li o'zgaruvchan tok tarmog'iga ulangan. Zanjirda kuchlanish rezonansi hosil bo'lishi uchun g'altak bilan ketma-ket ulash kerak bo'lgan kondensatorning sig'imi aniqlansin.

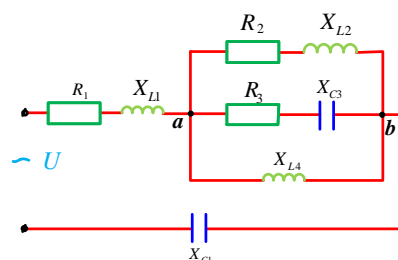
2.30-masala: Generator tomonidan hosil qilinayotgan EYuK maksimal qiymati 120 V . Faza $\omega t = 60^0$ bo'lsa, oniy qiymatini aniqlang.

2.31-masala: O'zgaruvchan tok zanjirida ampermetr $I = 6 A$ tokni, voltmetr $U = 220 V$ kuchlanishni vattmetr esa $P = 600 W$ quvvatni ko'rsatadi. Quvvat koeffitsiyentini, tok kuchi va kuchlanish orasidagi fazaning siljishini toping?

2.32-masala: Qurilmaning to'la quvvati $S = 800 VA$, Vattmetrdagi aktiv quvvat ko'rsatkichi 720 W ga teng. Quvvat koeffitsiyentini toping.

2.33-masala: Standart chastotali va 220 V kuchlanishli o'zgaruvchan tok tarmog'iga ketma-ket q'ilib $R = 20 \Omega$ li qarshilik $L = 60 mH$ induktivlik g'altak va $C = 80 mkF$ sig'imli kondensator ulangan. Zanjirdagi tok kuchi g'altak va kondensatorlardagi kuchlanishlarni toping?

2.34-masala: Berilgan sxemada kuchlanishi $U = 220V$ bo'lgan elektr tarmog'iga ulangan. Agar $R_1 = 2,16 \Omega$, $X_{L1} = 60 \Omega$, $X_{C1} = 0,56 \Omega$, $R_2 = 3 \Omega$, $X_{L2} = 4 \Omega$, $R_3 = 6 \Omega$, $X_{C3} = 8 \Omega$, $X_{L4} = 25 \Omega$, bo'lsa, barcha tarmoqlardagi toklar aniqlansin.



2.35-masala: G'altakning induktivligi $L = 15,9 mH$, aktiv qarshiligi $R = 0$. kondensator sig'imi $C = 637mkF$, aktiv o'tkazuvchanligi $G = 0$. Agar g'altak bilan kondensatorning har birida $f = 50 Hz$ chastotada kuchlanish $U = 100V$ bo'lsa, zanjirning shu elementlarining quvvatini aniqlang.

HISOB-GRAFIK ISHINI BAJARISHGA NA'MUNA

Sinusoidal o'zgaruvchan tok zanjirlarini hisoblash.

a) Chastotasi $f = 50 \text{ Hz}$, kuchlanishi $U = 220 \text{ V}$ bo'lgan sinusoidal tok zanjiriga ikkita g'altak va kondensator ketma-ket ulangan. G'altaklarning va kondensatorning parametrlari quyidagi qiymatlarga teng.

$$R_1 = 4 \Omega; L_1 = 0,032 \text{ H}; R_2 = 5 \Omega; L_2 = 0,016 \text{ H}; C = 400 \text{ mkF}.$$

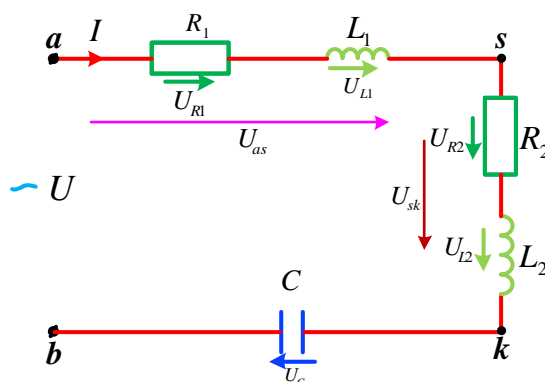
1. Zanjirdagi tok va kuchlanishlarning ta'sir etuvchi qiymatlari aniqlansin.

2. Zanjirdagi aktiv, reaktiv va to'la quvvatlar aniqlansin.

3. Butun zanjir va uning as va sk uchastkalari uchun faza siljishi aniqlansin.

4. Vektor diagrammasi qurilsin.

Yechilishi:



1. Zanjirning sxemasini chizamiz.

2. G'altaklarning induktiv va to'la qarshiliklarini aniqlaymiz.

$$\omega = 2\pi f = 2 \cdot 3,14 \cdot 50 = 314 \left(\frac{\text{rad}}{\text{sek}} \right)$$

$$X_{L1} = \omega L_1 = 314 \cdot 0,032 = 10 \text{ } (\Omega)$$

$$Z_1 = \sqrt{R_1^2 + X_{L1}^2} = \sqrt{4^2 + 10^2} = \sqrt{116} = 10,6 \text{ } (\Omega)$$

$$X_{L2} = \omega L_2 = 314 \cdot 0,016 = 5 \text{ } (\Omega)$$

$$Z_2 = \sqrt{R_2^2 + X_{L2}^2} = \sqrt{5^2 + 5^2} = \sqrt{50} = 7,07 \text{ } (\Omega)$$

$$\omega = 2\pi f = 2 \cdot 3,14 \cdot 50 = 314 \left(\frac{\text{rad}}{\text{sek}} \right)$$

3. Kondensatorning qarshiligini aniqlaymiz.

$$X_c = \frac{1}{\omega C} = \frac{10^6}{314 \cdot 400} = 8 \text{ } (\Omega)$$

4. Butun zanjirning to'la qarshiligini aniqlaymiz.

$$Z = \sqrt{R_{um}^2 + X_{um}^2} = \sqrt{(R_1 + R_2)^2 + (X_{L1} + X_{L2} - X_c)^2}$$

$$= \sqrt{(4 + 5)^2 + (10 + 5 - 8)^2} = \sqrt{130} = 11,4 \text{ } (\Omega)$$

5. Zanjirdan o'tayotgan tokni aniqlaymiz.

$$I = \frac{U}{Z} = \frac{220}{11,4} = 19,3 \text{ } (A)$$

6. Zanjir elementlaridagi kuchlanishlar pasayishlarini aniqlaymiz.

$$U_{R1} = I \cdot R_1 = 19,3 \cdot 4 = 77,2 \text{ } (V)$$

$$U_{L1} = I \cdot X_{L1} = 19,3 \cdot 10 = 193 \text{ } (V)$$

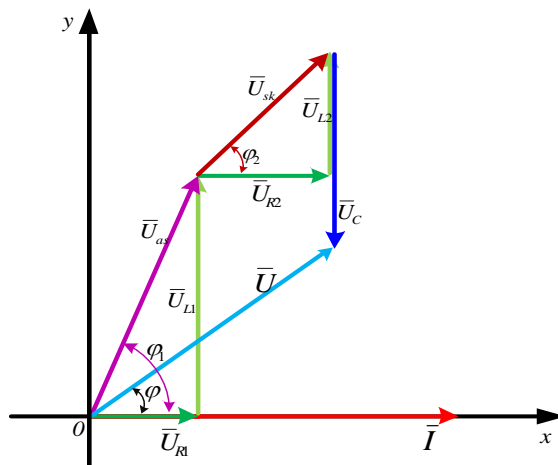
$$U_{R2} = I \cdot R_2 = 19,3 \cdot 5 = 96,5 \text{ } (V)$$

$$U_{L2} = I \cdot X_{L2} = 19,3 \cdot 5 = 96,5 \text{ } (V)$$

$$U_c = I \cdot X_c = 19,3 \cdot 8 = 154,4 \text{ } (V)$$

7. Aniqlangan kuchlanishlar uchun masshtab tanlaymiz va vektor diagramma quramiz. Vektor diagrammani butun zanjir uchun umumiy bo'lgan \vec{I} tok vektoridan boshlab quramiz. \vec{U}_{R1} kuchlanish vektori tok bilan ustma-ust tushadi.

$$\text{Masshtab: } m_U = 40 \frac{V}{sm}, m_I = 2 \frac{A}{sm}.$$



Bu vektorning uchidan tok vektoridan 90^0 ga ilgarilangan \vec{U}_{L1} kuchlanish vektorini qo'yamiz. \vec{U}_{L1} vektorning uchidan tok bilan bir fazaga ega bo'lgan \vec{U}_{R2} kuchlanish vektorini o'tkazamiz. \vec{U}_{R2} vektorining

uchidan undan 90^0 ga ilgarilangan \overline{U}_{L2} kuchlanish vektorini chizamiz. \overline{U}_{L2} ning uchidan tokdan 90^0 ga orqada qoluvchi \overline{U}_C kuchlanish vektorini o'tkazamiz. \overline{U}_C kuchlanish vektorining oxirgi uchini \overline{U}_{R1} vektorining bosh uchi bilan birlashtirsak, \overline{U} manba kuchlanishi vektori kelib chiqadi (yuqorida shu zanjirning vektor diagrammasi chizilgan).

8. Tok va kuchlanishlar faza siljishini aniqlaymiz.

Butun zanjir uchun $\varphi = \arctg \frac{X_L - X_C}{R} = \arctg \frac{15-8}{9} = \arctg \frac{7}{9} = 38^0$

bu yerda,

$$X_L = X_{L1} + X_{L2} = 10 + 5 = 15 (\Omega)$$

$$R = R_1 + R_2 = 4 + 5 = 9 (\Omega),$$

as uchastkasining kuchlanishi U_1 bilan tok orasidagi faza siljishi:

$$\varphi_1 = \arctg \frac{X_{L1}}{R_1} = \arctg \frac{10}{4} = 68^0,$$

sk uchastkasining kuchlanishi U_2 bilan tok orasidagi faza siljishi:

$$\varphi_2 = \arctg \frac{X_{L2}}{R_2} = \arctg \frac{5}{5} = 45^0,$$

kb uchastkasining kuchlanishi $U_3 = U_C$ bilan tok orasidagi faza siljishi:

$$\varphi_3 = -90^0.$$

Endi zanjirning iste'mol qilayotgan aktiv, reaktiv va to'la quvvatlarini aniqlaymiz.

$$P = I^2 \cdot R_1 + I^2 \cdot R_2 = U \cdot I \cdot \cos\varphi = 220 \cdot 19,3 \cdot \cos 38^0 = 220 \cdot 19,3 \cdot 0,78 = 3345,89 (W)$$

$$Q = I^2 \cdot X_{L1} + I^2 \cdot X_{L2} - I^2 \cdot X_C = U \cdot I \cdot \sin\varphi = 220 \cdot 19,3 \cdot \sin 38^0 = 220 \cdot 19,3 \cdot 0,616 = 2614,1 (VAr)$$

$$S = \sqrt{P^2 + Q^2} = U \cdot I = 220 \cdot 19,3 = 4246 (VA)$$

2.1-jadval

Variant	R_1	R_2	R_3	L_1	L_2	C
№	Ω	Ω	Ω	mH	mH	mkF
1	10	4	5	31,8	16	318

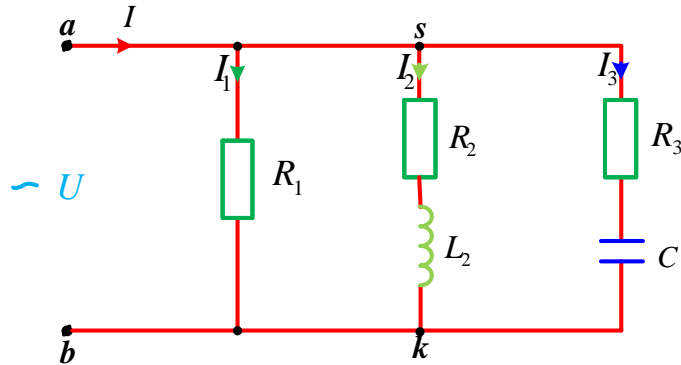
2	10	5	3	95,5	25,5	265
3	10	6	6	25,5	31,8	530
4	10	5	4	51	48	79,6
5	10	6	5	79,6	31,8	79,6
6	15	3	5	79,6	16	127
7	15	4	3	79,6	16	199
8	15	5	4	79,6	25,5	199
9	15	6	3	25,5	31,8	1,6
10	15	4	6	48	25,5	79,6
11	20	4	4	48	51	159
12	20	5	5	63,7	51	212
13	20	5	6	63,7	48	127
14	20	4	6	111	31,8	90,9
15	20	4	5	111	16	79,6
16	25	7	3	111	31,8	530
17	25	2	8	31,8	16	79,6
18	25	3	4	31,8	95,5	127
19	25	5	4	31,8	76	199
20	25	4	3	16	95,5	199
21	16	7	6	25,5	111	212
22	16	5	8	25,5	16	79,6
23	16	6	4	25,5	127	79,6
24	16	3	5	48	127	90,9
25	16	4	8	48	16	90,9
26	28	2	8	48	31,8	212
27	28	4	6	31,8	111	159
28	28	6	6	31,8	127	79,6
29	28	10	2	31,8	16	31,8
30	28	8	4	51	127	106

- b) 1.** Zanjirning tarmoqlaridagi toklar aniqlansin.
2. Zanjirning aktiv, reaktiv va to‘la quvvatlari aniqlansin.
3. Vektor diagramma qurilsin.

Chastotasi $f = 50 \text{ Hz}$, kuchlanishi $U = 220 \text{ V}$ bo'lgan manbaga aktiv va reaktiv qarshiliklar parallel biriktirilgan.

Ularning parametrlari quyidagicha:

$$R_1 = 110 \Omega, R_2 = 40 \Omega, R_3 = 30 \Omega, L = 0,0637 \text{ H}, C = 79,6 \text{ mkF}.$$



Yechilishi:

1. Tarmoqlardagi to'la qarshiliklarni aniqlaymiz

$$Z_1 = R_1 = 110 (\Omega)$$

$$\omega = 2\pi f = 2 \cdot 3,14 \cdot 50 = 314 \left(\frac{\text{rad}}{\text{sek}} \right)$$

$$X_L = \omega L = 314 \cdot 0,0637 = 20 (\Omega)$$

$$Z_2 = \sqrt{R_2^2 + X_L^2} = \sqrt{40^2 + 20^2} = \sqrt{2000} = 44,7 (\Omega)$$

yoki kompleks shaklda $Z_2 = R_2 + j\omega L = 40 + j20 = 44,7e^{j27^\circ} (\Omega)$

bu yerda $\varphi_2 = \arctg \frac{X_L}{R_2} = \arctg \frac{20}{40} = 27^\circ$

$$X_C = \frac{1}{\omega C} = \frac{10^6}{314 \cdot 79,6} = 40 (\Omega)$$

$$Z_3 = \sqrt{R_3^2 + X_C^2} = \sqrt{30^2 + 40^2} = \sqrt{2500} = 50 (\Omega)$$

yoki $Z_3 = R_3 - jX_C = 30 - j40 = 50e^{-j53^\circ} (\Omega)$

bu yerda $\varphi_3 = \arctg \frac{X_L - X_C}{R} = \arctg \frac{-X_C}{R_3} = \arctg \left(-\frac{40}{30} \right) = -53^\circ$

2. Tarmoqlardagi toklarni aniqlaymiz. Manba kuchlanishining boshlang'ich fazasini 0° ga teng deb olamiz.

$$I_1 = \frac{U}{Z_1} = \frac{U}{R_1} = \frac{220}{110} = 2 (A)$$

$$I_2 = \frac{U}{Z_2} = \frac{220}{44,7} = 4,92 \text{ (A)}$$

yoki

$$I_2 = \frac{U}{Z_2} = \frac{220}{44,7e^{j27^0}} = 4,92e^{-j27^0} \text{ (A)}$$

$$I_3 = \frac{U}{Z_3} = \frac{220}{50} = 4,4 \text{ (A)}$$

yoki

$$I_3 = \frac{U}{Z_3} = \frac{220}{50e^{-j53^0}} = 4,4e^{j53^0} \text{ (A)}$$

3. Zanjirning tarmoqlanmagan qismidagi tok Kirxgofning 1-chi qonuniga binoan $\bar{I} = \bar{I}_1 + \bar{I}_2 + \bar{I}_3$ ga teng bo'ladi. Kompleks sonlar yordamida aniqlaydigan bo'lsak shaxobchalardagi toklarni aktiv va reaktiv tashkil etuvchilarga ajratib qo'shib chiqamiz.

$$\bar{I}_1 = 2 \text{ (A)}$$

$$\bar{I}_2 = 4,92e^{-j27^0} = 4,92 \cdot \cos 27^0 + j4,92 \sin(-27^0) = 4,38 - j2,23 \text{ (A)}$$

$$\bar{I}_3 = 4,4e^{j53^0} = 4,4 \cdot \cos 53^0 + j4,4 \sin 53^0 = 2,64 + j3,52 \text{ (A)}$$

$$\bar{I} = \bar{I}_1 + \bar{I}_2 + \bar{I}_3 = 2 + 4,38 - j2,23 + 2,64 + j3,52 = 9,02 + j1,29 \text{ (A)}$$

yoki

$$\bar{I} = \sqrt{9,02^2 + 1,29^2} e^{j \arctg \frac{1,29}{9,02}} = \sqrt{83,02} e^{j8^0} \text{ (A)}$$

bu yerda, $\varphi = \arctg \frac{1,29}{9,02} = 8^0$.

4. Agar kompleks sonlar ishlatilmasa tok \bar{I} vektor diagramma qurish yo'li bilan aniqlanadi. Masshtab tanlab, zanjirning hamma tarmoqlari uchun umumiy bo'lgan kuchlanish vektoriga nisbatan toklar vektorini chizamiz.

$\varphi_1 = 0^0$ bo'lganligi uchun \bar{I}_1 toki kuchlanish bilan ustma-ust tushadi.

\bar{I}_2 tok vektori kuchlanishdan $\varphi_2 = \arctg \frac{X_L}{R_2} = \arctg \frac{20}{40} = 27^0$

burchakka orqada qoladi.

\bar{I}_3 tok vektori kuchlanishdan:

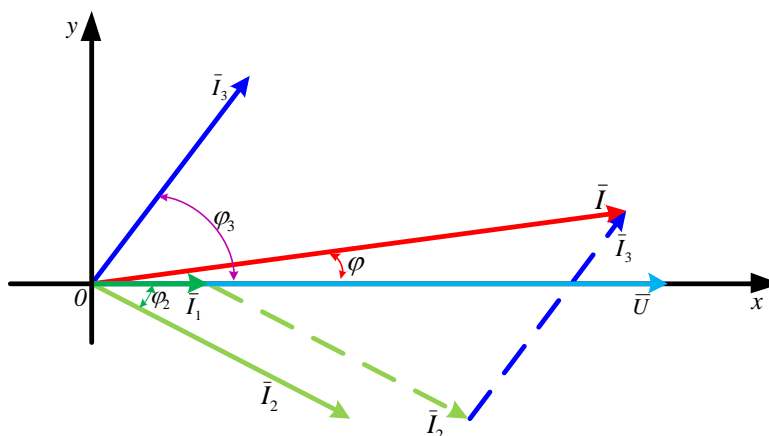
$$\varphi_3 = \arctg \frac{X_L - X_C}{R} = \arctg \frac{-X_C}{R_3} = \arctg \left(-\frac{40}{30} \right) = -53^\circ \quad \text{oldinda}$$

keladi.

Shu uchala vektorni qo‘shish natijasida \vec{I} tok vektorini hosil qilamiz.

Diagrammadan $I = 9,1 \text{ A}$ ga va $\varphi = 8^\circ$ ga tengligini aniqlaymiz.

Masshtab: $m_U = 20 \frac{\text{V}}{\text{sm}}, m_I = 1 \frac{\text{A}}{\text{sm}}$.



Endi zanjirdagi aktiv, reaktiv va to‘la quvvatlarini aniqlaymiz.

$$P = I_1^2 \cdot R_1 + I_2^2 \cdot R_2 + I_3^2 \cdot R_3 = U \cdot I \cdot \cos \varphi = 220 \cdot 9,1 \cdot \cos 8^\circ = 220 \cdot 9,1 \cdot 0,99 = 1981,98 \text{ (W)}$$

$$Q = I_2^2 \cdot X_{L2} - I_3^2 \cdot X_C = U \cdot I \cdot \sin \varphi = 220 \cdot 9,1 \cdot \sin 8^\circ = 220 \cdot 9,1 \cdot 0,14 = 280,3 \text{ (VAr)}$$

$$S = \sqrt{P^2 + Q^2} = U \cdot I = 220 \cdot 9,1 = 2002 \text{ (VA)}$$

yoki,

$$S = UI = 220 \cdot 9,1 e^{-j8^\circ} = 2002 e^{-j8^\circ} = 1981,98 - j280,3 \text{ (VA)}$$

2.2-жадвал

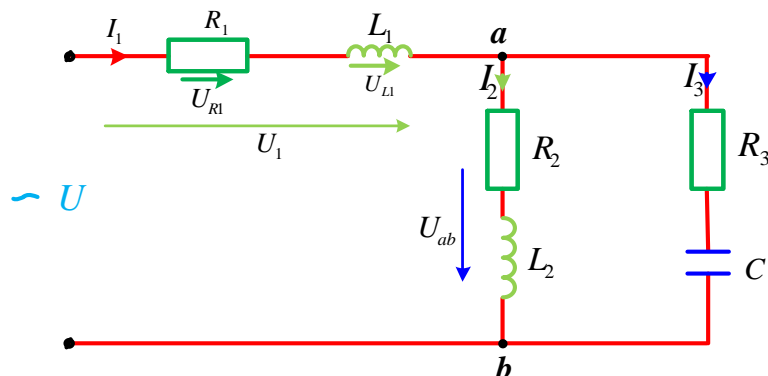
Variant	R_1	R_2	R_3	L	C
№	Ω	Ω	Ω	H	mkF
1	20	10	6	0,032	398
2	30	20	40	0,127	106
3	50	5	8	0,016	398
4	20	10	6	0,0255	212
5	40	15	20	0,0318	127

6	20	25	30	0,0796	90,9
7	25	30	8	0,111	530
8	25	15	12	0,048	199
9	30	12	20	0,051	265
10	20	6	20	0,0255	106
11	40	10	10	0,0637	318
12	20	15	15	0,0796	159
13	40	40	25	0,0965	106
14	40	30	30	0,127	159
15	30	40	20	0,127	318
16	25	15	10	0,0318	212
17	20	6	8	0,016	530
18	10	8	25	0,0318	127
19	20	12	15	0,051	159
20	20	15	10	0,0796	212
21	30	20	30	0,048	106
22	25	30	40	0,0955	106
23	20	20	10	0,0637	318
24	30	40	30	0,127	90,9
25	15	6	30	0,0255	79,6
26	16	9	20	0,016	159
27	20	30	10	0,127	212
28	25	20	20	0,111	127
29	30	15	12	0,048	199
30	40	16	8	0,038	530

d) Chastotasi $f = 50 \text{ Hz}$, kuchlanishi $U = 220 \text{ V}$ bo'lgan sinusoidal tok manbaiga $R_1 = 5 \Omega$, $L_1 = 16 \text{ mH}$, $R_2 = 4 \Omega$, $L_2 = 25,5 \text{ mH}$ parametrlariga ega bo'lgan g'altaklar va $R_3 = 6 \Omega$, $C = 398 \text{ mkF}$ kondensator sinusoidal tok manbaiga ikkita g'altak va kondensator aralash ulangan.

1. Zanjir tarmoqlaridagi toklarni va kuchlanishlarni aniqlang.
2. Zanjirning aktiv, reaktiv va to'la quvvatlarini aniqlang.

3. Vektor diagrammasini quring.



Yechilishi:

1. Zanjirni kompleks sonlar yordamida hisoblaymiz. Iste'molchilar aralash ulangani uchun zanjirning to'la qarshiligi quyidagicha aniqlansin:

$$\underline{Z} = \underline{Z}_1 + \frac{\underline{Z}_2 \cdot \underline{Z}_3}{\underline{Z}_2 + \underline{Z}_3}.$$

bu yerda, \underline{Z}_1 - 1- tarmoqning to'la qarshiligi:

$$\begin{aligned} \underline{Z}_1 &= R_1 + jX_{L1} = R_1 + j\omega L_1 = 5 + j314 \cdot 16 \cdot 10^{-3} = 5 + j5 \\ &= \sqrt{5^2 + 5^2} e^{j \arctg \frac{5}{5}} = 7,07 e^{j45^\circ} (\Omega). \end{aligned}$$

\underline{Z}_2 -2- tarmoqning to'la qarshiligi:

$$\begin{aligned} \underline{Z}_2 &= R_2 + jX_{L2} = R_2 + j\omega L_2 = 4 + j314 \cdot 16 \cdot 10^{-3} = 4 + j8 \\ &= \sqrt{4^2 + 8^2} e^{j \arctg \frac{8}{4}} = 8,9 e^{j63^\circ} (\Omega). \end{aligned}$$

\underline{Z}_3 - 3- tarmoqning to'la qarshiligi:

$$\begin{aligned} \underline{Z}_3 &= R_3 + j(X_{L3} - X_C) \\ X_{L3} &= 0 \\ \underline{Z}_3 &= R_3 - jX_C = R_3 - j \frac{1}{\omega C} = 6 - \frac{10^6}{314 \cdot 318} = 6 - j10 \\ &= \sqrt{6^2 + 10^2} e^{j \arctg \left(\frac{-10}{6} \right)} = 11,7 e^{-j59^\circ} (\Omega). \end{aligned}$$

Butun zanjirning to'la qarshiligi:

$$\begin{aligned} \underline{Z} &= \underline{Z}_1 + \frac{\underline{Z}_2 \cdot \underline{Z}_3}{\underline{Z}_2 + \underline{Z}_3} = 5 + j5 + \frac{(4 + j8) \cdot (6 - j10)}{4 + j8 + 6 - j10} = 5 + j5 + \frac{104 + j8}{10 - j2} \\ &= \\ &= 5 + j5 + \frac{(104 + j8) \cdot (10 + j2)}{(10 - j2) \cdot (10 + j2)} = 5 + j5 + \frac{1024 + j288}{104} = \end{aligned}$$

$$= 5 + j5 + 9,85 + j2,77 = 14,85 + j7,77 =$$

$$= \sqrt{14,85^2 + 7,77^2} e^{j \arctg\left(\frac{7,77}{14,85}\right)} = 16,7 e^{j27^0} (\Omega).$$

Zanjirning tarmoqlanmagan qismidagi tok:

$$\underline{i} = \frac{\underline{U}}{\underline{Z}} = \frac{220}{16,7 e^{j27^0}} = 13,17 e^{-j27^0} (A),$$

bu tok, \underline{Z}_1 qarshiligida $\underline{U}_1 = \underline{i}_1 \cdot \underline{Z}_1$ kuchlanishning pasayishini hosil qiladi.

$$\underline{U}_1 = \underline{i}_1 \cdot \underline{Z}_1 = 13,17 e^{-j27^0} \cdot 7,07 e^{j45^0} = 93,12 e^{j18^0} (V).$$

\underline{Z}_2 va \underline{Z}_3 qarshiliklar parallel ulangani uchun ulardagi kuchlanishning pasayishi bir xil bo'lib $\underline{U}_{ab} = \underline{i} \cdot \underline{Z}_{2-3}$ ga teng,

bu yerda,

$$\underline{Z}_{2-3} = \frac{\underline{Z}_2 \cdot \underline{Z}_3}{\underline{Z}_2 + \underline{Z}_3} = \frac{(4 + j8) \cdot (6 - j10)}{4 + j8 + 6 - j10} = \frac{104 + j8}{10 - j2}$$

$$= \frac{(104 + j8) \cdot (10 + j2)}{(10 - j2) \cdot (10 + j2)} = \frac{1024 + j288}{104} = 9,85 + j2,77$$

$$= \sqrt{9,85^2 + 2,77^2} e^{j \arctg\left(\frac{2,77}{9,85}\right)} = 10,2 e^{j15,7^0} (\Omega).$$

Kuchlanishning pasayishi:

$$\underline{U}_{ab} = \underline{i} \cdot \underline{Z}_{2-3} = 13,17 e^{-j27^0} \cdot 10,2 e^{j15,7^0} = 134,3 e^{-j11,3^0} (V).$$

Kuchlanish \underline{U}_{ab} va \underline{Z}_2 va \underline{Z}_3 qarshiliklar ma'lum bo'lgani uchun \underline{i}_2 va \underline{i}_3 toklarni aniqlaymiz:

$$\underline{i}_2 = \frac{\underline{U}_{ab}}{\underline{Z}_2} = \frac{134,3 e^{-j11,3^0}}{8,9 e^{j63^0}} = 15,1 e^{-j74,3^0} (A)$$

$$\underline{i}_3 = \frac{\underline{U}_{ab}}{\underline{Z}_3} = \frac{134,3 e^{-j11,3^0}}{11,7 e^{-j59^0}} = 11,5 e^{j47,7^0} (A).$$

Zanjirdagi aktiv, reaktiv va to'la quvvatlarni aniqlaymiz:

Aktiv quvvatlar:

$$P_1 = I_1^2 \cdot R_1 = 13,17^2 \cdot 5 = 867,2 (W)$$

$$P_2 = I_2^2 \cdot R_2 = 15,1^2 \cdot 4 = 912 (W)$$

$$P_3 = I_3^2 \cdot R_3 = 11,5^2 \cdot 6 = 793,5 (W)$$

$$P = I_1^2 \cdot R_1 + I_2^2 \cdot R_2 + I_3^2 \cdot R_3 = P_1 + P_2 + P_3$$

$$P = 867,2 + 912 + 793,5 = 2572,7 (W)$$

Reaktiv quvvatlar

$$Q_1 = I_1^2 \cdot X_{L1} = 13,17^2 \cdot 5 = 867,2 \text{ (VAr)}$$

$$Q_2 = I_2^2 \cdot X_{L2} = 15,1^2 \cdot 8 = 1824,08 \text{ (VAr)}$$

$$Q_3 = I_3^2 \cdot (-X_C) = -11,5^2 \cdot 10 = -1322,5 \text{ (VAr)}$$

3-tarmoqdagi zanjir aktiv va sig‘im xarakterli bo‘lgani uchun bu tarmoqning reaktiv quvvati minus ishora bilan olinadi, sababi u sig‘imga tegishlidir:

$$Q = I_1^2 \cdot X_{L1} + I_2^2 \cdot X_{L2} + I_3^2 \cdot (-X_C) = Q_1 + Q_2 + Q_3$$

$$Q = 867,2 + 1824,08 - 1322,5 = 1368,78 \text{ (VAr)}.$$

To‘la quvvat:

$$S = P + jQ = 2572,7 + j1368,78 \text{ (VA)},$$

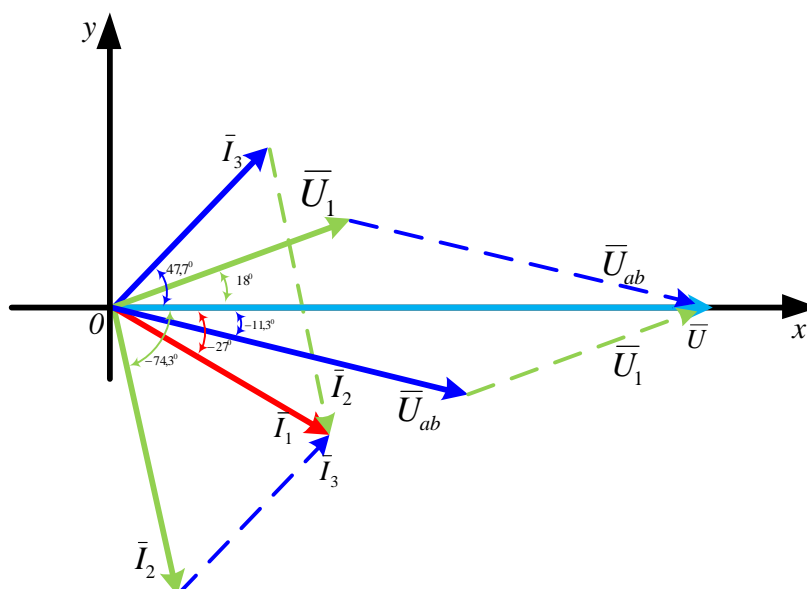
yoki uning moduli quyidagiga teng

$$S = \sqrt{P^2 + Q^2} = \sqrt{2572,7^2 + 1368,78^2} = 2914,16 \text{ (VA)}.$$

Vektor diagramma quramiz.

Manba kuchlanishining boshlang‘ich fazasini 0 ga teng deb olamiz. Masshtab tanlab shu masshtablarda tok va kuchlanishlar vektorini quramiz.

Masshtab: $m_U = 20 \frac{\text{V}}{\text{sm}}, m_I = 3 \frac{\text{A}}{\text{sm}}.$



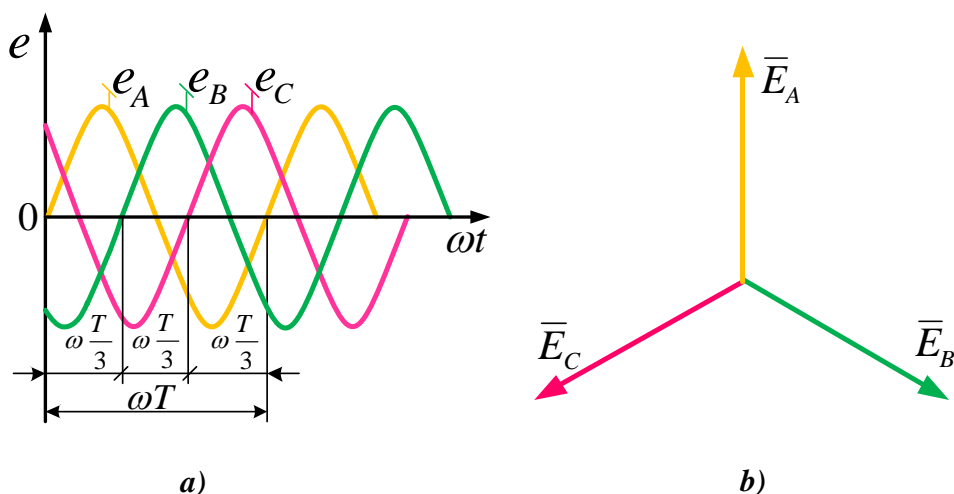
2.3-Jadval

Variant	R ₁	R ₂	R ₃	L ₁	L ₂	C
№	Ω	Ω	Ω	mH	mH	mkF
1	10	6	20	25,5	16	106
2	15	12	20	48	51	265
3	10	10	6	25,5	25,5	212
4	5	15	20	127	31,8	127
5	13	12	20	127	51	265
6	10	20	40	63,7	127	106
7	14	10	6	63,7	31,8	398
8	12	5	8	63,7	16	398
9	16	15	20	79,6	31,8	127
10	10	25	30	48	79,6	90,9
11	12	10	20	48	96	106
12	20	30	8	-	111	530
13	15	15	15	-	79,6	159
14	25	20	10	-	48	159
15	10	30	15	-	48	127
16	16	30	8	38,2	63,7	318
17	12	20	-	38,2	63,7	106
18	20	40	-	38,2	960	79,6
19	5	40	-	16	79,6	199
20	8	15	-	16	31,8	199
21	10	30	20	16	127	199
22	15	15	10	16	79,6	159
23	20	8	15	16	31,8	159
24	30	10	25	127	48	159
25	35	25	30	127	96	159
26	10	15	15	48	16	212
27	12	-	25	48	111	212
28	15	-	20	48	63,7	212
29	20	-	5	48	25,5	212
30	20	-	20	79,6	63,7	127

3. UCH FAZALI O‘ZGARUVCHAN TOK ELEKTR ZANJIRLARI

3.1. Uch fazali EYuK, kuchlanish va tok.

Fazalari bilan 120° farq qiluvchi, chastota va amplitudalari bir xil bo‘lgan uchta bir fazali sinusoidal o‘zgaruvchan tok zanjiriga - **uch fazali tok sistemalari** yoki **zanjirlari** deyiladi



3.1-rasm.

Amplituda va chastotalari bir xil bo‘lgan, ammo bir-birlaridan faza bo‘yicha 2 ga (yoki $\frac{T}{3}$ davrga) farqlanuvchi quyidagi sinusoidal o‘zgaruvchan EYuK larning analitik ifodasi:

$$\left. \begin{aligned} e_A &= E_m \sin \omega t \\ e_B &= E_m \sin\left(\omega t - \frac{2\pi}{3}\right) \\ e_C &= E_m \sin\left(\omega t - \frac{4\pi}{3}\right) \end{aligned} \right\} .$$

Uch fazali kuchlanish va tok sistemasi uchun ham quyidagi ifodalarni yozish mumkin:

$$\left. \begin{aligned} u_A &= U_m \sin \omega t \\ u_B &= U_m \sin\left(\omega t - \frac{2\pi}{3}\right) \\ u_C &= U_m \sin\left(\omega t - \frac{4\pi}{3}\right) \end{aligned} \right\} \cdot \left. \begin{aligned} i_A &= I_m \sin \omega t \\ i_B &= I_m \sin\left(\omega t - \frac{2\pi}{3}\right) \\ i_C &= I_m \sin\left(\omega t - \frac{4\pi}{3}\right) \end{aligned} \right\} . \quad (3.1)$$

Demak, uch fazali EYuK, kuchlanish va toklarning o'zgarish qonuniyatlari bir xil ekan.

3.2. Manba va iste'molchilarni to'rt simli yulduz usulida ulash.

Generator va iste'molchi fazalarining oxirgi uchlarini tegishlicha O va O' nuqtalarga ulash "yulduz" usulida ulash deyiladi (3.2-rasm). Bunday ulash usuli " λ " belgisi bilan belgilanadi. O va O' nuqtalar generator va iste'molchining nolinchi (yoki neytral) nuqtalari deyiladi. Ana shu nuqtalarni birlashtiruvchi sim nolinchi (yoki neytral) sim deyiladi.

Manba va iste'molchining bir nomli fazalarining bosh uchlarini birlashtiruvchi $A - A', B - B'$ va $C - C'$ simlar liniya simlari deyiladi. Ana shu simlardan o'tadigan I_A, I_B, I_C toklar liniya toklari deyiladi va ular I_L deb belgilanadi.

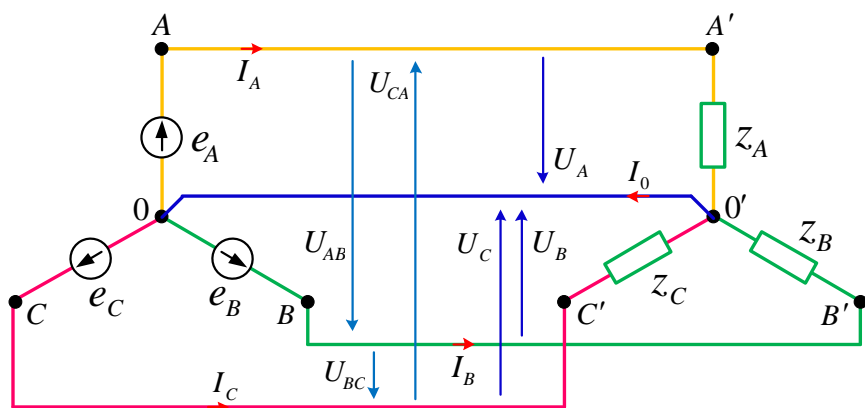
Manba va iste'molchining bir nomli fazalaridan o'tadigan I_A, I_B, I_C toklar faza toklari deyiladi va ular I_F deb belgilanadi. Yulduz usuli bilan ulashda liniya va faza toklari o'zaro teng bo'ladi:

$$I_L = I_F \quad (3.2)$$

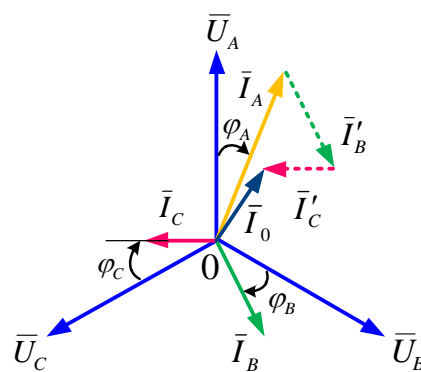
$$I_A = \frac{U_A}{Z_A}; \quad I_B = \frac{U_B}{Z_B}; \quad I_C = \frac{U_C}{Z_C} \quad \text{yoki} \quad I_F = \frac{U_F}{Z_F}$$

$$\cos \varphi_A = \frac{R_A}{Z_A}; \quad \cos \varphi_B = \frac{R_B}{Z_B}; \quad \cos \varphi_C = \frac{R_C}{Z_C}; \quad \text{yoki} \quad \cos \varphi_F = \frac{R_F}{Z_F}$$

$$\sin \varphi_A = \frac{X_A}{Z_A}; \quad \sin \varphi_B = \frac{X_B}{Z_B}; \quad \sin \varphi_C = \frac{X_C}{Z_C} \quad \text{yoki} \quad \sin \varphi_F = \frac{X_F}{Z_F}$$



3.2-rasm.



3.3-rasm.

Nolinchi simdan oʻtadigan tok I_0 tarzda belgilanadi. Kirxgofning birinchi qonuniga muvofiq nolinchi simdagi tok liniya (yoki faza) toklarining geometrik yigʻindisiga teng, yaʼni

$$\bar{I}_0 = \bar{I}_A + \bar{I}_B + \bar{I}_C \quad (3.3)$$

3.2-rasmdagi sxema uch fazali zanjirning toʻrt simli sistemasi (yoki nol simli yulduz usulida ulash sxemasi) deyiladi.

$$U_L = \sqrt{3}U_F \quad (3.4)$$

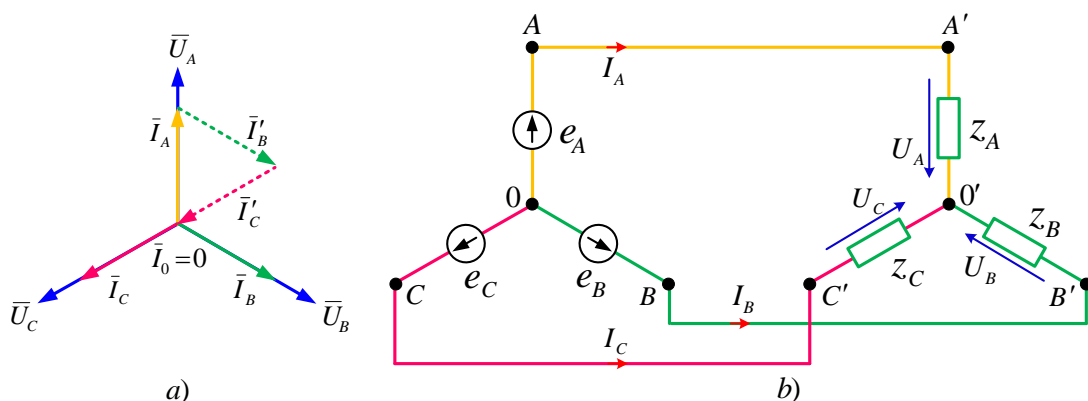
Demak, elektr isteʼmolchilari yulduz usulida ulanganda liniya kuchlanishi faza kuchlanishidan $\sqrt{3}$ marta katta boʻlar ekan.

3.3. Manba va isteʼmolchilarni uch simli yulduz usulida ulash.

Simmetrik yuklamada liniya toklarining geometrik yigʻindisi nolga teng, yaʼni

$$\bar{I}_0 = \bar{I}_A + \bar{I}_B + \bar{I}_C = 0 \quad (3.5)$$

(3.5) ifodaga mos vektor diagramma 3.4 a -rasmda koʻrsatilgan. Ushbu vektorlar diagrammasidan koʻrinadiki, simmetrik yuklamada nolinchi simdan tok oʻtmaydi.

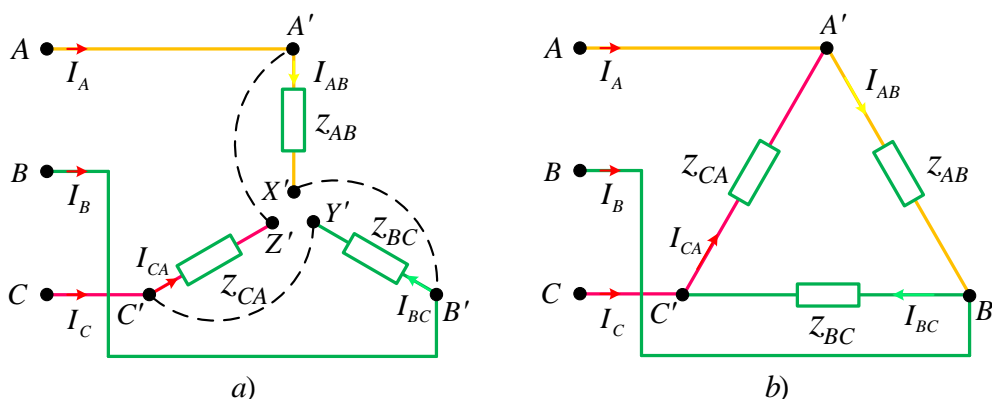


3.4-rasm.

Simmetrik yuklamada faza va liniya kuchlanishlari o‘zaro teng bo‘ladi. Uch simli yulduz usulida ulashda $U_L = \sqrt{3}U_F$ ifoda yuklama simmetrik bo‘lgandagina kuchga ega.

3.4. Iste‘molchilarni uchburchak usulida ulash.

Uch fazali tok iste‘molchilarini *uchburchak usulida* ulash deb, birinchi fazaning oxirgi uchi X' ni ikkinchi fazaning bosh uchi B' bilan, ikkinchi fazaning oxirgi uchi Y' ni uchinchi fazaning bosh uchi C' bilan va uchinchi fazaning oxirgi uchi Z' ni birinchi fazaning bosh uchi A' bilan ulashga aytiladi (3.5 a-rasm). Bunday ulash usuli “ Δ ” belgisi bilan ko‘rsatiladi.



3.5-rasm.

Bunday ulash sxemasida liniya va fazaning kuchlanishlari o‘zaro teng bo‘ladi:

$$U_L = U_F.$$

$$I_L = \sqrt{3}I_F$$

Demak, iste‘molchilarni uchburchak usulida ulaganda liniya toklari faza toklaridan $\sqrt{3}$ marta katta bo‘lar ekan.

Iste‘molchining faza qarshiliklaridan o‘tayotgan I_{AB}, I_{BC}, I_{CA} toklarga faza toklari deyiladi. Liniya simlaridan o‘tayotgan toklar I_A, I_B, I_C esa liniya toklari deyiladi.

Faza kuchlanishlari va qarshiliklarining ma‘lum qiymatlarida har bir faza tokini va quvvat ko‘effitsiyentini hisoblab topish mumkin:

$$I_{AB} = \frac{U_{AB}}{Z_{AB}}; I_{BC} = \frac{U_{BC}}{Z_{BC}}; I_{CA} = \frac{U_{CA}}{Z_{CA}}$$

$$\cos \varphi_{AB} = \frac{R_{AB}}{Z_{AB}}; \cos \varphi_{BC} = \frac{R_{BC}}{Z_{BC}}; \cos \varphi_{CA} = \frac{R_{CA}}{Z_{CA}},$$

yoki umumiy holda,

$$I_F = \frac{U_F}{Z_F}; \cos \varphi_F = \frac{R_F}{Z_F}; \sin \varphi_F = \frac{X_F}{Z_F}.$$

Masalan, pasportida “ $\lambda/\Delta - 380/220$ ” yozuvi bo‘lgan uch fazali asinxron motorning liniya kuchlanishi $U_L = 380 V$ li tarmoqqa yulduz usulida, liniya kuchlanishi $U_L = 220 V$ li tarmoqqa esa uchburchak usulida ulash mumkin. Agar $U_L = 380 V$ li tarmoqqa uchburchak usulida ulanilsa, $U_{nom} = U_L = 380 V$ bo‘lib, stator chulg‘amlari kuyib ketadi. Agar $U_L = 220 V$ li tarmoqqa yulduz usulida ulanilsa, $U_{nom} = U_F = 127 V$ bo‘lib, motor to‘la quvvat bilan ishlamaydi.

3.5. Uch fazali zanjirlarning quvvati.

Bir fazali tok zanjirida ko‘rilgan aktiv, reaktiv va to‘la quvvat tushunchalari uch fazali tok zanjirida ham o‘z ma’nosini to‘la saqlaydi.

1. Yuklama nosimmetrik bo‘lganda har bir fazaning quvvati alohida hisoblab topiladi.

Yulduz λ usulida ulanganda

$$I_A \neq I_B \neq I_C$$

Uchburchak Δ usulida ulanganda

$$I_{AB} \neq I_{BC} \neq I_{CA}$$

Aktiv quvvat

$$P_A = U_A \cdot I_A \cdot \cos \varphi_A$$

$$P_{AB} = U_{AB} \cdot I_{AB} \cdot \cos \varphi_{AB}$$

$$P_B = U_B \cdot I_B \cdot \cos \varphi_B$$

$$P_{BC} = U_{BC} \cdot I_{BC} \cdot \cos \varphi_{BC}$$

$$P_C = U_C \cdot I_C \cdot \cos \varphi_C$$

$$P_{CA} = U_{CA} \cdot I_{CA} \cdot \cos \varphi_{CA}$$

Uch fazali zanjirning aktiv quvvati alohida fazalar aktiv quvvatlarining yig'indisiga teng, ya'ni:

$$P_{\lambda} = P_A + P_B + P_C \qquad P_{\Delta} = P_{AB} + P_{BC} + P_{CA}$$

Reaktiv quvvat

$$\begin{aligned} Q_A &= U_A \cdot I_A \cdot \sin \varphi_A & Q_{AB} &= U_{AB} \cdot I_{AB} \cdot \sin \varphi_{AB} \\ Q_B &= U_B \cdot I_B \cdot \sin \varphi_B & Q_{BC} &= U_{BC} \cdot I_{BC} \cdot \sin \varphi_{BC} \\ Q_C &= U_C \cdot I_C \cdot \sin \varphi_C & Q_{CA} &= U_{CA} \cdot I_{CA} \cdot \sin \varphi_{CA} \end{aligned}$$

Uch fazali zanjirning reaktiv quvvati alohida fazalar reaktiv quvvatlarining yig'indisiga teng, ya'ni:

$$Q_{\lambda} = Q_A + Q_B + Q_C \qquad Q_{\Delta} = Q_{AB} + Q_{BC} + Q_{CA}$$

To'la quvvat

$$\begin{aligned} S_A &= \sqrt{P_A^2 + Q_A^2} & S_{AB} &= \sqrt{P_{AB}^2 + Q_{AB}^2} \\ S_B &= \sqrt{P_B^2 + Q_B^2} & S_{BC} &= \sqrt{P_{BC}^2 + Q_{BC}^2} \\ S_C &= \sqrt{P_C^2 + Q_C^2} & S_{CA} &= \sqrt{P_{CA}^2 + Q_{CA}^2} \end{aligned}$$

Uch fazali zanjirning to'la quvvati

$$S_{\lambda} = \sqrt{P_{\lambda}^2 + Q_{\lambda}^2} \qquad S_{\Delta} = \sqrt{P_{\Delta}^2 + Q_{\Delta}^2}$$

2. Yuklama simmetrik bo'lganda

$$\begin{aligned} I_A &= I_B = I_C = I_F & I_{AB} &= I_{BC} = I_{CA} = I_F \\ \varphi_A &= \varphi_B = \varphi_C = \varphi_F & \varphi_{AB} &= \varphi_{BC} = \varphi_{CA} = \varphi_F \end{aligned}$$

Aktiv quvvat

$$P_A = P_B = P_C = P_F \qquad P_{AB} = P_{BC} = P_{CA} = P_F$$

$$P_F = U_F \cdot I_F \cdot \cos \varphi_F$$

$$P_F = U_F \cdot I_F \cdot \cos \varphi_F$$

$$P_\lambda = 3U_F \cdot I_F \cdot \cos \varphi_F = 3P_F$$

$$P_\Delta = 3U_F \cdot I_F \cdot \cos \varphi_F = 3P_F$$

Reaktiv quvvat

$$Q_A = Q_B = Q_C = Q_F$$

$$Q_{AB} = Q_{BC} = Q_{CA} = Q_F$$

$$Q_F = U_F \cdot I_F \cdot \sin \varphi_F$$

$$Q_F = U_F \cdot I_F \cdot \sin \varphi_F$$

$$Q_\lambda = 3U_F \cdot I_F \cdot \sin \varphi_F = 3Q_F$$

$$Q_\Delta = 3U_F \cdot I_F \cdot \sin \varphi_F = 3Q_F$$

To'la quvvat

$$S_A = S_B = S_C = S_F$$

$$S_{AB} = S_{BC} = S_{CA} = S_F$$

$$S_F = U_F \cdot I_F$$

$$S_F = U_F \cdot I_F$$

$$S_\lambda = 3U_F \cdot I_F = 3S_F$$

$$S_\Delta = 3U_F \cdot I_F = 3S_F$$

Aktiv, reaktiv va to'la quvvatlarni aniqlashning quyidagi umumlashgan formulalarini yozish mumkin:

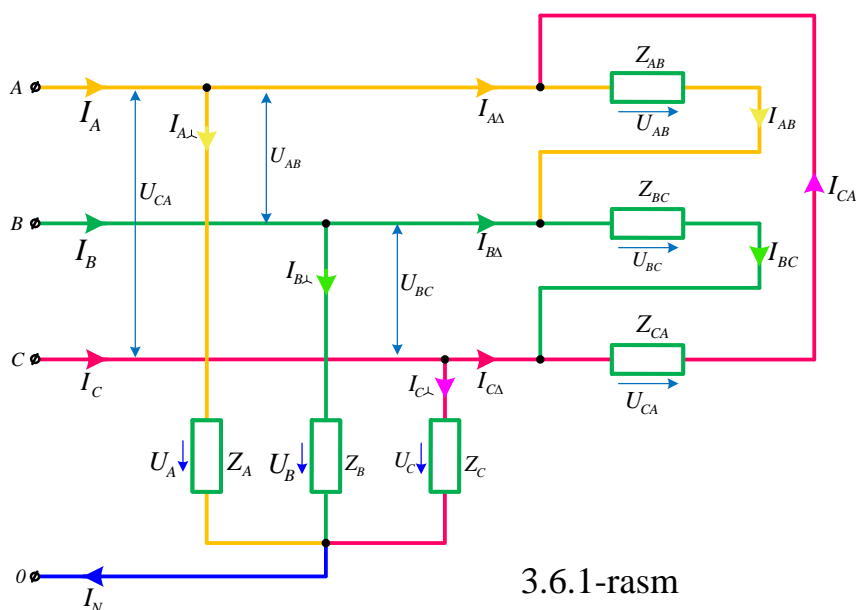
$$P = \sqrt{3}U_L I_L \cos \varphi_F; \quad Q = \sqrt{3}U_L I_L \sin \varphi_F; \quad S = \sqrt{3}U_L I_L.$$

3.6. Amaliy mashg'ulotlar uchun masalalar va hisob grafik ishlari.

3.1-masala: Liniya kuchlanishi $U_L = 360 V$ bo'lgan simmertik uch fazali generatorga tegishli noli simli yulduz va uchburchaklik usulida ikki grupp iste'molchi ulangan 3.6.1-rasmda iste'molchilarning faza qarshiliklari quyidagicha:

$$Z_1 = 55 \Omega, Z_2 = 33 - j44 \Omega, Z_{12} = Z_{23} = Z_{31} = Z_{\Delta} = 38e^{j30^\circ} \Omega$$

(liniya va neytral simlarning qarshiliklari e'tiborga olinmaydi); butun sistemasining to'la, aktiv va reaktiv quvvatlari aniqlansin.



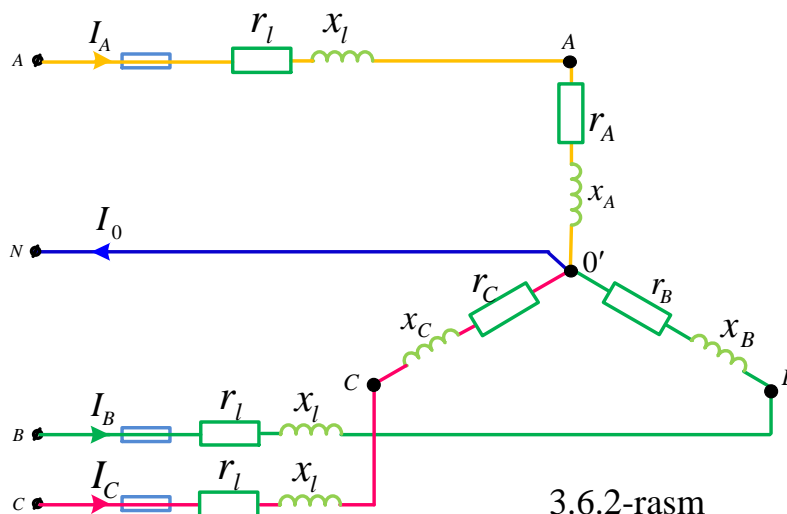
3.6.1-rasm

3.2-masala: Liniya kuchlanishi $U_L = 380 V$ bo'lgan uch fazali tok tarmog'iga aktiv-induktiv xarakterdagi iste'molchilar to'rt simli yulduz sxemada ulangan. Ularning aktiv quvvatlari $P_A = 3 kW$, $P_B = 3,6 kW$, $P_C = 4,4 kW$,

Quvvat koeffitsiyentlari esa tegishli $\cos\varphi_A = 0,8$; $\cos\varphi_B = 0,86$; $\cos\varphi_C = 0,9$ ni tashkil etadi. Fazalardagi va nolinchisiimdagi toklar, hamda uch fazali zanjirning aktiv, reaktiv va to'la quvvatlari aniqlansin. Masshtabda tok va kuchlanishlarning vektor diagrammasi qurilsin.

3.3-masala: Qarshiliklari $r_A = 17 \Omega$, $r_B = 14 \Omega$, $r_C = 13 \Omega$, $x_{LA} = 22 \Omega$, $x_{LB} = 18 \Omega$, $x_{LC} = 28 \Omega$ bo'lgan iste'molchi liniya kuchlanishi $U_L = 380 V$ li uch fazali tok tarmog'iga to'rt simli yulduz sxemada ulangan 3.6.2-rasmda. Har bir liniya simining aktiv va induktiv qarshiliri $r_l = 10 \Omega$, $x_{Ll} = 2 \Omega$ ni tashkil etadi. Fazalardagi va nolinchisiimdagi

toklar, hamda uch fazali zanjirning aktiv, reaktiv va to‘la quvvatlari aniqlansin.

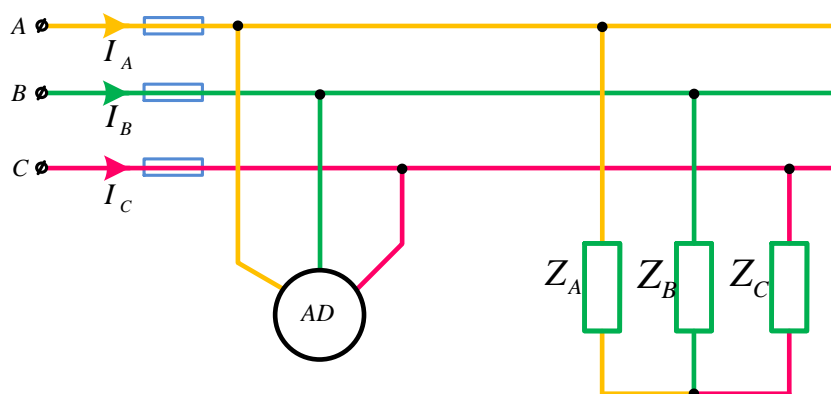


3.4-masala: Liniya kuchlanishi $U_L = 380\text{ V}$ bo‘lgan uch fazali tok tarmog‘iga elektr pech ulangan. Pechning qizdirish elementlari yulduz sxemada ulansa, tarmoqdan iste‘mol qiladigan quvvat $P = 5\text{ kW}$ bo‘ladi. Agar pechning qizdirish elementlari uchburchak sxemada ulansa, faza toklari va tarmoqdan iste‘mol qilinadigan quvvat qanday o‘zgaradi?

3.5-masala: Liniya kuchlanishi $U_L = 380\text{ V}$ bo‘lgan uch fazali tok tarmog‘iga quvvat koeffitsiyenti $\cos\varphi = 0,8$ va $P = 5\text{ kW}$ quvvat iste‘mol qiluvchi induksion pech ulangan. Pechning qizdirish elementlari yulduz sxema ulangan. Har bir fazaning parametrlari aniqlansin.

3.6-masala: Liniya kuchlanishi $U_L = 380\text{ V}$ bo‘lgan uch fazali tok tarmog‘iga induksion pech ulangan. Pechning qizdirish elementlari yulduz sxemada ulanganda tarmoqdan iste‘mol qilgan quvvati $P = 7\text{ kW}$ ($\cos\varphi = 0,8$) ga teng. Agar qizdirish elementlari uchburchak sxemada ulansa, pechning tarmoqdan iste‘mol qiladigan aktiv, reaktiv va to‘la quvvati qanday o‘zgaradi?

3.7-masala: Liniya kuchlanishi $U_L = 380\text{ V}$ bo‘lgan uch fazali tok tarmog‘iga asinxron dvigatel va qizdirgich pechi ulangan (3.6.3-rasm).

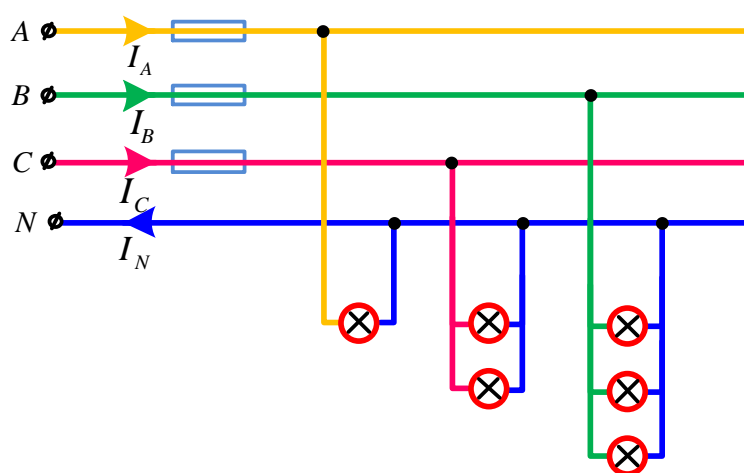


3.6.3-rasm

Quvvat koeffitsiyenti $\cos\varphi = 0,8$ da dvigatelning iste'mol qiladigan quvvati $P_{DV} = 16 \text{ kW}$, pechning iste'mol qiladigan quvvati $P_P = 6 \text{ kW}$. Uch fazali zanjirning quvvati va barcha qurilmalarning quvvat koeffitsiyenti aniqlansin.

3.8-masala: To'rt simli elektr tarmog'iga uch fazali iste'molchi ulangan. Liniya toklari $I_A = I_B = I_C = 10 \text{ A}$. Quvvat koeffitsiyentlari $\cos\varphi_A = 0,6$; $\cos\varphi_B = 0,75$; $\cos\varphi_C = 0,9$. Yuklamani simmetrik deb hisoblash mumkinmi?

3.9-masala: Liniya kuchlanishi $U_L = 220 \text{ V}$ bo'lgan to'rt simli elektr tarmog'iga yoritgich yuklama ulangan (3.6.4-rasm). Yoritgichlarning fazalardagi iste'mol quvvati: $P_A = 5,5 \text{ kW}$, $P_B = 6,6 \text{ kW}$, $P_C = 2,75 \text{ kW}$



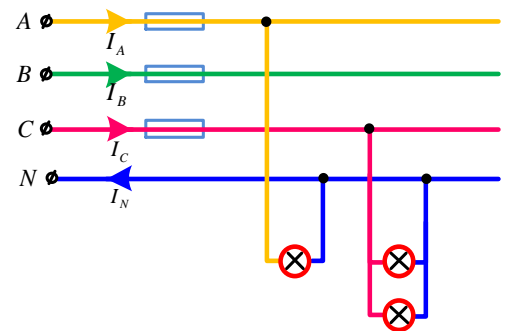
3.6.4-rasm

Quyidagilar aniqlansin:

1. Fazalardagi toklar
2. Vektor diagrammadan tok I_0 ning qiymati.
3. Tarmoqdan isteʼmol qilinayotgan umumiy quvvat
4. Masshatbda tok va kuchlanishlarning vektor diagrammasi qurilsin.

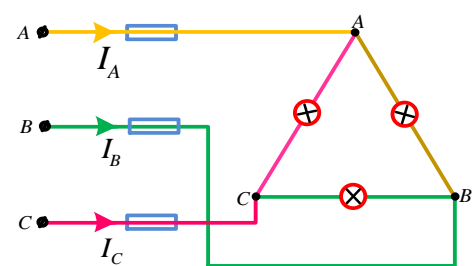
3.10-masala: Quvvati $P = 2,4 kW$ boʻlgan uch fazali simmetrik isteʼmolchi yulduz sxemada ulangan. Faza kuchlanishi $U_F = 120 V$. Fazalardan birortasiga $R = 24 \Omega$ aktiv qarshilik ketma-ket ulanganda neytral simdagi tok aniqlansin.

3.11-masala: Har birining quvvati $P_A = 2,2 kW$, $P_B = 4,4 kW$ boʻlgan ikkita lampalar guruhi liniya kuchlanishi $U_L = 380 V$ li uch fazali tok tarmogʻiga ulangan (3.6.5-rasm). Fazalardagi toklarning kattaligi va neytral sim uzilganda har bir guruh qismlaridagi kuchlanish aniqlansin. Masshtabda tok va kuchlanishlarning vektor diagrammasi qurilsin.



3.6.5-rasm

3.12-Masala: Har birining quvvati 1000 vattdan boʻlgan uchta elektr lampa, liniya kuchlanishi $U_L = 220 V$ li uch fazali tok tarmogʻiga ulangan (3.6.6-rasm). 1. B fazadagi saqlagich kuyganda har bir lampa qismlaridagi kuchlanish aniqlansin. Masshtabda vektor diagrammasi qurilsin. 2. Lampalardan biri kuyganda liniya simlaridagi toklar aniqlansin. Masshtabda vektor diagrammasi qurilsin.



3.6.6-rasm

3.13-masala: Yulduz sxemada ulangan uch fazali iste'molchining faza qarshiliklari o'zaro teng: $R_A = X_B = X_C$. Faza kuchlanishlarini simmetrik qilish uchun neytral sim kerakmi ?

3.14-masala: Liniya kuchlanishlari $U_L = 380 V$ bo'lgan simmetrik uch fazali generatorga, yulduz sxemada biriktirilgan uch fazali asimmetrik iste'molchi neytral simsiz ulangan. Iste'molchining ikkita fazasidagi kuchlanish bir-biriga teng. $U_b = U_c = 237,5 V$ Uchinchi fazadagi kuchlanish U_a va neytralning siljishi aniqlansin.

3.15-masala: Uch fazali simmetrik aktiv quvvat iste'molchisi faza kuchlanishi $U_F = 220V$ bo'lgan to'rt simli elektr tarmog'iga yulduz sxemada ulangan. Liniya simlaridagi toklar $I_A = I_B = I_C = 10 A$. Bitta liniya simi, undan so'ng ikkita liniya simi uzilganda neytral simdagi tok aniqlansin.

3.16-masala: Asinxron dvigatelning stator chulg'ami yulduz sxemada ulangan bo'lib, liniya kuchlanishi $U_L = 380 V$ bo'lgan uch fazali tok tarmog'iga ulangan. Dvigatelning tarmoqdan iste'mol qiladigan quvvati $P_1 = 162 kW$ quvvat koeffitsiyenti $\cos\varphi = 0,78$.

Fazalardagi kuchlanish va tok aniqlansin:

1. Dvigatel normal ishlaganda.
2. C fazadagi saqlagich kuyganda
3. C fazadagi qisqa tutashuv sodir bo'lganda

Barcha uchta rejim uchun vektor diagramma chizilsin.

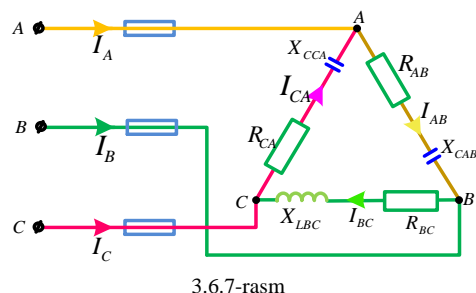
3.17-masala: Binoning yoritish qurilmasida nominal quvvati $60 W$ bo'lgan 150 ta elektr lampa bor. Har birining nominal kuchlanishi $U_{nom} = 220 V$. Lampalar liniyalar kuchlanishi $U_L = 220 V$ bo'lgan uch fazali tarmoqqa ulangan va simmetrik yuklamani hosil qiladi. Faza va liniya toklarini, har qaysi fazadagi va barcha zanjirdagi yoritish yuklamasining quvvatini aniqlang. $U_{nom} = 127 V$, tarmoqdagi kuchlanish esa $U_l = 220 V$ deb hisoblab, masalani yeching.

3.18-masala: Uch fazali transformatorga har qaysining quvvati $40 W$ dan bo‘lgan elektr lampalar ulangan, har qaysi fazada 100 tadan lampa bor va elektr dvigatelning nominal quvvati $P_{nom} = 10 kW$, FIK $\eta = 85\%$, $\cos\varphi = 0,8$. Quyidagi ikki holda liniyadagi toklarni aniqlang: a) elektr iste‘molchilar yulduz usulida ulangan, transformator ikkilamchi chulg‘aming liniya kuchlanishi $U_L = 380 V$, b) elektr iste‘molchilar uchburchak usulida ulangan, transformatorning ikkinchi chulg‘amidagi liniya kuchlanishi $U_L = 220 V$.

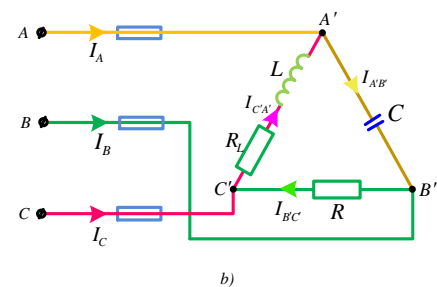
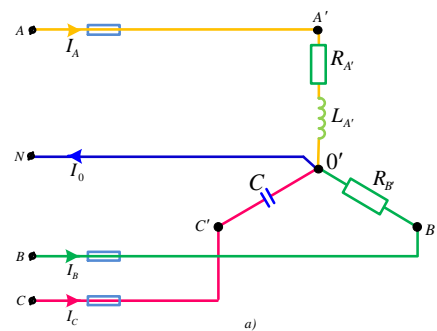
3.19-masala: Liniya kuchlanishi $380 V$ bo‘lgan uch fazali to‘rt simli oltita bir xil elektr lampa ($P_{nom} = 100 W$, $U_{nom} = 220 V$, fazada ikkitadan) ulangan. Lampalarning hammasi ulanganda (yuklama simmetrik), shuningdek, quyidagi ikki holda nosimmetrik yuklamada simlardagi (liniya simlari va nolinci simdagi) toklarni aniqlang: a) har qaysi fazadan navbatma-navbat ikkitadan lampa o‘chiriladi, b) har qaysi fazadan bittadan lampa o‘chiriladi.

3.20-masala: Lampalar ($P_{nom} = 100 W$, $U_{nom} = 220 V$) liniya kuchlanishi $220 V$ bo‘lgan har qaysi fazada ikkitadan uch fazali uch simli tarmoqqa ulanadi. Lampalar bir vaqtda ulangandagi (simmetrik yuklama), shuningdek, ikki holda nosimmetrik yuklamadagi faza toklari bilan liniya toklarini aniqlang; a) har qaysi fazadan bittadan lampa uziladi, b) har qaysi fazadan ikkitadan lampa uziladi.

3.21-masala: Liniya kuchlanishlari $220 V$ bo‘lgan uch fazali tarmoqqa nosimmetrik yuklama uchburchak usulda ulangan (3.6.7- rasm). Yuklamaning parametrlari; $R_{ab} = 2,3 \Omega$ va $X_{Cab} = -1,5 \Omega$; $R_{bc} = 1,8 \Omega$ va $X_{Lbc} = 3,1 \Omega$; $R_{ca} = 1,3 \Omega$; $X_{Cca} = -2,7 \Omega$ Faza va liniya toklari, har bir fazaning quvvat koeffitsiyenti aniqlansin.

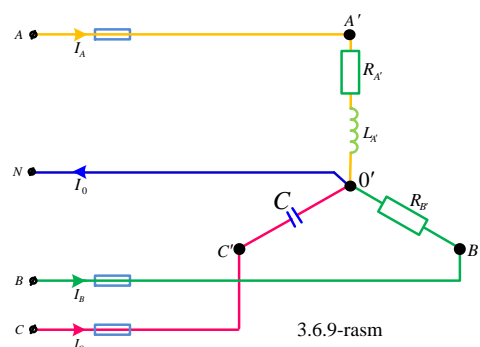


3.22-masala: Liniya kuchlanishi 220 V , chastotasi 50 Hz bo'lgan uch fazali tarmoqqa nosimmetrik uch fazah yuklama awal yulduz, keyin esa uchburchak usulda ulangan (3.6.8-rasm). Agar $R = 10\ \Omega$, $R_L = 5\ \Omega$; $L = 60\text{ mH}$; $C = 100\text{ mkF}$ bo'lsa, yuklamaning aktiv va reaktiv quvvati aniqlansin.



3.6.8-rasm

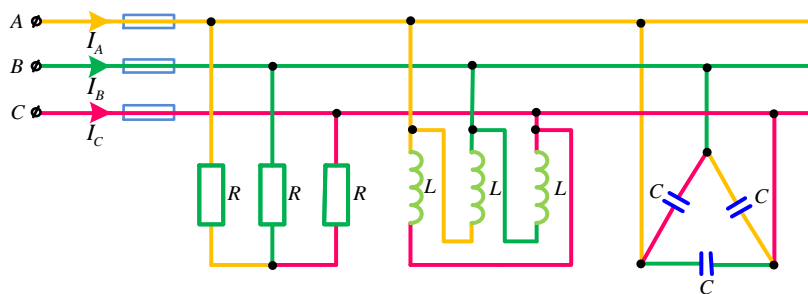
3.23-masala: Neytral simli liniya kuchlanishi 380 V li uch fazali tarmoqqa rezistor $R = 13\ \Omega$, aktiv qarshiligi $R_g = 1,5\ \Omega$, induktivligi $L = 20\text{ mH}$ bo'lgan real g'altak va sig'imi $C = 150\text{ mkF}$ li kondensator yulduz usulda ulangan (3.6.9-rasm). Fazalardan va neytral simdan o'tuvchi toklar aniqlansin.



3.6.9-rasm

3.24-Masala: Liniya kuchlanishi 380 V li uch fazali elektr tarmog'iga uchta bir xil $L_1 = L_2 = L_3 = 50\text{ mH}$ induktiv g'altaklarga ketma-ket $R_a = 33\ \Omega$, $R_b = 19\ \Omega$, $R_c = 27\ \Omega$ li rezistorlar uchburchak usulda ulangan. Liniya toklari aniqlansin.

3.25-Masala: Simmetrik aktiv-induktiv xarakterli iste'molchilar $R_L = 5\ \Omega$ va $X_L = 15\ \Omega$ hamda aktiv $R = 20\ \Omega$ qarshilikli uch fazali tarmoqqa ulangan (3.6.10-rasm). Agar liniya kuchlanishini 220 V , chastotani 50 Hz va quvvat koeffitsiyentini $0,97$ gacha oshirish lozim bo'lsa, ulanadigan C kondensatorlarning sig'imi topilsin.



3.6.10-rasm

3.26-masala: Liniya kuchlanishi 220 V , chastotasi 50 Hz bo'lgan uch fazali tarmoqqa parametrlari $R = 10\ \Omega$, $R_L = 8\ \Omega$ va $X_L = 17\ \Omega$ bo'lgan ikkita simmetrik yuklama hamda sig'imi $C = 150\text{ m}\mu\text{F}$ li kondensatorlar batareyasi ulangan (3.6.10-rasm). Kondensatorlar ulanishidan avvalgi va ulanishidan keyingi hollar uchun liniya toklari aniqlansin.

3.27-masala: Quvvatlari $P_a = 2,2\text{ kW}$, $P_b = 4,4\text{ kW}$ bolgan ikkita chug'lanma lampalar guruhi liniya kuchlanishi $U_{lin} = 380\text{ V}$ neytral simli uch fazali manbaga ulangan. Fazalardagi toklarning qiymatlari va neytral sim uzilganda har bir guruh qismalaridagi kuchlanish aniqlansin. Tok va kuchlanishlarning vektor diagrammasi qurilsin.

3.28-masala: Qiymatlari bir xil va aktiv qarshilikdan iborat bo'lgan iste'molchilar neytral simsiz yulduz sxemada ulangan. Agar A fazasida qisqa tutashuv sodir bo'lsa A liniya simidagi tokining B liniya simidagi tokiga nisbati topilsin.

3.29-masala: Liniya kuchlanishi $U_L = 220\text{ V}$ bo'lgan uch fazali tok tarmog'iga nosimmetrik iste'molchi uchburchak sxemada ulangan. Iste'molchi fazasining parametrlari quyidagicha: $r_{AB} = 20\ \Omega$, $r_{BC} = 20\ \Omega$, $r_{CA} = 20\ \Omega$, $x_{LAB} = 40\ \Omega$, $x_{LBC} = 30\ \Omega$, $x_{LCA} = 20\ \Omega$, $x_{CAB} = 20\ \Omega$, $x_{CBC} = 50\ \Omega$, $x_{CCA} = 20\ \Omega$. Iste'molchilarning faza va liniya toklari, butun zanjirning aktiv, reaktiv va to'la quvvatlari aniqlansin. Masshtabda tok va kuchlanishning vektor diagrammasi qurilsin.

3.30-masala: Chastotasi $f = 50\text{ Hz}$, liniya kuchlanishi $U_L = 380\text{ V}$ bo'lgan uch fazali tok tarmog'iga reaktiv quvvatlari $Q_A = Q_B = Q_C = 1800\text{ VAR}$ dan bo'lgan aktiv-sig'im xarakterdagi simmetrik iste'molchi uchburchak sxemada ulangan. Fazalardagi tok va kuchlanishlar oralaridagi faza siljish burchaklari tegishlicha $\varphi_A = \varphi_B = \varphi_C = 60^\circ$. Iste'molchining

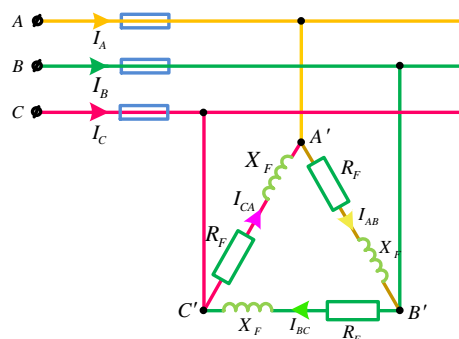
faza va liniya toklari, fazalarining aktiv, reaktiv va to'la qarshiliklari, shuningdek kondensatorning sig'imi aniqlansin.

3.31-masala: Cho'lg'amlari yulduz sxemada ulangan uch fazali generatorning faza kuchlanishi nosimmetrik va 127 V ga teng. Generatorga energiya iste'molchisi uchburchak sxemasiga muvofiq ulangan. Iste'molchining faza qarshiliklari: $Z_{AB} = 22\ \Omega$, $Z_{BC} = 19\ \Omega$, $Z_{CA} = 19\ \Omega$.

1. Faza va liniya toklarni aniqlang. Masshtab bo'yicha kuchlanishlar va toklarning vektor diagrammasini chizing.

2. C faza simi uzilgan hol uchun xuddi shu qiymatlarni aniqlang. Diagramma chizing.

3.32-masala: Liniya kuchlanishi 380 V li uch fazali elektr tarmog'iga uchta bir xil $R_F = 33\ \Omega$, $X_{LF} = 4\ \Omega$ uchburchak ulangan. Faza va liniya simlardagi quvvatni aniqlang. Oqim va kuchlanishning vektor diagrammasini tuzing.



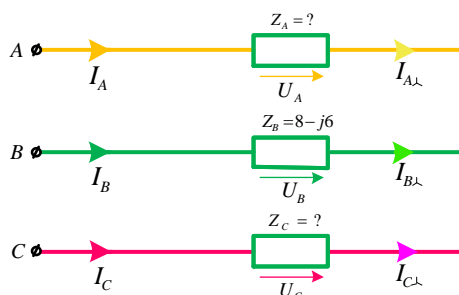
3.6.11-rasm

3.33-masala: Berilishi $\dot{U}_A = 100\text{ V}$, $\dot{U}_B = 100 \cdot e^{-j90^\circ}\text{ V}$, $\dot{U}_C = 150 \cdot e^{j135^\circ}\text{ V}$, $Z_B = 8 - j6\ \Omega$

Z_A, Z_C (joriy simmetriyaga bog'liq) -?
 U_{AB}, U_{BC}, U_{CA} -?

Topografik kuchlanish diagrammasini tuzing ?

Oqimlarning vektor diagrammasini tuzing ?



3.6.12-rasm

HISOB-GRAFIK ISHINI BAJARISHGA NA'MUNA

Uch fazali tok zanjirlarini hisoblash.

Chastotasi $f = 50 \text{ Hz}$, liniya kuchlanishi $U_L = 380 \text{ V}$ bo'lgan uch fazali tok tarmog'iga elektr energiyasining iste'molchilari yulduz va uchburchak sxemada ulangan (3.6.13-rasm).

Quyidagilarni bajaring:

1. Yulduz sxemada biriktirilgan iste'molchilarning $I_{A\lambda}, I_{B\lambda}, I_{C\lambda}$ faza toklarini aniqlang;

2. Uchburchak sxemada biriktirilgan iste'molchilarning I_{AB}, I_{BC}, I_{CA} faza toklari va $I_{A\Delta}, I_{B\Delta}, I_{C\Delta}$ liniya toklarini aniqlang (agar fazalar simmetrik rejimda yuklangan bo'lsa);

3. Yulduz va uchburchak sxemada biriktirilgan iste'molchilar toki va kuchlanishlarining yagona vektor diagrammasini biror tanlangan masshtabda chizing;

4. Yulduz sxemada biriktirilgan iste'molchilarning nolinci (neytral) simdagi I_0 tokining, shuningdek, uchburchak sxemada biriktirilgan iste'molchilarning $I_{A\Delta}, I_{B\Delta}, I_{C\Delta}$ liniya toklarining qiymatlarini grafik ravishda vektor diagrammadan aniqlang.

5. Vektor diagrammadan grafik ravishda A_1, A_2, A_3 ampermetrlarning ko'rsatishlarini, ya'ni liniyadagi umumiy toklar I_1, I_2 va I_3 lar aniqlansin.

6. Analitik usul bilan yulduz va uchburchak sxemada biriktirilgan iste'molchilarning aktiv P , reaktiv Q va to'la S quvvatlarini hisoblang. Bunda induktiv xarakterdagi reaktiv quvvat Q_L ni plyus "+" ishora bilan, sig'im xarakterdagi reaktiv quvvat Q_C ni esa minus "-" ishora bilan ko'rsatish qabul qilingan.

7. Vektor diagrammadan grafik usul bilan olingan ma'lumotlar bo'yicha uch fazali zanjirning aktiv, reaktiv (ishorasini ko'rsatib) va to'la quvvatlarini aniqlang.

8. Uch fazali zanjirning analitik va grafik usul bilan hisoblangan to'la quvvatlarini taqqoslang.

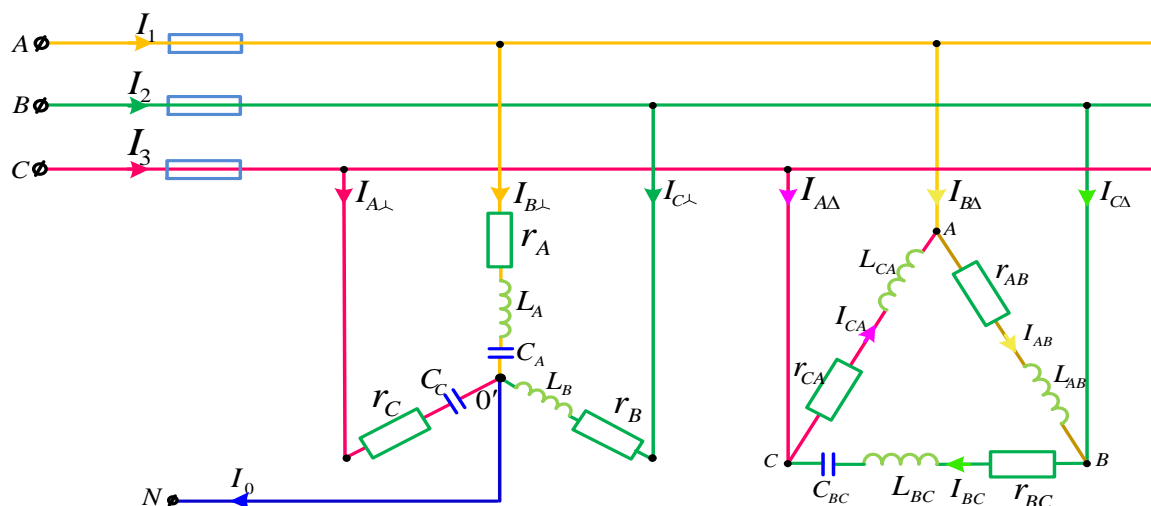
Yulduz sxemada biriktirilgan iste'molchilarning parametrlari:

r_A	r_B	r_C	L_A	L_B	L_C	C_A	C_B	C_C
Ω	Ω	Ω	mH	mH	mH	mkF	mkF	mkF
15	10	10	32	-12	-	318	-	852

Uchburchak sxemada biriktirilgan iste'molchilarning parametrlari:

r_{AB}	r_{BC}	r_{CA}	L_{AB}	L_{BC}	L_{CA}	C_{AB}	C_{BC}	C_{CA}
Ω	Ω	Ω	mH	mH	mH	mkF	mkF	mkF
9	13	13	28	48	24	-	419	-

Hisoblanadigan uch fazali zanjirning sxemasi 3.6.13-rasmda ko'rsatilgan.



3.6.13-rasm

Yechilishi:

1. Yulduz sxemada biriktirilgan iste'molchilarning faza toklarini aniqlash. Buning uchun avval har bir fazaning to'la qarshiliklarini hisoblaymiz:

$$z_A = \sqrt{r_A^2 + \left(\omega L_A - \frac{1}{\omega C_A}\right)^2} = \sqrt{15^2 + \left(314 \cdot 31 \cdot 10^{-3} - \frac{10^6}{314 \cdot 318}\right)^2}$$

$$=$$

$$= \sqrt{15^2 + (10 - 10)^2} = 15 \Omega$$

$$Z_A = \sqrt{r_B^2 + (\omega L_B)^2} = \sqrt{10^2 + (314 \cdot 12 \cdot 10^{-3})^2} = \sqrt{10^2 + 3,76^2}$$

$$= 10,7 \Omega$$

$$Z_C = \sqrt{r_C^2 + \left(\frac{1}{\omega C_C}\right)^2} = \sqrt{10^2 + \left(\frac{1}{314 \cdot 852 \cdot 10^{-6}}\right)^2} = \sqrt{10^2 + 3,74^2} =$$

$$= 10,7 \Omega$$

Iste'molchilar yulduz sxemada biriktirilganda uning faza kuchlanishi:

$$U_F = \frac{U_L}{\sqrt{3}} = \frac{380}{1,73} = 220 V$$

$U_A = U_B = U_C = U_F$ ekanligini hisobga olganda fazalardagi toklar:

$$I_{A\lambda} = \frac{U_A}{Z_A} = \frac{220}{15} = 14,67 A$$

$$I_{B\lambda} = \frac{U_B}{Z_B} = \frac{220}{10,7} = 20,56 A$$

$$I_{C\lambda} = \frac{U_C}{Z_C} = \frac{220}{10,7} = 20,56 A.$$

2. Uchburchak sxemada biriktirilgan iste'molchilarning faza toklarini aniqlash.

Buning uchun avval har bir fazaning to'la qarshiligini alohida hisoblash kerak:

$$Z_{AB} = \sqrt{r_{AB}^2 + (\omega \cdot L_{AB})^2} = \sqrt{9^2 + (314 \cdot 28 \cdot 10^{-3})^2} = \sqrt{9^2 + 8,8^2}$$

$$= \sqrt{158,4} = 12,6 \Omega$$

$$Z_{BC} = \sqrt{r_{BC}^2 + \left(\omega \cdot L_{BC} - \frac{1}{\omega C_{BC}}\right)^2} =$$

$$= \sqrt{13^2 + \left(314 \cdot 48 \cdot 10^{-3} - \frac{1}{314 \cdot 419 \cdot 10^{-6}}\right)^2} =$$

$$= \sqrt{13^2 + (15,1 - 7,6)^2} = \sqrt{13^2 + 7,5^2} = 15 \Omega$$

$$Z_{CA} = \sqrt{r_{CA}^2 + (\omega \cdot L_{CA})^2} = \sqrt{13^2 + (314 \cdot 24 \cdot 10^{-3})^2} = \sqrt{13^2 + 7,54^2}$$

$$= \sqrt{225,8} = 15 \Omega$$

Iste'molchilar uchburchak sxemada biriktirilganda liniya va faza kuchlanishlari o'zaro teng, ya'ni $U_{AB} = U_{BC} = U_{CA} = U_L = 380 V$. U holda fazalardagi toklar:

$$I_{AB} = \frac{U_{AB}}{Z_{AB}} = \frac{380}{12,6} = 30,16 A,$$

$$I_{BC} = \frac{U_{BC}}{Z_{AB}} = \frac{380}{15} = 25,3 A,$$

$$I_{CA} = \frac{U_{CA}}{Z_{CA}} = \frac{380}{15} = 25,3 A.$$

3. Yulduz va uchburchak sxemada biriktirilgan iste'molchilar tok va kuchlanishlarining yagona vektor diagrammasini biror tanlangan masshtabda quramiz.

a) Vektor diagrammani avval yulduz sxemada biriktirilgan iste'molchilar toki va kuchlanishlarining vektor diagrammasini qurishdan boshlaymiz. Buning uchun kuchlanish masshtabini $m_u = 5 V/mm$, tok masshtabini esa $m_i = 1 A/mm$ qilib tanlab olamiz. Ixtiyoriy 0 nuqtadan (3.6.14-rasm) A fazaning faza kuchlanishi vektorini vertikal qo'yamiz.

So'ngra, \bar{U}_A faza kuchlanishiga nisbatan soat strelkasining harakat yo'nalishi bo'yicha 120° va 240° dan so'ng tegishli \bar{U}_B va \bar{U}_C faza kuchlanishlarining vektorlari chiziladi. Nolinchi sim bo'lganda faza kuchlanishlarining vektorlari chiziladi. Nolinchi sim bo'lganda faza kuchlanishlar U_A , U_B , U_C o'zaro teng bo'lib, uch fazali simmetrik sistemani tashkil qiladi. Faza kuchlanishlari vektorlarining oxirini biriktirib U_{AB} , U_{BC} va U_{CA} liniya kuchlanishlarining uchburchagini hosil qilamiz (3.6.14-rasm).

Iste'molchilarning tok vektorlarini qurish uchun, avval bu toklarning tegishli faza kuchlanishlariga nisbatan faza siljish burchaklarini aniqlaymiz.

Iste'molchining A fazasida $\omega L_A = \frac{1}{\omega C}$ bo'lgani uchun reaktiv kuchlanishlar U_{LA} , U_{CA} bir-birlarini kompensatsiya qiladi va shu tufayli zanjir aktiv xarakterga ega bo'ladi. Shuning uchun

$$\cos \varphi_A = \frac{r_A}{Z_A} = \frac{15}{15} = 1 \text{ yoki } \varphi_A = 0^\circ.$$

Demak, bu fazada \bar{I}_A tokining vektori \bar{U}_A faza kuchlanishining vektori bilan bir xil yo'nalishda bo'ladi.

Iste'molchining B fazasidagi zanjir aktiv-induktiv xarakterga ega bo'lib,

$$\cos \varphi_B = \frac{r_B}{Z_B} = \frac{10}{10,7} = 0,93 \text{ yoki } \varphi_B = 21^\circ 30'$$

ga teng bo'ladi va \bar{I}_B tok vektori \bar{U}_B kuchlanish vektoridan faza bo'yicha $21^\circ 30'$ ga orqada qoladi.

Iste'molchining C fazasidagi zanjir aktiv-sig'im xarakteriga ega bo'lib,

$$\cos \varphi_C = \frac{r_C}{z_C} = \frac{10}{10,7} = 0,93 \text{ yoki } \varphi_C = 21^\circ 30'$$

ga teng bo'ladi va \bar{I}_C tok vektori \bar{U}_C kuchlanish vektoridan faza jihatidan $21^\circ 30'$ ga oldin keladi.

Endi iste'molchilarning tok vektorlarini tegishli faza kuchlanishlariga nisbatan hisoblangan burchaklar ostida 0 nuqtadan boshlab chizamiz (3.6.14-rasm).

b) Yuqoridagiga o'xshash usul bilan uchburchak sxemada biriktirilgan iste'molchilar faza toklari I_{AB} , I_{BC} va I_{CA} ning tegishli faza kuchlanishlari U_{AB} , U_{BC} va U_{CA} larga nisbatan faza siljish burchaklari aniqlansin.

Iste'molchining AB fazasidagi zanjir aktiv-induktiv xarakterga ega bo'lib

$\cos \varphi_{AB} = \frac{r_{AB}}{z_{AB}} = \frac{9}{12,5} = 0,71$, u holda $\varphi_{AB} = 45^\circ$ ga teng bo'ladi va \bar{I}_{AB} tok vektori \bar{U}_{AB} kuchlanish vektoridan faza jihatdan 45° ga orqada qoladi.

Iste'molchining BC fazasidan $\omega L_{BC} > 1/\omega C_{BC}$, ya'ni $15,1 > 7,6$ bo'lgani uchun zanjir aktiv-induktiv xarakterga ega. Shuning uchun

$\cos \varphi_{BC} = \frac{r_{BC}}{z_{BC}} = \frac{13}{15} = 0,87$, u holda $\varphi_{BC} = 29^\circ 30'$ ga teng bo'ladi va \bar{I}_{BC} tok vektori \bar{U}_{BC} kuchlanish vektoridan faza jihatdan $29^\circ 30'$ ga orqada qoladi.

Iste'molchining CA fazasida ham zanjir aktiv-induktiv xarakterga ega bo'lib,

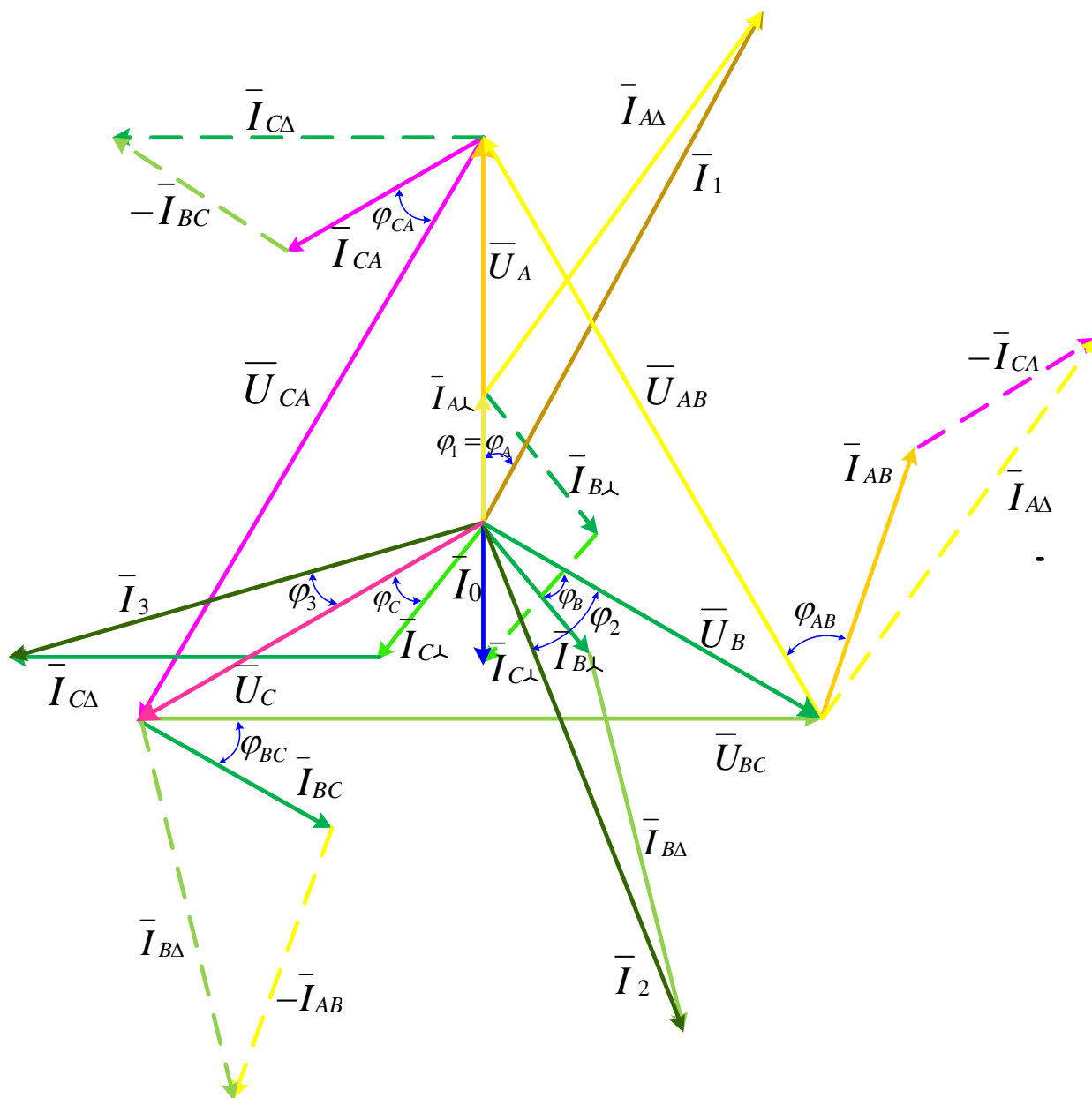
$\cos \varphi_{CA} = \frac{r_{CA}}{z_{CA}} = \frac{13}{15} = 0,87$, u holda $\varphi_{CA} = 29^\circ 30'$ ga teng bo'ladi va \bar{I}_{CA} tok vektori \bar{U}_{CA} kuchlanish vektoridan faza jihatdan $29^\circ 30'$ ga orqada qoladi.

Vektor diagrammada $\bar{I}_{AB}, \bar{I}_{BC}, \bar{I}_{CA}$, toklarining vektorlarini iste'molchilarning tegishli $\bar{U}_{AB}, \bar{U}_{BC}$ va \bar{U}_{CA} faza kuchlanishlari bo'yicha chizib chiqiladi (3.6.14-rasm).

4. Vektor diagrammadan (3.6.14-rasm) nolinch simdagi I_0 tokni va uchburchak sxemadagi $I_{A\Delta}, I_{B\Delta}$ va $I_{C\Delta}$ liniya toklarini aniqlash:

a) nolinch simdagi I_0 tok Kirxgofning birinchi qonuniga binoan faza toklarining geometrik (yoki vektorlar) yig'indisiga teng:

$$\bar{I}_0 = \bar{I}_{A\lambda} + \bar{I}_{B\lambda} + \bar{I}_{C\lambda}.$$



3.6.14-rasm

Uning haqiqiy qiymatini aniqlash uchun vektor \bar{I}_0 ning uzunligini o'lchab, uni tok masshtabiga ko'paytirish kerak, ya'ni $I_0 = I_{10} \cdot m_1 = 16mm \cdot 1A/mm = 16A$

b) uchburchak sxemada biriktirilgan iste'molchilarning $\bar{I}_{A\Delta}$, $\bar{I}_{B\Delta}$ va $\bar{I}_{C\Delta}$ liniya toklari Kirxgofning birinchi qonuniga binoan ma'lum faza toklari vektorlarining ayirmasiga teng (3.6.14-rasm):

$$\bar{I}_{A\Delta} = \bar{I}_{AB} - \bar{I}_{CA};$$

$$\bar{I}_{B\Delta} = \bar{I}_{BC} - \bar{I}_{AB};$$

$$\bar{I}_{C\Delta} = \bar{I}_{CA} - \bar{I}_{BC};$$

Demak, ularning qiymatlari $\bar{I}_{A\Delta}$, $\bar{I}_{B\Delta}$ va $\bar{I}_{C\Delta}$ vektorlarining uzunliklariga teng (chunki ixtiyoriy tanlangan tok masshtabida $1 \text{ mm} = 1A$); ya'ni

$$\bar{I}_{A\Delta} = 51 \text{ mm} \quad \text{yoki} \quad \bar{I}_{A\Delta} = 51A;$$

$$\bar{I}_{B\Delta} = 43,5 \text{ mm} \quad \text{yoki} \quad \bar{I}_{B\Delta} = 43,5A;$$

$$\bar{I}_{C\Delta} = 43,5 \text{ mm} \quad \text{yoki} \quad \bar{I}_{C\Delta} = 43,5A.$$

5. Vektor diagrammadan (5-rasm) A_1 , A_2 va A_3 ampermetrlarning ko'rsatishlarini, ya'ni I_1 , I_2 va I_3 toklarining qiymatlari aniqlanadi. Buning uchun yulduz sxemada biriktirilgan iste'molchilarning $I_{A\lambda}$, $I_{B\lambda}$ va $I_{C\lambda}$ faza toklarini uchburchak sxemada biriktirilgan iste'molchilarning $I_{A\Delta}$, $I_{B\Delta}$ va $I_{C\Delta}$ liniya toklari bilan Kirxgofning birinchi qonuniga muvofiq geometrik qo'shiladi:

$$\bar{I}_1 = \bar{I}_{A\lambda} + \bar{I}_{A\Delta};$$

$$\bar{I}_2 = \bar{I}_{B\lambda} + \bar{I}_{B\Delta};$$

$$\bar{I}_3 = \bar{I}_{C\lambda} + \bar{I}_{C\Delta}.$$

Demak, ularning qiymatlari \bar{I}_1 , \bar{I}_2 va \bar{I}_3 vektorlarining uzunliklariga teng (tanlangan tok masshtabi bo'yicha):

$$\bar{I}_1 = 65 \text{ mm} \quad \text{yoki} \quad I_1 = 65 A;$$

$$\bar{I}_2 = 63 \text{ mm} \quad \text{yoki} \quad I_2 = 63 A;$$

$$\bar{I}_3 = 58 \text{ mm} \quad \text{yoki} \quad I_3 = 58 A.$$

6. a) yulduz sxemada biriktirilgan iste'molchilarning aktiv, reaktiv va to'la quvvatlarini aniqlash.

Har bir fazaning aktiv quvvati:

$$P_A = U_A \cdot I_{A\lambda} \cdot \cos \varphi_A = 220 \cdot 14,67 \cdot 1 = 3227W = 3,23 kW;$$

$$P_B = U_B \cdot I_{B\lambda} \cdot \cos \varphi_B = 220 \cdot 20,56 \cdot 0,93 = 4207W = 4,2 kW;$$

$$P_C = U_C \cdot I_{C\lambda} \cdot \cos \varphi_C = 220 \cdot 20,56 \cdot 0,93 = 4207W = 4,2 kW.$$

Uchala fazaning aktiv quvvati:

$$P_\lambda = P_A + P_B + P_C = 3227 + 4207 + 4207 = 11641W = 11,64 kW.$$

Har bir fazaning reaktiv quvvati:

$$Q_A = U_A \cdot I_{A\lambda} \cdot \sin \varphi_A = 220 \cdot 14,66 \cdot 0 = 0;$$

$$Q_B = U_B \cdot I_{B\lambda} \cdot \sin \varphi_B = 220 \cdot 20,56 \cdot 0,37 = 1674 Var = 1,67 kVar;$$

$$Q_C = U_C \cdot I_{C\lambda} \cdot \sin \varphi_C = 220 \cdot 20,56 \cdot (-0,37) = -1674 Var = 1,67 kVar.$$

Uchala fazaning reaktiv quvvati:

$$Q_\lambda = Q_A + Q_B + Q_C = 0 + 1674 - 1674 = 0$$

Har bir fazaning to'la quvvati:

$$S_A = \sqrt{P_A^2 + Q_A^2} = \sqrt{3,23^2 + 0^2} = 3,23 kVA;$$

$$S_B = \sqrt{P_B^2 + Q_B^2} = \sqrt{4,2^2 + 1,67^2} = \sqrt{20,43} = 4,5 kVA;$$

$$S_C = \sqrt{P_C^2 + Q_C^2} = \sqrt{4,2^2 + 1,67^2} = \sqrt{20,43} = 4,5 kVA.$$

Uchala fazaning to'la quvvati:

$$S_\lambda = \sqrt{P_\lambda^2 + Q_\lambda^2} = \sqrt{11,64^2 + 0^2} = 11,64 kVA.$$

b) uchburchak sxemada biriktirilgan iste'molchilarning aktiv, reaktiv va to'la quvvatlari.

Har bir fazaning aktiv quvvati:

$$P_{AB} = U_{AB} \cdot I_{AB} \cdot \cos \varphi_{AB} = 380 \cdot 30,16 \cdot 0,71 = 8137W = 8,14 kW;$$

$$P_{BC} = U_{BC} \cdot I_{BC} \cdot \cos \varphi_{BC} = 380 \cdot 25,3 \cdot 0,887 = 8364W = 8,36 kW;$$

$$P_{CA} = U_{CA} \cdot I_{CA} \cdot \cos \varphi_{CA} = 380 \cdot 25,3 \cdot 0,87 = 8364W = 8,36 kW.$$

Uchala fazaning aktiv quvvati:

$$P_{\Delta} = P_{AB} + P_{BC} + P_{CA} = 8,14 + 8,36 + 8,36 = 24,86 kW.$$

Har bir fazaning reaktiv quvvati:

$$\begin{aligned} Q_{AB} &= U_{AB} \cdot I_{AB} \cdot \sin \varphi_{AB} = 380 \cdot 30,16 \cdot 0,71 = 8137VAr \\ &= 8,14k VAr; \end{aligned}$$

$$\begin{aligned} Q_{BC} &= U_{BC} \cdot I_{BC} \cdot \sin \varphi_{BC} = 380 \cdot 25,3 \cdot 0,49 = 4710VAr \\ &= 4,71 kVAr; \end{aligned}$$

$$Q_{CA} = U_{CA} \cdot I_{CA} \cdot \sin \varphi_{CA} = 380 \cdot 25,3 \cdot 0,49 = 4710VAr = 4,71 kVAr.$$

Uchala fazaning reaktiv quvvati:

$$Q_{\Delta} = Q_{AB} + Q_{BC} + Q_{CA} = 8,14 + 4,71 + 4,71 = 17,56 kVA;$$

Har bir fazaning to'la quvvati:

$$S_{AB} = \sqrt{P_{AB}^2 + Q_{AB}^2} = \sqrt{8,14^2 + 8,14^2} = 11,5 kVA;$$

$$S_{BC} = \sqrt{P_{BC}^2 + Q_{BC}^2} = \sqrt{8,36^2 + 4,71^2} = \sqrt{92,09} = 9,6 kVA;$$

$$S_{CA} = \sqrt{P_{CA}^2 + Q_{CA}^2} = \sqrt{8,36^2 + 4,71^2} = \sqrt{92,09} = 9,6 kVA.$$

Uchala fazaning to'la quvvati:

$$S_{\Delta} = \sqrt{P_{\Delta}^2 + Q_{\Delta}^2} = \sqrt{25,86^2 + 17,56^2} = 30,44 \text{ kVA}.$$

7. Vektor diagrammadan (3.6.14-rasm) olingan natijalar bo'yicha uch fazali zanjirning aktiv, reaktiv va to'la quvvatini grafik usulda aniqlash.

Buning uchun avval vektor diagrammadagi φ_1 , φ_2 va φ_3 burchaklar o'lchab olinadi.

$$\varphi_1 = 27^{\circ}30'; \quad \varphi_2 = 35^{\circ}30'; \quad \varphi_3 = 15^{\circ}.$$

Aniqlangan burchaklarning kosinuslari:

$$\cos \varphi_1 = 0,887; \quad \cos \varphi_2 = 0,871; \quad \cos \varphi_3 = 0,966.$$

Aniqlangan burchaklarning sinuslari:

$$\sin \varphi_1 = 0,462; \quad \sin \varphi_2 = 0,581; \quad \sin \varphi_3 = 0,258.$$

Har bir liniyaning aktiv quvvati:

$$P_1 = U_A \cdot I_1 \cdot \cos \varphi_1 = 220 \cdot 65 \cdot 0,887 = 1284W = 12,7 \text{ kW};$$

$$P_2 = U_C \cdot I_2 \cdot \cos \varphi_2 = 220 \cdot 633 \cdot 0,814 = 11282W = 11,3 \text{ kW};$$

$$P_3 = U_C \cdot I_3 \cdot \cos \varphi_3 = 220 \cdot 58 \cdot 0,966 = 12326W = 12,3 \text{ kW}.$$

Uchala liniyaning aktiv quvvati:

$$P_{gr} = P_1 + P_2 + P_3 = 12,7 + 11,3 + 12,3 = 36,3 \text{ kW}.$$

Har bir liniyaning reaktiv quvvati:

$$Q_1 = U_A \cdot I_1 \cdot \sin \varphi_1 = 220 \cdot 65 \cdot 0,462 = 6602VAr = 6,6 \text{ kVAr};$$

$$Q_2 = U_B \cdot I_2 \cdot \sin \varphi_2 = 220 \cdot 63 \cdot 0,581 = 8052VAr = 8,05 \text{ kVAr};$$

$$Q_3 = U_C \cdot I_3 \cdot \sin \varphi_3 = 220 \cdot 58 \cdot 0,258 = 3292VAr = 3,3 \text{ kVAr}.$$

Uchala liniyaning reaktiv quvvati:

$$Q_{gr} = Q_1 + Q_2 + Q_3 = 6,6 + 8,05 + 3,3 = 17,95 \text{ kVAr}.$$

Har bir liniyaning to'la quvvati:

$$S_1 = \sqrt{P_1^2 + Q_1^2} = \sqrt{12,7^2 + 6,6^2} = 14,3 \text{ kVA};$$

$$S_2 = \sqrt{P_2^2 + Q_2^2} = \sqrt{11,3^2 + 8,05^2} = \sqrt{192,5} = 13,9 \text{ kVA};$$

$$S_3 = \sqrt{P_3^2 + Q_3^2} = \sqrt{12,3^2 + 3,3^2} = \sqrt{162,2} = 12,8 \text{ kVA}.$$

Uchala liniyaning to'la quvvati:

$$S_{gr} = \sqrt{P_{gr}^2 + Q_{gr}^2} = \sqrt{36,3^2 + 17,95^2} = 40,94 \text{ kVA}.$$

8. Analitik va grafik usullar bilan aniqlangan quvvatlarni taqqoslash.

Buning uchun avval yulduz va uchburchak sxemada biriktirilgan iste'molchilarning birgalikdagi to'la quvvatlarini aniqlaymiz:

$$P_{AN} = P_\lambda + P_\Delta = 11,64 + 24,86 = 36,5 \text{ kW},$$

$$Q_{AN} = Q_\lambda + Q_\Delta = 0 + 17,6 = 17,6 \text{ kVAr},$$

$$S_{AN} = \sqrt{P_{AN}^2 + Q_{AN}^2} = \sqrt{36,5^2 + 17,6^2} = \sqrt{1637,68} = 40,52 \text{ kVA}$$

$$\Delta S = \frac{S_{AN} - S_{gr}}{S_{AN}} \cdot 100 = \frac{40,52 - 40,49}{40,52} \cdot 100 = \frac{+3,00}{40,47} = 0,07\%$$

Uch fazali zanjirlarni hisoblashga oid variantlar quyidagi 3.1,3.2-jadvallarda berilgan.

*Uch fazali zanjirning**Yulduz "Λ" sxemada biriktirilgan iste'molchilarning parametrlari:*

Variantlar№	r_A	r_B	r_C	L_A	L_B	L_C	C_A	C_B	C_C
	Ω	Ω	Ω	mH	mH	mH	mkF	mkF	mkF
1	20	25	-	-	115	76,4	106	199	133
2	25	20	16	80	-	95,5	-	159	212
3	-	50	30	96	76,4	57,3	71	-	-
4	60	-	35	159	51	127	27	-	52
5	65	-	15	-	38,4	-	127	80	177
6	-	20	45	96	127	144	127	-	76
7	10	-	30	112	38,4	-	91	159	-
8	20	28	10	143	89	66,9	318	-	-
9	30	40	20	-	63,6	76,4	71	-	106
10	35	-	10	-	127	48	318	188	-
11	30	15	40	159	-	95,5	106	80	177
12	35	20	14	96	51	163	-	88,5	64
13	20	-	30	-	-	115	127	-	96,5
14	55	25	40	64	102	-	64	159	82
15	20	40	10	127	38,4	57	-	66,4	106
16	50	-	30	64	96	-	318	133	88,5
17	25	40	30	127	80	-	159	-	133
18	15	40	-	48	140	96	91	-	-
19	35	50	15	63,6	153	48	318	199	152
20	50	-	-	127	-	127	-	127	133
21	35	30	40	-	-	66,9	318	-	159
22	40	50	25	-	64	112	106	72,4	-
23	-	10	30	127	-	66,9	91	133	-
24	40	10	25	63,6	115	-	106	159	-
25	55	-	30	-	64	153	-	133	88,5
26	10	36	-	143	-	115	91	114	71
27	50	-	10	32	127	-	318	100	80
28	15	10	25	127	-	86,4	80	114	318
29	-	10	40	112	80	57,3	-	99,5	106
30	40	15	-	112	127	66,9	80	-	177

*Uch fazali zanjirning**Uchburchak "Δ" sxemada biriktirilgan iste'molchilarning parametrlari:*

Variantlar№	r_{AB}	r_{BC}	r_{CA}	L_{AB}	L_{BC}	L_{CA}	C_{AB}	C_{BC}	C_{CA}
	Ω	Ω	Ω	mH	mH	mH	mkF	mkF	mkF
1	40	15	-	112	127	66,9	80	-	177
2	-	10	40	112	80	57,3	-	99,5	106
3	15	10	25	127	-	86,4	80	114	318
4	50	-	10	32	127	-	318	100	80
5	10	36	-	143	-	115	91	114	71
6	55	-	30	-	64	153	-	133	88,5
7	40	10	25	63,6	115	-	106	159	-
8	-	10	30	127	-	66,9	91	133	-
9	40	50	25	-	64	112	106	72,4	-
10	35	30	40	-	-	66,9	318	-	159
11	50	-	-	127	-	127	-	127	133
12	35	50	15	63,6	153	48	318	199	152
13	15	40	-	48	140	96	91	-	-
14	25	40	30	127	80	-	159	-	133
15	50	-	30	64	96	-	318	133	88,5
16	20	40	10	127	38,4	57	-	66,4	106
17	55	25	40	64	102	-	64	159	82
18	20	-	30	-	-	115	127	-	96,5
19	35	20	14	96	51	163	-	88,5	64
20	30	15	40	159	-	95,5	106	80	177
21	35	-	10	-	127	48	318	188	-
22	30	40	20	-	63,6	76,4	71	-	106
23	20	28	10	143	89	66,9	318	-	-
24	10	-	30	112	38,4	-	91	159	-
25	-	20	45	96	127	144	127	-	76
26	65	-	15	-	38,4	-	127	80	177
27	60	-	35	159	51	127	27	-	52
28	-	50	30	96	76,4	57,3	71	-	-
29	25	20	16	80	-	95,5	-	159	212
30	20	25	-	-	115	76,4	106	199	133

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MUNDARIJA

KIRISH	3
1. O‘ZGARMAS TOK ELEKTR ZANJIRLARI	
1.1. Elektr zanjiri va uning elementlari.....	4
1.2. Elektr zanjirlarining asosiy qonunlari.....	6
1.3. Elektr tokining quvvati.....	9
1.4. Elektr zanjirida quvvatlar muvozanati.....	9
1.5. Elektr zanjiridagi qarshiliklarni ulash sxemalari.....	10
1.6. Amaliy mashg‘ulotlar uchun masalalar va hisob grafik ishlari.....	14
2. BIR FAZALI O‘ZGARUVCHAN TOK ELEKTR ZANJIRLARI	
2.1. O‘zgaruvchan tok	42
2.2. Sinusoidal o‘zgaruvchan funktsiyaning ta’sir etuvchi va o‘rtacha qiymatlari.....	43
2.3. Sinusoidal o‘zgaruvchan kattaliklarni aylanuvchan vektorlar yordamida ifodalash.....	43
2.4. Aktiv qarshilik, induktiv g‘altak va kondensator ulangan o‘zgaruvchan tok zanjirlari.....	45
2.5. Aktiv va reaktiv qarshiliklari o‘zaro ketma-ket ulangan zanjir.....	47
2.6. Aktiv va reaktiv qarshiliklari o‘zaro parallel ulangan zanjir.....	48
2.7. O‘zgaruvchan tok zanjirining quvvati va quvvat koeffitsiyenti.....	50
2.8. Kuchlanishlar rezonansi.....	51
2.9. Toklar rezonansi.....	52
2.10. Sinusoidal kattaliklarni kompleks tekislikda vektorlar bilan tasvirlash.	54
2.11. Quvvat kompleksi va sinusoidal tok zanjirlarida quvvatlar balansi.	56
2.12. Amaliy mashg‘ulotlar uchun masalalar va hisob grafik ishlari.....	58
3. UCH FAZALI O‘ZGARUVCHAN TOK ELEKTR ZANJIRLARI	
3.1. Uch fazali EYuK, kuchlanish va tok.....	75
3.2. Manba va iste’molchilarni to‘rt simli yulduz usulida ulash.....	76
3.3. Manba va iste`molchilarni uch simli yulduz usulida ulash.....	77
3.4. Iste`molchilarni uchburchak usulida ulash.....	78
3.5. Uch fazali zanjirlarning quvvati.....	79
3.6. Amaliy mashg‘ulotlar uchun masalalar va hisob grafik ishlari.....	82
FOYDALANILGAN ADABIYOTLAR RO‘YXATI.....	106

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