

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

**TOSHKENT DAVLAT TEXNIKA UNIVERSITETI TERMIZ
FILIALI**

**TRANSPORT TIZIMLARI VA TEXNOLOGIK MASHINALAR
KAFEDRASI**

B.X.XUSHBOQOV, M.R.SHAYMANOV

ELEKTROTEXNIKA VA ELEKTRONIKA

*5310600–Yer usti transport tizimlari va ularning ekspluatatsiyasi
(transport turlari bo'yicha);*

5320300–Texnologik mashinalar va jixozlar (tarmoqlar bo'yicha);

*5320900–Yengil sanoat buyumlari konstruksiyasini ishlash va texnologiyasi
(ishlab chiqarish turlari bo'yicha);*

5630100–Ekologiya va atrof-muhit muhofazasi (tarmoqlar va sohalar bo'yicha)

Ta'lim yo'nalishlaridagi 2-bosqich talabalari uchun

“O'ZGARMAS TOK ZANJIRLARINI HISOBLASH”

**mavzusida hisob-grafik ishini mustaqil bajarish uchun
USLUBIY KO'RSATMA**

TERMIZ-2019

UDK 621.39

Elektrotexnika va elektronika asoslari. Uslubiy ko'rsatma (1-qism). Xushboqov B.X., Shaymanov M.R. TDTU Termiz filiali, Termiz: 2019, 34 – bet.

“Elektrotexnika va elektronika” fanidan фанидан ***“o'zgarmas tok zanjirlarini hisoblash”*** mavzusida hisob-grafik ishini mustaqil bajarish uchun mo'ljallangan ushbu uslubiy ko'rsatma 5310600–Yer usti transport tizimlari va ularning ekspluatatsiyasi (transport turlari bo'yicha); 5320300–Texnologik mashinalar va jixozlar (tarmoqlar bo'yicha); 5320900–Yengil sanoat buyumlari konstruksiyasini ishlash va texnologiyasi (ishlab chiqarish turlari bo'yicha) va 5630100–Ekologiya va atrof-muhit muhofazasi (tarmoqlar va sohalar bo'yicha) ta'lim yo'nalishi talabalari nazariy va amaliy mashgulotlarda olgan bilimlari asosida o'zgarmas tok zanjirlarini mustaqil hisoblash ko'nikmasini olish uchun xizmat qiladi.

Uslubiy ko'rsatma filial O'quv-uslubiy Kengashi tomonidan nasrga tavsiya etilgan.

Taqrizchilar: Z.R.Xudoyqulov – TerDU, “Bino-inshootlar arxitekturasi va qurilishi” kafedrası mudiri, t.f.n., dotsent.

F.J.Nosirov – TDTU Termiz filiali “Umumkasbiy fanlar” kafedrası dotsenti, t.f.n., dotsent.

© Toshkent davlat texnika universiteti Termiz filiali, 2019.

I. Qisqacha nazariy ma'lumotlar

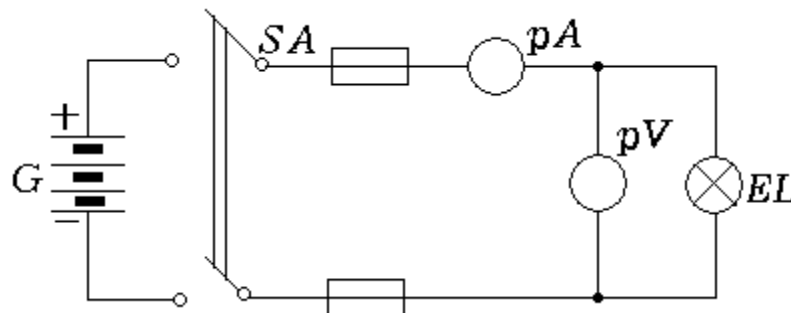
1. Elektr zanjir va uning elementlari

Elektr energiya manbai, iste'molchi va ularni o'zaro birlashtiruvchi o'tkazgichlar elektr zanjirning asosiy elementlari, o'lchash asboblari, ulab-uzgichlar va himoyalash qurilmalari esa uning yordamchi elementlari hisoblanadi.

Elektr zanjirning elementlari shartli belgilar bilan tasvirlanadi.

Elektr zanjirning elementlari va ularni o'zaro ulanishining grafik tasviri elektr zanjirining sxemasi deb ataladi.

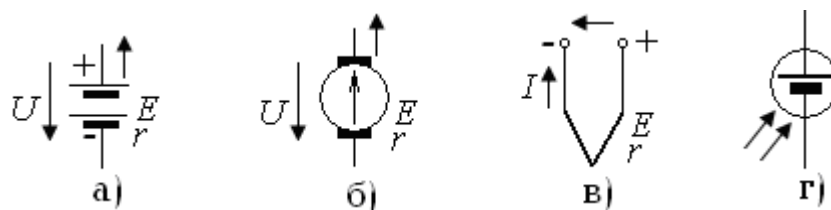
1-rasmda oddiy elektr zanjirining sxemasi keltirilgan.



1 – rasm. Elektr zanjir sxemasi

G – akkumulyator – elektr energiya manbai. U kimyoviy energiyani elektr energiyaga aylantiradi. EL – cho'g'lanma lampa – iste'molchi, unda elektr energiyasi yorug'lik energiyasiga aylantiriladi. SA – kalit, zanjirni ulab uzadi. pA – ampermetr, pV – voltmeter. To'g'ri chiziqlar – ulagich simlar - o'tkazgichlardir.

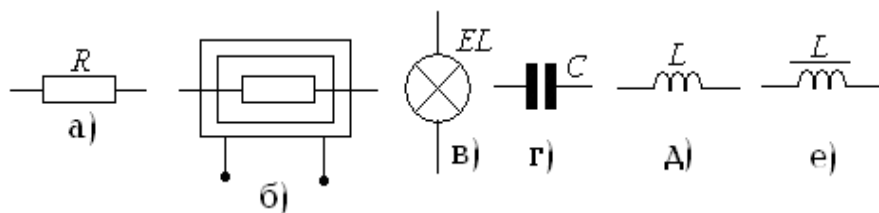
Elektr energiya manbalarining shartli belgilari – sxemalari 2- rasmda keltirgan.



2- rasm. Elektr energiya manbalari sxemalari

a) galvanik element, b) o'zgarmas tok elektr generatori,
v) termojuft, g) fotoelement.

Elektr energiyasi iste'molchilarining shartli belgilari - sxemalari 3 - rasmda keltirilgan.



3- rasm. Elektr energiyasi iste'molchilari sxemalari

a) rezistor, b) elektr qizdirgich, v) cho'g'lanma lampa, g) kondensator,
d) induktiv g'altak, e) o'zakli g'altak – drossel.

Elektr energiya iste'molchilari (elektr motorlar, elektr qo'ralar, issiqlik asboblari, cho'g'lanish lampalari, rezistorlar va b.) elektr energiyani boshqa tur energiyaga aylantirish uchun xizmat qiladi.

Manba bilan iste'molchilar o'zaro o'tkazgich simlar yordamida birlashtiriladi. Har qanday elektr zanjirining asosiy vazifasi elektr energiyasini manbadan iste'molchiga uzatishdan iboratdir.

Elektr zanjirdagi elektromagnit jarayonlar EYUK, tok, kuchlanish, qarshilik (o'tkazuvchanlik), induktivlik, sig'im tushunchalari bilan ifodalanadi.

Har qanday tur energiyani elektr energiyaga aylantirishda EYUK hosil bo'ladi.

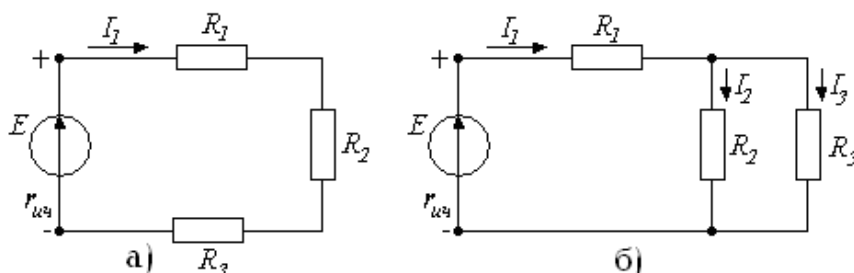
Berk zanjirda EYUK ta'sirida I tok hosil bo'ladi. Elektr zanjirlar **tarmoqlanmagan** va **tarmoqlangan** bo'ladi.

Agar berk zanjirning barcha qismlaridan bitta tok o'tsa, u holda bunday zanjir **tarmoqlanmagan** bo'ladi (4, a – rasm).

Tarmoqlangan zanjirning har bir shoxobchasida o'zining toki bo'ladi (4, b – rasm). Elektr sxemada shoxobcha, tugun va kontur tushunchalaridan foydalaniladi.

Shoxobcha – elektr zanjirning bir xil qiymatli tok o'tuvchi qismi. Bunda elektr zanjirning elementlari ketma-ket ulangan qismi tushuniladi.

Tugun–elektr zanjirning uchtdan kam bo'lmagan shoxobchalari ulangan o'rni.

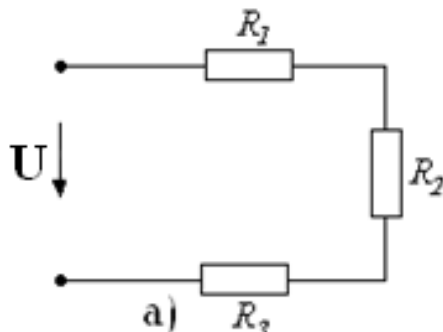


4- rasm. Tarmoqlanmagan(a) va tarmoqlangan(b) elektr zanjirlar

Kontur–elektr zanjirning shoxobchalaridan hosil bo'lgan berk yo'l. O'zgarmas tok - I harfi bilan, qarshilik – R va o'tkazuvchanlik - G harflar bilan belgilanadi.

Elektr zanjirini hisoblash chogʻida isteʼmolchi(qarshilik)larni ketma-ket, parallel, aralash ulash, hamda "uchburchak" ni "yulduz"ga va aksincha "yulduz" ni "uchburchak" ga oʻzgartirishning quyidagi formulalaridan foydalaniladi:

Qarshiliklarni ketma-ket ulash (5-rasm).



5-rasm. Qarshiliklari ketma-ket ulangan sxema

Elementlar bunday ulangan holda ularning umumiy qarshiligi quyidagi ifoda bilan aniqlanadi:

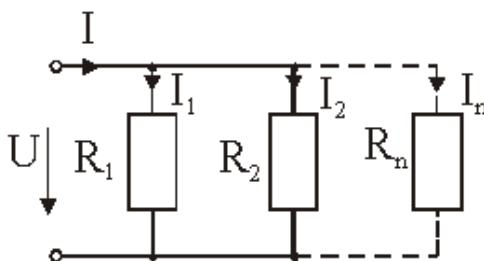
$$R_{um} = R_1 + R_2 + \dots + R_n.$$

Agar $R_1 = R_2 = \dots = R_n$, boʻlsa, u holda ularning umumiy qarshiligi:

$$R_{um} = n R_1$$

bunda p –ketma-ket ulangan qarshiliklar soni.

Qarshiliklarni parallel ulash (6-rasm).



6-rasm. Qarshiliklari parallel ulangan sxema

Elementlar bunday ulangan holda ularning umumiy qarshiligi quyidagi ifoda bilan aniqlanadi:

$$\frac{1}{R_{ym}} = \frac{1}{R_1} + \frac{1}{R_2} + \dots + \frac{1}{R_n}$$

Parallel ulangan qarshiliklar soni ikkita boʻlsa, u holda ularning umumiy qarshiligi:

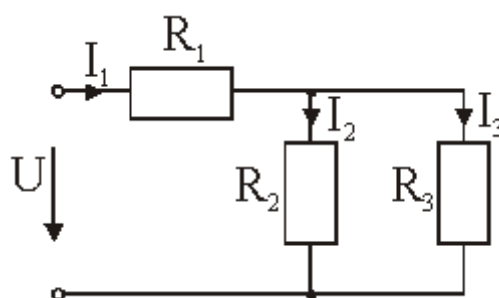
$$R_{ym} = \frac{R_1 \cdot R_2}{R_1 + R_2}$$

Agar $R_1 = R_2 = \dots R_n$, bo'lsa, u holda ularning umumiy qarshiligi:

$$R_{ym} = \frac{R_1}{n},$$

bunda p –parallel ulangan qarshiliklar soni.

Qarshiliklarni aralash ulash (7-rasm)



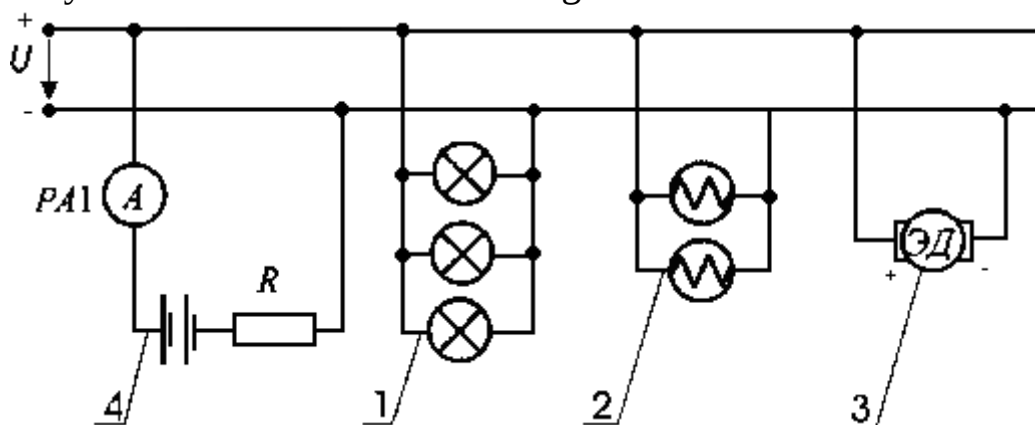
7-rasm. Qarshiliklari aralash ulangan sxema

Elementlar bunday ulangan holda ularning umumiy qarshiligi quyidagi

$$R_{ym} = R_1 + \frac{R_2 \cdot R_3}{R_2 + R_3}$$

ifoda bilan aniqlanadi:

8-rasmda elektr zanjirga parallel ulangan cho'g'lanma lampa 1, isitish asboblari 2, elektrmotor 3 i zaryadlash uchun ulangan akkumulyator 4 namuna sifatida keltirilgan.



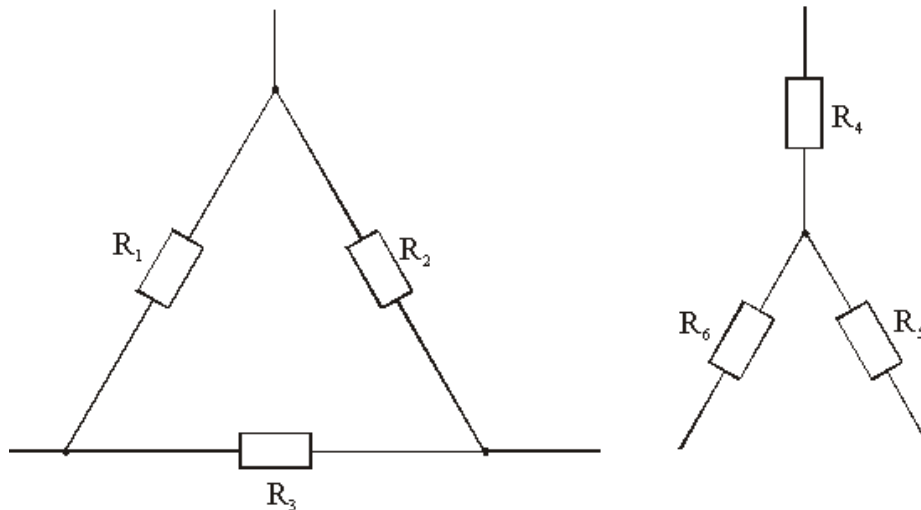
8-rasm. Elektr energiya iste'molchilari parallel ulangan elektr zanjir sxemasi

"Uchburchak" sxemani "Yulduz" sxemaga o'zgartirishda qarshiliklar orasidagi munosabatlar (9-rasm):

$$R_4 = \frac{R_1 \cdot R_2}{R_1 + R_2 + R_3},$$

$$R_5 = \frac{R_2 \cdot R_3}{R_1 + R_2 + R_3},$$

$$R_6 = \frac{R_1 \cdot R_3}{R_1 + R_2 + R_3},$$



9-rasm. Qarshiliklari "Uchburchak" va "Yulduz" ko'rinishida ulangan sxemalar

"Yulduz" sxemani "Uchburchak" sxemaga o'zgartirishda qarshiliklar orasidagi munosabatlar (9-rasm):

$$R_1 = R_4 + R_6 + \frac{R_4 \cdot R_6}{R_5},$$

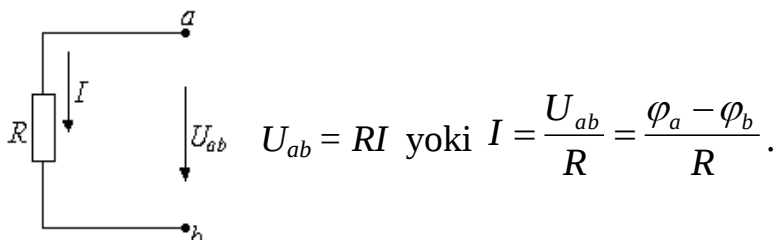
$$R_2 = R_4 + R_5 + \frac{R_4 \cdot R_5}{R_6},$$

$$R_3 = R_5 + R_6 + \frac{R_5 \cdot R_6}{R_4},$$

2.Om qonuni

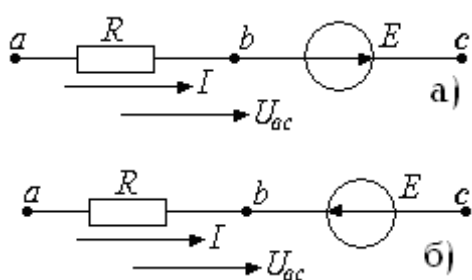
Elektr zanjirlarini hisoblashda izlanayotgan elektr kattaliklar va ularning nisbatlarini aniqlash uchun umumiy holda Om va Kirxgof qonunlari asosida tuzilgan tenglamalar (yoki tenglamalar sistemasi)ni echish zarur.

Agar zanjirning biror qismida (10- rasm) EYUK manbai bo‘lmasa, u holda undagi tok va rezistorning qismalaridagi kuchlanish U_{ab} ning o‘zaro bog‘lanishini Om qonuniga binoan quyidagicha aniqlanadi:



10- rasm. EYUK manbai bo‘lmagan zanjir

Agar zanjirning biror qismida EYUK manbai bo‘lsa, u holda bu zanjir uchun potentsiallar ayirmasi EYUKning yo‘nalishini e‘tiborga olgan holda aniqlanadi. Om qonuni esa quyidagicha ifodalanadi:



11, a – rasm uchun

$$I = \frac{\varphi_a - \varphi_c + E}{R} = \frac{U_{ac} + E}{R}.$$

11, b – rasm uchun

$$I = \frac{\varphi_a - \varphi_c - E}{R} = \frac{U_{ac} - E}{R}.$$

11- rasm. EYUK manbai bo‘lgan zanjir

Umumiy holda, ya’ni elektr zanjir tarkibida bir nechta EYUK manbai va rezistorlar bo‘lsa, tok quyidagi ifodadan aniqlanadi:

$$I = \frac{\varphi_a - \varphi_c + \Sigma E}{\Sigma R_{ac}}.$$

Bu formula **umumlashgan Om qonuni** deyiladi.

Bir konturli elektr zanjiri uchun Om qonuni quyidagicha yoziladi:

$$I = \Sigma E / \Sigma R,$$

bunda ΣR - ichki va tashqi qarshiliklarning zanjir bo‘yicha arifmetik yig‘indisi, ΣE - 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.

3. Potensial diagramma

Zanjirning biror qismi yoki berk zanjir (kontur) uchun belgilangan nuqtalardagi potenciallar qiymatini shu zanjir qarshiliklarining qiymatiga qarab o'zgarish grafigiga **potensial diagramma** deb ataladi.

Potensial diagrammani qurish uchun to'g'ri burchakli koordinatalar tekisligining abssissa o'qiga kontur bo'yicha olingan rezistorlar qarshiliklari qiymati, ordinata o'qiga esa tegishli potenciallar qiymati qo'yiladi. Diagrammadan zanjirning yoki konturning biror qismiga tegishli potenciallarni aniqlash mumkin bo'ladi.

4. Elektr zanjirida quvvatlar balansi

Energiya saqlanish qonuniga ko'ra zanjirga ulangan manbalarning algebraik quvvati zanjirning barcha qismlaridagi quvvatlarning arifmetik yig'indisiga tengdir:

$$\sum EI = \sum I^2 R.$$

Bu ifoda **quvvat balansi tenglamasi** deyiladi, ya'ni manbalarning ishlab chiqargan quvvati iste'molchilarda, uzatish liniyasida va manbalarning o'zida sarf bo'lgan quvvatlarga tengdir.

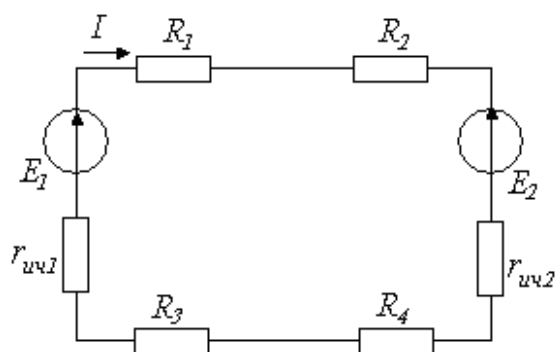
Agar elektr zanjiriga EYUK va tok manbalari ulangan bo'lsa, ya'ni zanjirning ayrim tugunlariga EYUK manbaidan tashqari tok manbai ham ulangan bo'lsa, u holda bir tugundan ikkinchi tugun tomon yo'nalgan tok manbaidan hosil bo'lgan quvvat sarfini hisobga olish kerak bo'ladi.

Masalan, zanjirning a tuguniga I_k tok kirib b tugunidan chiqsa, u holda tok manbai sarflayotgan quvvat $P = U_{ab} I_k$ bo'ladi. Bunday holda quvvat balans tenglamasi quyidagicha yoziladi:

$$\sum_{i=1}^n R_i I_i^2 = \sum_{k=1}^m EI_k + \sum_{k=1}^m U_{ab} I_k.$$

Bu tenglama **quvvatlar balansining umumiy tenglamasi** deyiladi.

12-rasmda keltirilgan zanjir uchun quvvat balans tenglamasi quyidagi ko'rinishga ega:



12 – rasm

$$E_1 I - E_2 I = R_1 I^2 + R_2 I^2 + R_3 I^2 + R_4 I^2 + r_{u\gamma 1} I^2 + r_{u\gamma 2} I^2.$$

5. Kirxgof qonunlari

Har qanday elektr zanjiridagi jarayonlar Kirxgofning 1- va 2 - qonunlari bilan ifodalanadi.

1-qonun. Kirxgofning 1 - qonuni zanjirning tugunlariga tegishli bo'lib, unga ko'ra zanjirning istalgan tugunida toklarning algebraik yig'indisi nolga teng bo'ladi, ya'ni: $\sum_{k=1}^m I_k = 0$,

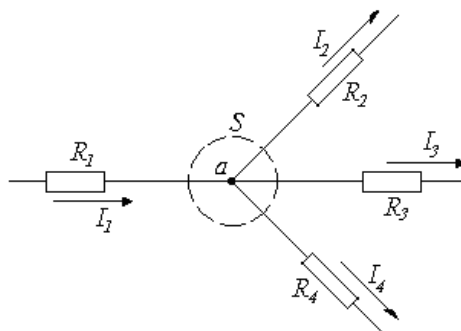
yoki elektr zanjirning istalgan tuguniga kiruvchi toklarning arifmetik yig'indisi shu tugundan chiquvchi toklarning arifmetik yig'indisiga tengdir, ya'ni:

$$\sum_{i=1}^m I_i = \sum_{j=1}^q I_j.$$

13 – rasmda elektr zanjirning a tuguni ko'rsatilgan. Agar a tugunga kiruvchi toklar musbat ishora bilan olinsa, tugundan chiquvchi toklar ishorasi manfiy olinadi (yoki aksincha).

Kirxgofning 1 - qonuniga asosan:

$$I_1 - I_2 - I_3 - I_4 = 0 \text{ yoki } I_1 = I_2 + I_3 + I_4.$$



13 – rasm

Kirxgof 1- qonunining fizik ma'nosi: elektr zanjirining tugunida zaryadlarning harakati uzluksizdir va unda zaryadlar to'planib qolmaydi.

2-qonun. Kirxgofning 2-qonuni zanjirning berk konturlariga tegishli bo'lib, unga ko'ra elektr zanjirining istalgan berk konturida kuchlanishlar tushuvining algebraik yig'indisi shu konturdagi EYUKlarning algebraik yig'indisiga teng, ya'ni

$$\sum_{k=1}^n R_k I_k = \sum_{i=1}^m E_i.$$

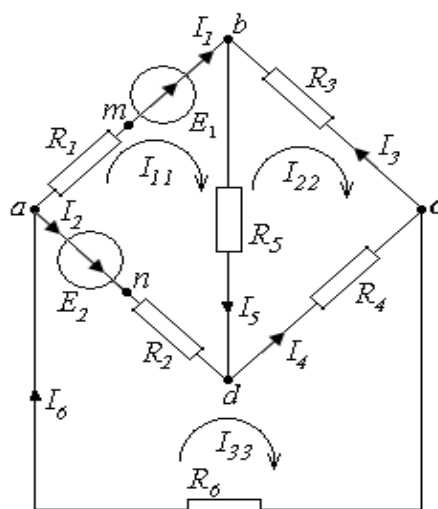
Agar konturni aylanib chiqish yo'nalishi bilan tok yoki EYUK yo'nalishi bir xil bo'lsa, u holda yig'indiga tegishli tashkil etuvchilar «**musbat**» ishora bilan, aks holda esa «**manfiy**» ishora bilan kiradi.

Kirxgofning 2 - qonunini boshqa ko‘rinishda yozish ham mumkin: zanjirning ixtiyoriy konturida kuchlanishlarning algebraik yig‘indisi nolga teng:

$$\sum_{k=1}^n U_k = 0.$$

Kirxgof qonunlarini chiziqli va nochiziqli elektr zanjirlarni hisoblash uchun qo‘llash mumkin.

Kirxgof qonunlari asosida tenglamalar tuzishni 14–rasmdagi zanjir misolida ko‘rib chiqamiz.



14 – rasm

1. Har bir shoxobchadagi toklar yo‘nalishi ixtiyoriy tanlab olinadi.
2. Kirxgofning birinchi qonuniga asosan tenglamalar tuzamiz.

Ularining soni zanjir tugunlaridan bitta kam bo‘ladi:

$$I_6 - I_1 - I_2 = 0 \quad a \text{ tugun uchun,}$$

$$I_1 + I_3 - I_5 = 0 \quad b \text{ tugun uchun,}$$

$$-I_3 + I_4 - I_6 = 0 \quad s \text{ tugun uchun.}$$

3. Zanjir konturlarini aylanib chiqish yo‘nalishi tanlanadi. Bunda tanlangan yo‘nalish bo‘yicha tuzilgan tenglamalar o‘zaro bog‘liq bo‘lmasligi lozim. Kirxgofning ikkinchi qonuniga ko‘ra mustaqil konturlar uchun tenglamalar tuziladi:

$$R_1 I_1 + R_5 I_5 - R_2 I_2 = E_1 - E_2 \quad abda \text{ kontur uchun,}$$

$$-R_5 I_5 - R_3 I_3 - R_4 I_4 = 0 \quad dbcd \text{ kontur uchun,}$$

$$R_2 I_2 + R_4 I_4 + R_6 I_6 = E_2 \quad adca \text{ kontur uchun.}$$

Bu tenglamalarda konturlarni aylanib chiqish yo‘nalishi bilan mos keladigan EYUK va toklar ishorasi musbat, aylanib chiqish yo‘nalishiga

qarama-qarshi bo'lgan EYUK va toklar ishorasi esa manfiy ishora bilan yoziladi. Bu misoldan ko'rinib turibdiki, tuzilgan tenglamalar soni zanjirdagi noma'lum toklar yoki toklari aniqlanishi kerak bo'lgan shoxobchalar soniga tengdir. Olti noma'lum tokli oltita tenglamalardan iborat sistema yuqorida ko'rilayotgan zanjirning matematik modelidir.

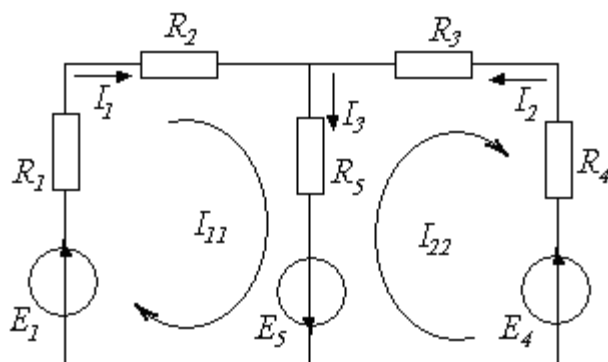
Agar hisoblash natijasida qandaydir tokning ishorasi manfiy chiqsa, u holda bu tokning haqiqiy yo'nalishi dastlab tanlangan yo'nalishga nisbatan qarama-qarshi bo'ladi.

6. Kontur toklar usuli

Bu usulda o'zaro bog'liq bo'lmagan (mustaqil) konturdan yagona *kontur toki* o'tadi deb faraz qilinadi va shoxobchalar toki shu kontur toklari orqali aniqlanadi. Kontur toklar usuli – Kirxgofning 2-qonuniga asoslanadi.

Tenglamalar shu kontur toklariga nisbatan tuziladi. Tenglamalar sistemasi echilib, noma'lum kontur toklar, ular orqali esa shoxobchalardagi haqiqiy toklar aniqlanadi. SHunday qilib, kontur toklar usuli asosida tuzilgan tenglamalarda noma'lumlar soni o'zaro bog'liq bo'lmagan konturlar soniga teng va zanjir bu usulda hisoblanganda Kirxgof tenglamalari usuliga nisbatan tenglamalar soni va ularni echishga sarf bo'ladigan vaqt kam bo'ladi. Kontur toklar usuli ko'pincha murakkab zanjirdagi mustaqil konturlar soni tugunlar sonidan kam bo'lganda qo'llaniladi.

15-rasmda keltirgan sxema uchun tenglamalarni tuzamiz. Bu sxemada ikkita bog'liq bo'lmagan kontur mavjud. Bu konturlardan o'tadigan kontur toklar orqali shoxobchalardagi toklarni aniqlash mumkin.



15-rasm

Faraz qilaylik, sxemaning chap konturida soat mili harakati yo'nalishida I_{11} , o'ngdagi konturda esa shu yo'nalishda I_{22} kontur toklari o'tmoqda. Har bir kontur uchun Kirxgofning 2-qonuniga asoslanib tenglamalar tuzamiz. Bunda R_5 qarshilikli shoxobchadan ikkala kontur toklarning ayirmasi (yoki yig'indisi) o'tishi mumkin. Bunday shoxobcha *yondosh shoxobcha* deyiladi.

Yondosh shoxobchalardagi haqiqiy toklarni aniqlash uchun kontur toklar yoʻnalishi albatta eʼtiborga olinishi kerak. Konturlarni aylanib chiqish yoʻnalishini ham soat mili boʻyicha olamiz.

1-kontur uchun:

$$\begin{aligned}(R_1 + R_2)I_{11} + R_5(I_{11} - I_{22}) &= E_1 + E_5 \text{ yoki} \\ (R_1 + R_2 + R_5)I_{11} + (-R_5)I_{22} &= E_1 + E_5.\end{aligned}\quad (1)$$

2 – kontur uchun:

$$\begin{aligned}R_5(I_{22} - I_{11}) + (R_3 + R_4)I_{22} &= -E_4 - E_5 \text{ yoki} \\ -R_5I_{11} + (R_3 + R_4 + R_5)I_{22} &= -E_4 - E_5.\end{aligned}\quad (2)$$

(1) tenglamada I_{11} oldidagi koeffitsient birinchi konturga tegishli xususiy qarshiliklar yigʻindisidir, uni R_{11} bilan belgilaymiz, I_{22} oldidagi koeffitsient esa konturlar orasidagi oʻzaro qarshilik, uni R_{12} bilan belgilaymiz. (2) tenglamada esa I_{11} oldidagi koeffitsientni R_{21} , I_{22} oldidagi koeffitsientni esa R_{22} bilan belgilaymiz. R_{11} , R_{22} – tegishli konturlarning *xususiy qarshiliklari*, $R_{12}=R_{21}$ lar esa-konturlararo oʻzaro *qarshiliklar* deyiladi. (1) va (2) tenglamalar oʻng tomonini mos ravishda E_{11} va E_{22} bilan belgilaymiz, bunda E_{11} , E_{22} – mos ravishda birinchi va ikkinchi konturdagi EYUK larning algebraik yigʻindisi. Bunda EYUK yoʻnalishi konturni aylanib chiqish yoʻnalishi bilan bir xil boʻlsa, *musbat ishora* bilan, aks holda esa *manfiy ishora* bilan olinadi. Bu holda yuqoridagi tenglamalarni quyidagi shaklda yozish mumkin:

$$R_{11}I_{11} + R_{12}I_{22} = E_{11}, \quad R_{21}I_{11} + R_{22}I_{22} = E_{22},$$

bu erda

$$\begin{aligned}R_{11} &= R_1 + R_2 + R_5, \quad R_{22} = R_3 + R_4 + R_5, \quad R_{12} = R_{21} = -R_5, \\ E_{11} &= E_1 + E_5, \quad E_{22} = -E_4 - E_5.\end{aligned}$$

Agar sxemada mustaqil konturlar soni ikkitadan koʻp, masalan uchta boʻlsa, u holda tenglamalar sistemasi quyidagi shaklda yoziladi:

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

yoki matritsa koʻrinishida: $[R][I] = [E]$, bunda

$$[R] = \begin{vmatrix} R_{11} & R_{12} & R_{13} \\ R_{21} & R_{22} & R_{23} \\ R_{31} & R_{32} & R_{33} \end{vmatrix}; \quad [I] = \begin{vmatrix} I_{11} \\ I_{22} \\ I_{33} \end{vmatrix}; \quad [E] = \begin{vmatrix} E_{11} \\ E_{22} \\ E_{33} \end{vmatrix}.$$

Har xil belgili qarshiliklar ishoralari bir xil boʻlishi uchun kontur toklarning yoʻnalishi bir xil yoʻnalishda: faqat soat mili harakati yoki unga teskari yoʻnalishda qabul qilinishi lozim. Tenglamalar sistemasi echimida qaysi bir kontur toki manfiy ishorali chiqsa, shu kontur tokining haqiqiy yoʻnalishi

dastlab qabul qilinganiga teskari bo‘ladi. Konturlararo qarshilikdan ikkita yondosh kontur toklari o‘tadi.

Shoxobchadagi toklar qiymati shu shoxobchadan o‘tadigan kontur toklar bilan aniqlanadi. Masalan, R_5 shoxobchasidan $I_{11}-I_{22}$ ayirma toki o‘tadi, bu ayirma tok shoxobchadagi haqiqiy tokdir. Agar elektr zanjirida n o‘zaro bog‘liq bo‘lmagan konturlar bo‘lsa, unda n ta mustaqil tenglamalar sistemasi tuziladi. Bunda n ta tenglamalar sistemasining umumiy echimi quyidagicha bo‘ladi:

$$I_{kk} = \frac{\Delta_{k1}}{\Delta} E_{11} + \frac{\Delta_{k2}}{\Delta} E_{22} + \frac{\Delta_{k3}}{\Delta} E_{33} + \dots + \frac{\Delta_{kn}}{\Delta} E_{nn}$$

bu tenglamada

$$\Delta = \begin{vmatrix} R_{11} & R_{12} & \dots & R_{1n} \\ R_{21} & R_{22} & \dots & R_{2n} \\ \dots & \dots & \dots & \dots \\ R_{n1} & R_{n2} & \dots & R_{nn} \end{vmatrix} - \text{sistemaning bosh determinanti,}$$

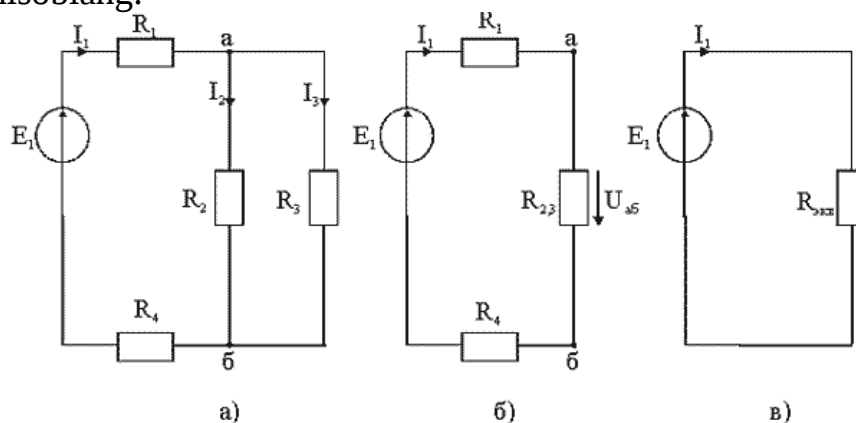
Δ_{km} – algebraik to‘ldiruvchi bo‘lib, uni hisoblashda Δ determinantdan k -ustun va m -qatorni o‘chirib, $(-1)^{k+m}$ ga ko‘paytirib olinadi.

Agar bosh aniqlovchining chap burchagi yuqorisidan o‘ng burchagi pastiga diagonal o‘tkazsak, u determinantni ikki qismga bo‘ladi. Bu determinantning bosh diagonalga nisbatan *simmetriklik xususiyatidir*. SHu simmetriyaga asoslanib, $\Delta_{km} = \Delta_{mk}$ tenglikni yozish mumkin.

II. Masala yechish namunalari

1. Elektr zanjir va uning elementlariga doir

1-namuna. 16-rasmda keltirilgan elektr zanjirining karshiliklari $R_1 = 3 \text{ Om}$; $R_2 = 2 \text{ Om}$; $R_3 = 5 \text{ Om}$; $R_4 = 10 \text{ Om}$ bo‘lsa, shu zanjirning ekvivalent (umumiy) qarshiligini hisoblang.



16-rasm. Ekvivalent o‘zgartirishlar namunasi:

- a) elektr zanjirning o‘zgartirishgacha bo‘lgan sxemasi;
- b) elektr zanjirning birinchi o‘zgartirishdan keyingi hisobiy sxemasi;
- v) elektr zanjirning yakuniy o‘zgartirishdan keyingi hisobiy sxemasi.

Berilgan: $R_1 = 3 \text{ Om}$; $R_2 = 2 \text{ Om}$; $R_3 = 5 \text{ Om}$; $R_4 = 10 \text{ Om}$.

Yechish: Parallel ulangan rezistor R_2 va R_3 larni, ularning ekvivalent qarshiligi $R_{2,3}$ bilan almashtiramiz:

$$R_{2,3} = \frac{R_2 \cdot R_3}{R_2 + R_3} = \frac{2 \cdot 5}{2 + 5} = 1,43 \text{ Om}.$$

Elektr zanjirning birinchi o'zgartirishdan keyingi hisobiy sxemasi 16, b.- rasmda ko'rsatilgan.

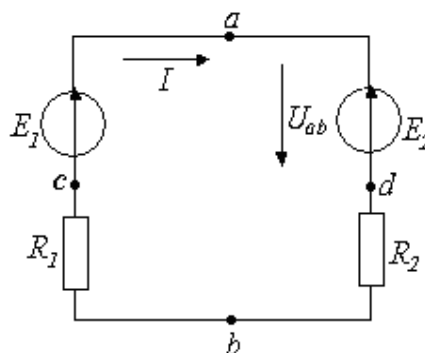
Ikkinchi o'zgartirishni amalga oshiramiz. Buning uchun ketma-ket ulangan R_1 , $R_{2,3}$, R_4 rezistorlarni bitta ekvivalent R_{EKV} qarshilik bilan almashtiramiz:

$$R_{EKV} = R_1 + R_{2,3} + R_4 = 3 + 1,43 + 10 = 14,43 \text{ Om}.$$

Elektr zanjirning ikkinchi o'zgartirishdan keyingi sodda ko'rinishga keltirilgan hisobiy sxemasi 16,v-rasmda ko'rsatilgan.

2.Om qonuniga doir

1-namuna. Tarmoqlanmagan zanjirda (17-rasm) EYUK $E_1=110 \text{ V}$, $E_2=48 \text{ V}$, rezistor $R_1=18 \text{ Om}$, $R_2 = 13 \text{ Om}$ bo'lsa, a va b nuqtalar orasidagi kuchlanishni aniqlang.



17- rasm

Berilgan: $E_1=110 \text{ V}$, $E_2=48 \text{ V}$, $R_1=18 \text{ Om}$, $R_2 = 13 \text{ Om}$.

Yechish: Tokning musbat yo'nalishini soat mili harakati yo'nalishi bo'yicha qabul qilamiz. Om qonuniga asosan:

$$I = \frac{\sum E}{\sum R} = \frac{E_1 - E_2}{R_1 + R_2} = \frac{110 - 48}{18 + 13} = 2 \text{ A}.$$

EYUK E_1 ning yo'nalishi tok I yo'nalishi bilan bir xil bo'lgani uchun E_1 musbat ishorada, E_2 yo'nalishi esa tok I yo'nalishiga teskari bo'lgani uchun manfiy ishorada olindi. Tok yo'nalishi ixtiyoriy qabul qilinadi. Agar topilgan tokning qiymati manfiy ishora bilan chiqsa, u holda tokning haqiqiy yo'nalishi dastlab qabul qilingan tok yo'nalishiga teskari yo'nalgan bo'ladi.

a va b nuqtalar orasidagi potentsiallar ayirmasi U_{ab} ni aniqlash uchun zanjirni adb qismini olib, unga zanjirning EYUK manbali qismi uchun Om qonuni qo'llaniladi:

$$I = \frac{\varphi_a - \varphi_b - E_2}{R_2} = \frac{U_{ab} - E_2}{R_2},$$

bundan

$$U_{ab} = E_2 + R_2 I = 48 + 13 \cdot 2 = 74 \text{ B}.$$

Zanjirning *asb* qismi uchun esa

$$I = \frac{\varphi_b - \varphi_a + E_1}{R_1} = \frac{U_{ba} + E_1}{R_1},$$

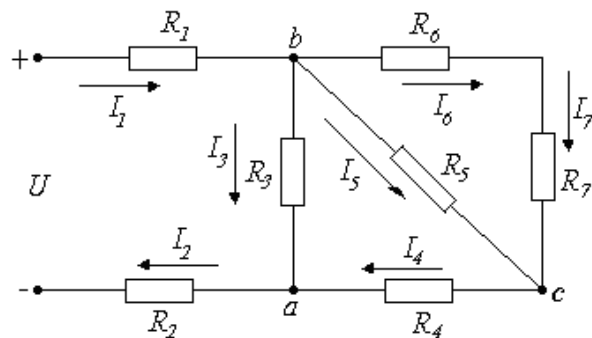
bundan

$$U_{ba} = -E_1 + R_1 I_1 = -110 + 18 \cdot 2 = -74 \text{ B}.$$

Demak, $U_{ab} = 74 \text{ B}$ yoki $U_{ba} = -74 \text{ B}$.

2-namuna. Sxemasi 18 - rasmda keltirilgan elektr zanjirda manba kuchlanishi $U=110\text{V}$, elementlar qarshiliklari $R_1=R_2=0,5 \text{ Om}$, $R_3=R_5=10 \text{ Om}$, $R_4=R_6=R_7=5 \text{ Om}$.

SHu elektr zanjiridagi toklar va elementlardagi kuchlanishlar tushuvi qiymatlarini aniqlang.



18- rasm. 2-namunaga doir sxema

Berilgan: $U=110\text{V}$, $R_1=R_2=0,5 \text{ Om}$, $R_3=R_5=10 \text{ Om}$, $R_4=R_6=R_7=5 \text{ Om}$.

Yechish. Toklar qiymatini to'g'ridan-to'g'ri aniqlash mumkin emas, chunki elementlardagi kuchlanish qiymatlari noma'lum. SHuning uchun elektr zanjir sxemasini o'zgartirish usulini qo'llab, uning ekvivalent qarshiligini hisoblaymiz.

$$R_{bc} = \frac{(R_6 + R_7)R_5}{R_6 + R_7 + R_5} = \frac{(5 + 5) \cdot 10}{5 + 5 + 10} = 5 \text{ Om},$$

$$R_{ab} = \frac{(R_{bc} + R_4)R_3}{R_{bc} + R_4 + R_3} = \frac{(5 + 5) \cdot 10}{5 + 5 + 10} = 5 \text{ Om},$$

$$R_{\text{экв}} = R_{ab} + R_1 + R_2 = 5 + 0,5 + 0,5 = 6 \text{ Om}.$$

Zanjirdagi umumiy tok Om qonuniga binoan aniqlanadi:

$$I_1 = \frac{U}{R_{\text{экв}}} = \frac{110}{6} = 18,33 \text{ A}.$$

Kuchlanish $U_{ab} = R_{ab}I_1 = 5 \cdot 18,33 = 91,65 \text{ B}$
 yoki $U_{ab} = U - (R_1 + R_2)I_1 = 110 - (0,5 + 0,5) \cdot 18,33 = 91,67 \text{ B}$.

SHoxobchalardan o'tuvchi toklar

$$I_3 = \frac{U_{ab}}{R_3} = \frac{91,65}{10} = 9,16 \text{ A},$$

$$I_4 = I_1 - I_3 = 18,33 - 9,16 = 9,17 \text{ A}.$$

$I_5 = I_6$ bo'lgani uchun R_5 va R_6 rezistorlardan o'tuvchi toklar

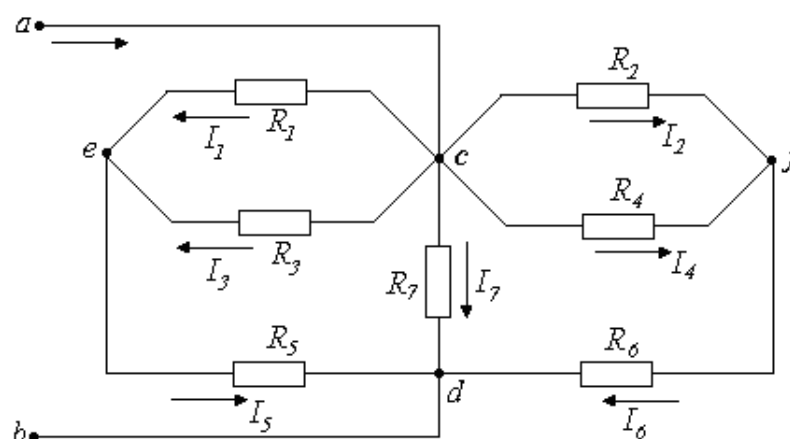
$$I_5 = I_6 = I_4 / 2 = 9,16 / 2 = 4,58 \text{ A}.$$

Tegishli kuchlanishlarning qiymatlari esa:

$$U_{bc} = R_5 I_5 = 10 \cdot 4,58 = 45,8 \text{ B},$$

$$U_{ac} = R_4 I_4 = 5 \cdot 9,17 = 45,85 \text{ B}.$$

3-namuna. 19 - rasmda keltirilgan elektr zanjirini hisoblang.



19- rasm. 3-namunaga doir sxema

Berilgan: $I_5 = 20 \text{ A}$, $R_1 = R_3 = 8 \text{ Om}$, $R_2 = R_4 = 4 \text{ Om}$, $R_5 = R_6 = 1,5 \text{ Om}$, $R_7 = 3 \text{ Om}$.

Yechish. E'tibor bering manba kuchlanishining qiymati berilmagan. SHuning uchun dastlab rezistor va shoxobcha toklari bo'yicha kuchlanishlarni hisoblaymiz:

$$U_{ed} = R_5 I_5 = 1,5 \cdot 20 = 30 \text{ B}.$$

$$U_{ec} = R_1 I_1 = R_3 I_3 = I_5 \frac{R_1 \cdot R_3}{R_1 + R_3} = 80 \text{ B},$$

$$U_{cd} = U_{ed} + U_{ec} = 110 \text{ B}.$$

Zanjirning shoxobchalanmagan qismidagi toklar

$$I_6 = \frac{U_{cd}}{R_{246}} = \frac{U_{cd}}{R_6 + R_2 \frac{R_4}{R_2 + R_4}} = \frac{110}{1,5 + 4 \frac{4}{4 + 4}} = \frac{110}{3,5} = 31,4 \text{ A},$$

chunki $R_1=R_3$. $R_2=R_4$ bo'lgani uchun $I_2=I_4$ bo'ladi, ya'ni:

$$I_2 = I_4 = \frac{I_6}{2} = \frac{31,4}{2} = 15,7 \text{ A.}$$

U_{cf} kuchlanish:

$$U_{cf} = R_2 I_2 = 4 \cdot 15,7 = 62,8 \text{ B.}$$

R_7 rezistordan o'tuvchi tok:

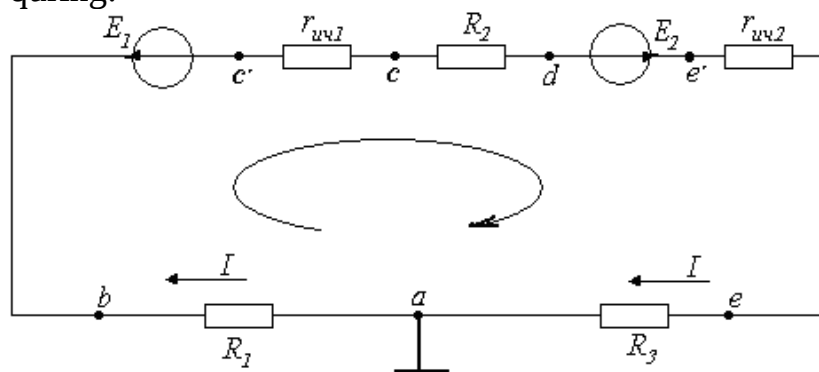
$$I_7 = \frac{U_{cd}}{R_7} = \frac{110}{3} = 36,6 \text{ A.}$$

Sxemaning shoxobchalanmagan qismidan o'tuvchi umumiy tok:

$$I = \frac{U_{cd}}{R_{ym}} = \frac{R_7 R_{246} R_{135} U_{cd}}{R_{246} R_{135} + R_7 R_{135} + R_7 R_{246}} = \frac{110}{1,25} = 88 \text{ A.}$$

3.Potensial diagrammaga doir

1-namuna. Bir konturli elektr zanjir (20 - rasm) uchun potentsiallar diagrammasini quring.



20- rasm. 1-namunaga doir sxema

Berilgan: $E_1 = 24 \text{ B}$; $E_2 = 110 \text{ B}$; $R_1 = 4 \text{ OM}$; $R_2 = 3 \text{ OM}$; $R_3 = 7 \text{ OM}$;
 $r_{uq1} = r_{uq2} = 1 \text{ OM}$.

Yechish. EYUK $E_2 > E_1$ bo'lganligi uchun tokning haqiqiy yo'nalishi E_2 EYUKning yo'nalishi bilan bir xil bo'ladi.

Berk zanjir uchun Om qonuniga ko'ra tokni topamiz:

$$I = \frac{E_2 - E_1}{R_1 + r_{uq1} + R_2 + r_{uq2} + R_3} = \frac{110 - 24}{4 + 1 + 3 + 1 + 7} = 5,375 \text{ A.}$$

Potensial diagrammani qurish uchun zanjirning barcha nuqtalari potentsiallarini bilish zarur. a nuqtani erga ulangan deb qabul qilamiz. SHuning uchun uning potentsiali $\varphi_a = 0$ bo'ladi. Elektr zanjirda a nuqtadan b nuqtaga o'tishda R_1 qarshilikli rezistor mavjud. Bu rezistorda $R_1 I$ – kuchlanish tushuvi hosil bo'ladi, ya'ni u a va b nuqtalar potentsiallari ayirmasiga teng:

$$\varphi_a - \varphi_b = R_1 I, \text{ bundan } \varphi_b = \varphi_a - R_1 I = -21,5 \text{ B.}$$

b va s' nuqtalar orasida E_1 EYUK manbai ulangani uchun s' nuqta potentsiali b nuqta potentsialidan E_1 kattalikka pasayadi, ya'ni:

$$\varphi_{c'} = \varphi_b - E_1 = -21,5 - 24 = -45,5 \text{ B.}$$

s' nuqtadan s nuqtaga o'tishda r_{ich1} rezistor bor. SHuning uchun:

$$\varphi_c = \varphi_{c'} - r_{uq1} \cdot I = -45,5 - 5,375 = -50,875 \text{ B.}$$

Endi boshqa nuqtalarning potentsiallarini topamiz:

$$\varphi_c - \varphi_d = R_2 I,$$

$$\varphi_d = \varphi_c - R_2 I = -50,875 - 16,12 = -66,995 \text{ B.}$$

$$\varphi_{e'} - \varphi_d = E_2$$

$$\varphi_{e'} = \varphi_d + E_2 = -66,995 + 110 \approx 43,01 \text{ B.}$$

$$\varphi_e = \varphi_{e'} - r_{uq2} I = 43 - 5,375 = 37,625 \text{ B.}$$

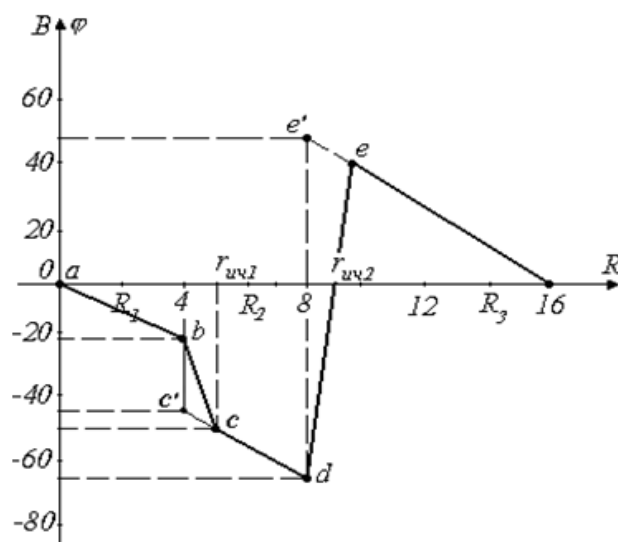
$$\varphi_e - \varphi_a = R_3 \cdot I$$

$$\varphi_a = \varphi_e - R_3 \cdot I = 37,625 - 37,625 = 0 \text{ B.}$$

Potensial diagrammani koordinatalar tekisligida qurish uchun berilgan konturning ekvivalent qarshiligini hisoblaymiz:

$$R_{\text{экв}} = R_1 + r_{uq1} + R_2 + r_{uq2} + R_3 = 16 \text{ Ом.}$$

Qarshilik va potensial uchun masshtab tanlaymiz:
 $m_R = 0,2 \text{ Ом} / \text{мм}$, $m_U = 2 \text{ B} / \text{мм}$. va potensial diagramma (21-rasm)ni quramiz.



21- rasm. 2-namunaga doir potensial diagramma

Potensial diagramma (21-rasm)dan berilgan kesmaning og‘ish burchagining tangensi tok miqdoriga teng bo‘lishiga ishonch hosil qilish mumkin. *de* uchastkada $E_2=110\text{ V}$, ya’ni $r_{ich}I = 5,37\text{ V}$ potensialidan 20 martadan ko‘proq.

4.Elektr zanjirlarida quvvatlar balansiga doir

1-namuna. 16, a-rasmda keltirilgan elektr zanjirda $E = 50\text{ V}$ bo‘lganda uning shoxchalaridagi toklarni aniqlang. Quvvat balansi tenglamasini yozing va tekshiring.

Berilgan: $R_1 = 3\text{ Om}$; $R_2 = 2\text{ Om}$; $R_3 = 5\text{ Om}$; $R_4 = 10\text{ Om}$, $E = 50\text{ V}$.

Yechish: Shoxchalardagi toklar yunalishlarini tanlaymiz (16, a-rasmda ko‘rsatilgandek). Yuqorida hisoblab topilgan ekvivalent R_{EKV} qarshilik qiymatidan foydalanib, soddalashgan sxema tokini topamiz:

$$I_1 = \frac{E}{R_{\text{ЭKB}}} = \frac{50}{14,43} = 3,47\text{ A}$$

Toklar I_2 va I_3 ni hisoblash uchun 16, b-rasmdan kuchlanish U_{ab} ni aniqlaymiz:

$$U_{ab} = R_{2,3} \cdot I_1 = 1,43 \cdot 3,47 = 4,96\text{ V}.$$

16, a-rasmga qaytib toklarni topamiz:

$$I_2 = \frac{U_{ab}}{R_2} = \frac{4,96}{2} = 2,48\text{ A},$$

$$I_3 = \frac{U_{ab}}{R_3} = \frac{4,96}{5} = 0,99\text{ A}.$$

Toklar to‘g‘ri hisoblanganligiga ishonch hosil qilish uchun quvvat balansi tenglamasini yozamiz va uni tekshirib ko‘ramiz. Elektr zanjirdagi barcha energiya manbalari ishlab chiqargan quvvat barcha elektr energiya iste’molchilari olgan quvvatga teng bo‘lishi kerak. Hisoblashning nisbiy xatoligi bir foizdan oshmasligi kerak.

E.YU.K. manbalari ishlab chiqaruvchi quvvat:

$$R_M = E \cdot I_1 = 50 \cdot 3,47 = 173,5\text{ Vt}.$$

Iste’molchilari olgan quvvat:

$$P_H = R_1 \cdot I_1^2 + R_4 \cdot I_1^2 + R_2 \cdot I_2^2 + R_3 \cdot I_3^2 =$$

$$= 36,12 + 120,4 + 12, +4,9 = 173,73 \text{ Вт.}$$

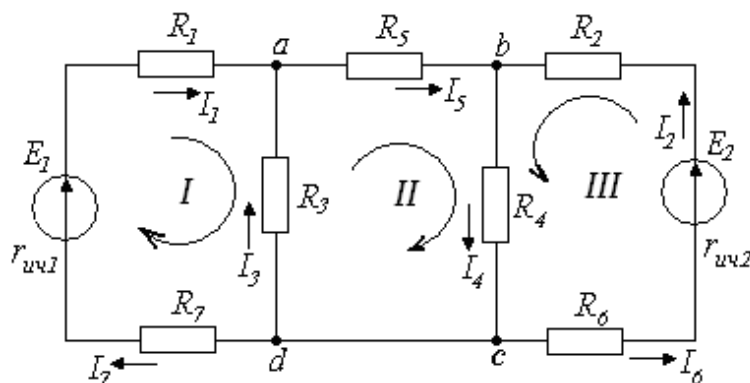
Quvvat balansi xatoligi:

$$\frac{P_M - P_H}{P_M} \cdot 100\% = \frac{173,5 - 173,73}{173,5} \cdot 100\% = -0,13\% \leq \pm 1\%.$$

Agar balans ruxsat etilgan xatolik aniqligida bajarilgan bo'lsa, u holda toklar qiymatlari to'g'ri topilgan bo'ladi.

5. Kirxgof qonunlariga doir

1-namuna. Kirxgof qonunlaridan foydalanib 22-rasmda keltirilgan elektr zanjir shoxobchalaridan o'tuvchi toklarni aniqlang.



22 – rasm

Berilgan: $R_1 = 0,3 \text{ Om}; R_7 = 0,3 \text{ Om}; R_2 = R_6 = 0,4 \text{ Om}; R_3 = R_4 = 0,4 \text{ Om}; R_5 = 6 \text{ Om}; E_1 = 110 \text{ B}; E_2 = 48 \text{ B}.$

EYUK manbalarining ichki qarshiliklari $r_{ich1} = 0,1 \text{ Om}, r_{ich2} = 0,2 \text{ Om}.$

Yechish. Berilgan sxemada tugunlar soni $n = 3$ (s va d nuqtalar potentsiallari bir xil). Noma'lum toklar yo'nalishlarini ixtiyoriy tanlaymiz. Sxemada beshta shoxobcha bo'lgani uchun shuncha tokni hisoblash zarur. Demak, beshta tenglama tuzib, ularni birgalikda echish kerak.

Kirxgofning birinchi qonuni bo'yicha tenglamalar soni $n-1 = 3-1 = 2.$

$$\begin{array}{ll} a \text{ tugun uchun:} & b \text{ tugun uchun:} \\ I_1 + I_3 - I_5 = 0 & I_2 + I_5 - I_4 = 0 \end{array}$$

I, II va III - konturlar uchun Kirxgofning ikkinchi qonuni asosida qolgan 3 ta tenglamani tuzamiz. Ma'lumki, konturlarni aylanib chiqish yo'nalishi ixtiyoriy tarzda tanlanadi.

I - kontur uchun:

$$E_1 = (r_{uv1} + R_1 + R_7)I_1 - R_3I_3,$$

III - kontur uchun

$$E_2 = (r_{u2} + R_2 + R_6)I_2 + R_4I_4,$$

nihojat II - kontur uchun

$$0 = R_3I_3 + R_5I_5 + R_4I_4,$$

CHunki II - kontur passiv kontur, u faqat passiv elementlar – R_3 , R_4 va R_5 rezistorlardan tarkib topgan. Unda EYUK manbai yo‘q.

Tenglamalar sistemasini echish natijasida $I_3 = -45A$ aniqlanadi. Manfiy ishora I_3 tokning haqiqiy yo‘nalishi dastlabki tanlangan yo‘nalishiga qarama-qarshi yo‘nalganligini ko‘rsatadi.

$$I_4 = 30A, I_1 = 50A, I_2 = 25A, I_5 = 5A.$$

Zanjirning sd qismi uchun tokning yo‘nalishini ixtiyoriy ravishda s tugundan d tugunga yo‘nalgan deb qabul qilaylik. Bu qism uchun $R_{cd} = 0$.

Kirxgof 1- qonuniga binoan:

$$I_4 = I_{cd} + I_6.$$

$$I_{cd} = I_4 - I_6 = 25 - 30 = -5A.$$

Manfiy ishora I_{cd} tokning haqiqiy yo‘nalishi dastlabki qabul qilingan yo‘nalishiga qarama-qarshi ekanligini bildiradi.

6. Kontur toklar usuliga doir

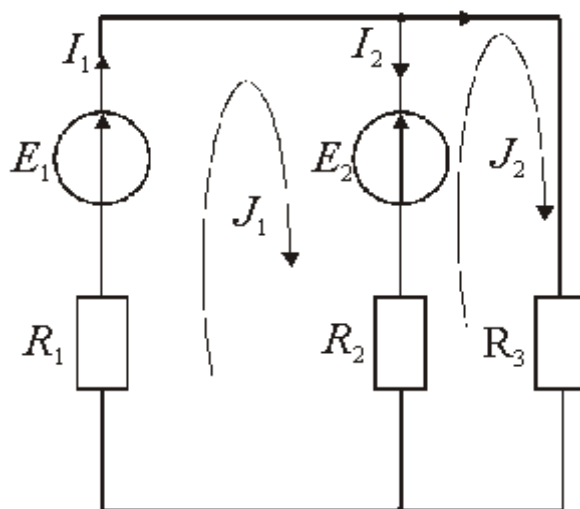
1-namuna. 23-rasmda ko‘rsatilgan elektr zanjir sxemasida quyidagilar ma’lum: $E_1 = 30\text{ B}$; $E_2 = 10\text{ V}$; $R_1 = 8\text{ Om}$; $R_2 = 15\text{ Om}$; $R_3 = 36\text{ Om}$. Zanjir shoxobchalaridagi toklar qiymatlarini hisoblang. Quvvat balansi tenglamasini tuzing va uni hisoblang.

Berilgan: $E_1 = 30\text{ B}$; $E_2 = 10\text{ V}$; $R_1 = 8\text{ Om}$; $R_2 = 15\text{ Om}$; $R_3 = 36\text{ Om}$.

Yechish. Elektr zanjir uchta shoxcha ($m=3$), ikki tugundan ($n=2$) iborat. Shoxchalardagi toklar musbat yo‘nalishlarini ixtiyoriy holda tanlaymiz. Kontur toklar usuliga binoan tuzilgan tenglamalar soni $m - (n - 1) = 2$ ta.

Kontur toklar yo‘nalishlarini ko‘rsatamiz (masalan, soat strelkasi bo‘yicha) va tenglamalar sistemasini tuzamiz:

$$\begin{aligned} (R_1 + R_2) \cdot J_1 - R_2 \cdot J_2 &= E_1 - E_2 \\ - R_2 \cdot J_1 + (R_2 + R_3) \cdot J_2 &= E_2. \end{aligned}$$



23 – Rasm. Elektr zanjirni kontur toklar usuliga binoan hisoblash

Elektr zanjir qarshiliklari va E.YU.K. oʻrniga ularning son qiymatlarini olingan tenglamalarga qoʻyib, kontur toklar J_1 va J_2 ni aniqlaymiz (masalan, aniqlovchilar yordamida):

$$20 = 23 \cdot J_1 - 15 \cdot J_2$$

$$10 = -15 \cdot J_1 + 51 \cdot J_2$$

$$J_1 = \frac{\begin{bmatrix} 20 & -15 \\ 10 & 51 \end{bmatrix}}{\begin{bmatrix} 23 & -15 \\ -15 & 51 \end{bmatrix}} = \frac{20 \cdot 51 + 10 \cdot 15}{23 \cdot 51 - 15 \cdot 15} = \frac{1170}{948} = 1,23 \text{ A},$$

$$J_2 = \frac{\begin{bmatrix} 23 & 20 \\ -15 & 10 \end{bmatrix}}{\begin{bmatrix} 23 & -15 \\ -15 & 51 \end{bmatrix}} = \frac{23 \cdot 10 + 15 \cdot 20}{23 \cdot 51 - 15 \cdot 15} = \frac{530}{948} = 0,56 \text{ A}.$$

SHoxchalardagi toklar quyidagi qiymatlarga ega:

$$I_1 = J_1 = 1,23 \text{ A}; I_2 = -J_2 + J_1 = 1,23 - 0,56 = 0,67 \text{ A}; I_3 = J_2 = 0,56 \text{ A}.$$

Quvvat balansini tenglamasini tuzamiz.

Generatorlar (manbalar) quvvati:

$$R_M = E_1 \cdot I_1 - E_2 \cdot I_2 = 30 \cdot 1,23 - 10 \cdot 0,67 = 30,2 \text{ Vt},$$

Bu tenglamada $E_2 \cdot I_2$ koʻpaytma manfiy ishoraga ega (manba orqali oʻtuvchi tok E.YU.K. yoʻnalishiga mos kelmaydi va demak ,E.YU.K. manbai elektr energiya isteʼmolchisi sifatidagi rejimda ishlamoqda).

YUklama isteʼmol qiluvchi quvvat quyidagiga teng:

$$R_l = R_1 \cdot I_1^2 + R_2 \cdot I_2^2 + R_3 \cdot I_3^2 = 8 \cdot 1,23^2 + 15 \cdot 0,56^2 + 36 \cdot 0,56^2 = 30,13 \text{ Vt}.$$

Hisoblash hatoligi:

$$\frac{P_M - P_H}{P_M} \cdot 100\% = \frac{30,2 - 30,13}{30,2} \cdot 100\% = 0,23\% \leq 1\%.$$

1% dan kamroq , demak toklar to‘g‘ri hisoblangan.

III.O‘zgarmas tok zanjiri bo‘yicha nazorat ishiga topshiriqlar

Nazorat uchun №1-topshiriq sharti

Elektr yurituvchi kuchi E ga teng bitta elektr energiya manbai va $R_1, R_2, R_3, R_4, R_5, R_6$ iste‘molchilari bo‘lgan tarmoklangan elektr zanjir berilgan.

Ekvivalent o‘zgartirishlar usuli bilan barcha shoxchalar toklari va zanjir elementlaridagi kuchlanishlarni toping. Quvvat balansini yozing va tekshiring. Dastlabki ma‘lumotlar 1-jadvalda keltirilgan.

1 – Jadval

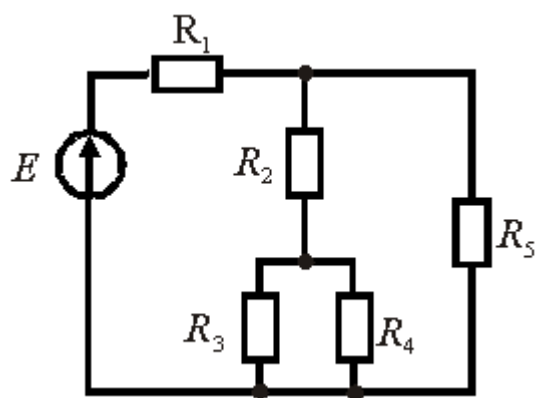
№1-topshiriq uchun variantlar

Variant raqami	Rasm raqami	E, B	$R_1,$	$R_2,$	$R_3,$	$R_4,$	$R_5,$	$R_6,$
			Om					
1	2	3	4	5	6	7	8	9
1	1	30	2	4	6	10	8	-
2	2	40	4	10	2	6	5	-
3	3	30	2	3	5	4	2	-
4	4	40	5	6	2	4	5	-
5	5	40	4	6	2	5	5	-
6	6	20	3	10	4	6	5	-
7	7	25	5	10	6	2	8	4
8	8	40	2	6	8	4	6	4
9	9	10	4	6	10	2	5	1
10	10	20	-	4	5	2	6	3
11	1	30	8	2	4	6	10	-
12	2	40	4	8	2	10	6	-
13	3	30	2	4	5	3	2	-
14	4	40	6	5	2	4	5	-
15	5	20	10	5	4	6	3	-
16	6	10	2	4	4	6	3	-
17	7	25	8	3	4	10	5	6
18	8	40	4	3	8	5	2	10
19	9	10	4	10	6	5	2	1

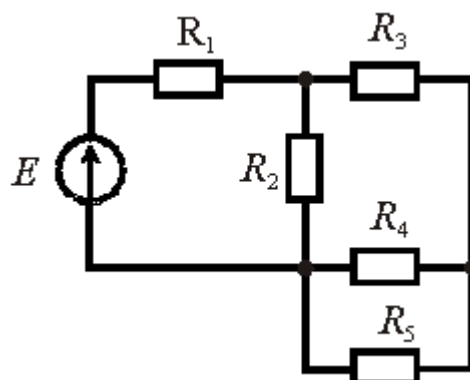
20	10	20	-	3	6	2	5	4
21	1	20	2	8	2	6	4	-
22	2	40	8	4	10	6	2	-
23	3	30	3	2	5	4	2	-
24	4	40	2	4	5	6	5	-
25	5	20	2	6	4	5	10	-
26	6	10	3	6	4	4	2	-
27	7	25	7	2	8	5	4	10
28	8	40	8	6	4	2	6	4
29	9	10	4	2	4	2	5	1
30	10	20	-	5	4	6	2	3
31	1	20	2	6	8	2	10	-
32	2	40	6	10	2	4	2	-
33	3	30	2	3	4	5	2	-
34	4	40	5	4	6	2	5	-
35	5	20	5	10	6	4	3	-
36	6	10	4	2	4	3	6	-
37	7	25	10	4	2	5	6	2
38	8	40	6	4	8	2	4	6
39	9	10	4	4	2	5	2	1
40	10	20	-	5	2	6	4	3
41	1	30	6	2	10	2	8	-
42	2	40	2	4	10	6	8	-
43	3	30	4	5	2	2	3	-
44	4	10	6	3	2	4	4	-
45	5	20	4	6	5	10	3	-
46	6	10	2	6	3	4	4	-
47	7	25	6	8	4	2	5	3
48	8	40	4	4	6	8	6	2
49	9	10	4	3	3	2	5	1
50	10	20	-	2	6	5	4	3
51	1	30	2	4	6	10	8	-
52	2	40	4	10	2	6	5	-
53	3	30	2	3	5	4	2	-
54	4	40	5	6	2	4	5	-
55	5	40	4	6	2	5	5	-
56	6	20	3	10	4	6	5	-
57	7	25	5	10	6	2	8	4

58	8	40	2	6	8	4	6	4
59	9	10	4	6	10	2	5	1
60	10	20	-	4	5	2	6	3
61	1	30	8	2	4	6	10	-
62	2	40	4	8	2	10	6	-
63	3	30	2	4	5	3	2	-
64	4	40	6	5	2	4	5	-
65	5	20	10	5	4	6	3	-
66	6	10	2	4	4	6	3	-
67	7	25	8	3	4	10	5	6
68	8	40	4	3	8	5	2	10
69	9	10	4	10	6	5	2	1
70	10	20	-	3	6	2	5	4
71	1	25	8	2	4	7	10	-
72	2	30	4	8	2	9	6	-
73	3	20	2	4	5	4	2	-
74	4	30	6	5	2	3	5	-
75	5	30	10	5	4	5	3	-
76	6	20	2	4	4	7	3	-
77	7	35	8	3	4	8	5	6
78	8	30	4	3	8	6	2	10
79	9	15	4	10	6	4	2	1
80	10	20	-	3	6	3	5	4
91	1	20	3	6	9	2	9	-
92	2	40	7	10	3	4	2	-
93	3	30	3	3	5	5	5	-
94	4	40	4	4	7	2	5	-
95	5	20	4	10	5	4	6	-
96	6	10	5	2	5	3	6	-
97	7	25	8	4	3	5	8	2
98	8	40	5	4	10	2	6	6
99	9	10	5	4	3	5	1	1
100	10	20	-	5	3	6	5	3

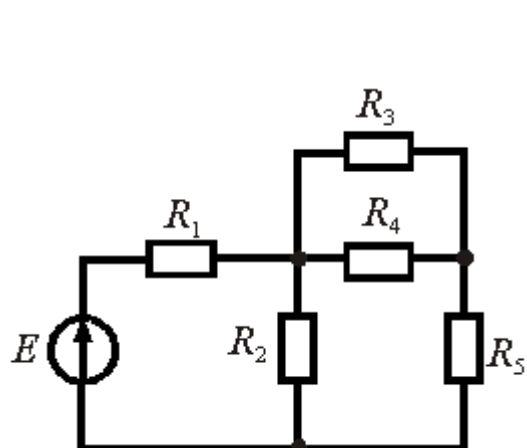
№1-topshiriqga doir sxemalar



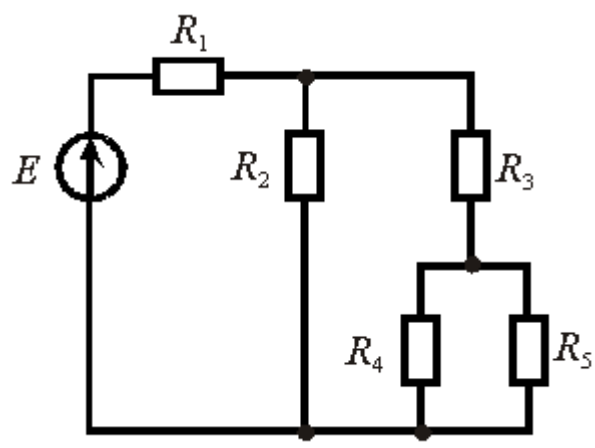
1-rasm



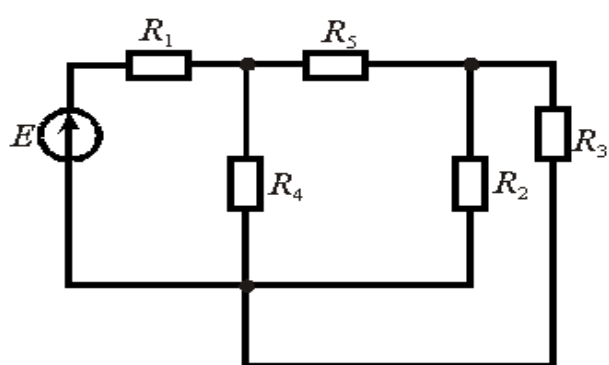
2-rasm



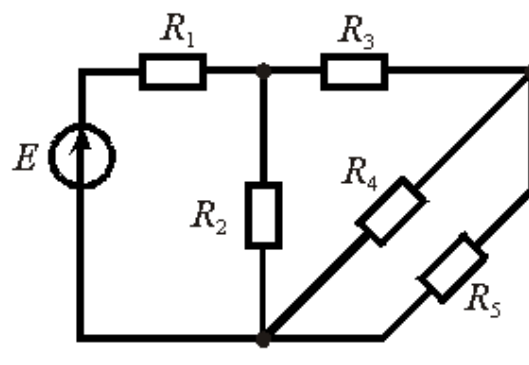
3-rasm



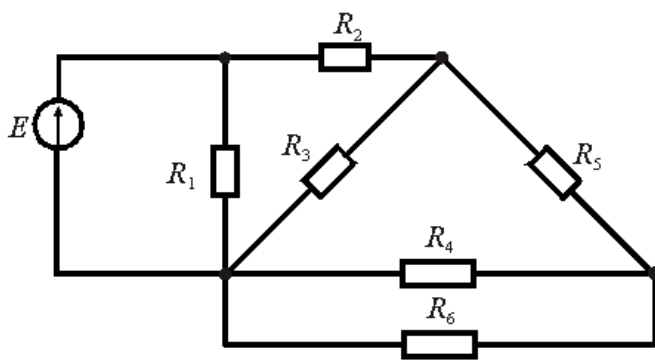
4-rasm



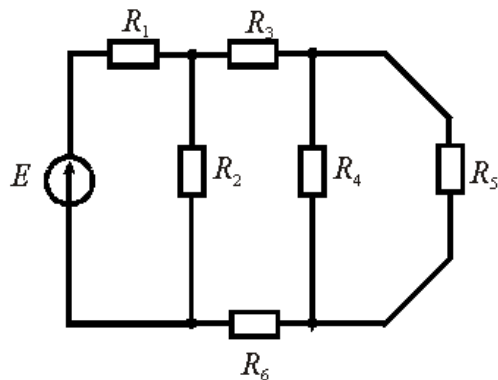
5-rasm



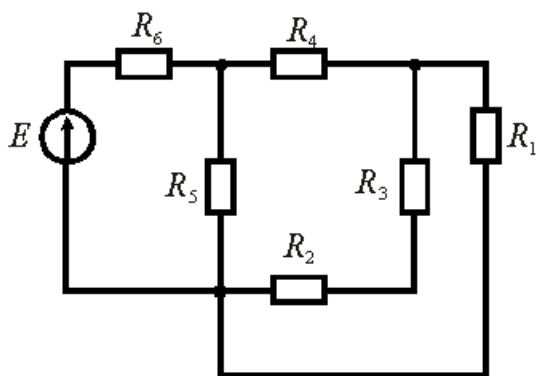
6-rasm



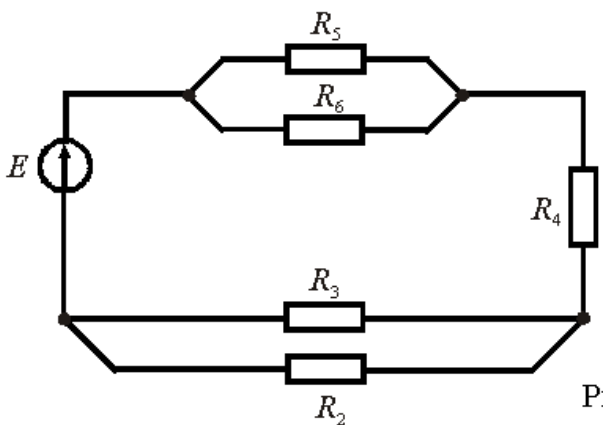
7-rasm



8-rasm



9-rasm



10-rasm

Nazorat uchun №2-topshiriq sharti

Elektr yurituvchi kuchi $E_1 = 12 \text{ V}$, ichki qarshiligi $R_1 = 0,5 \text{ Ohm}$ bo'lgan doimiy tok generatoriga zaryadlash uchun elektr yurituvchi kuchi E_2 , ichki qarshiligi R_2 bo'lgan akkumulyator va nominal kuchlanishi $U_n = 12 \text{ V}$, har birining quvvati P ga teng bo'lgan n ta cho'g'lanma lampalar o'zaro parallel ulangan. E_2 , R_2 , n va P larning qiymatlari 2-jadvalda keltirilgan. SHu elektr zanjir sxemasini chizing. Zanjir tarmoqlaridagi toklarni **Kirxgof qonunlari asosida** (toq yoki juft raqamdagi variantlar) va **Kontur toklar usuli** bilan (juft yoki toq raqamdagi variantlar) hisoblang. Quvvat balansi tekshirib ko'rsin.

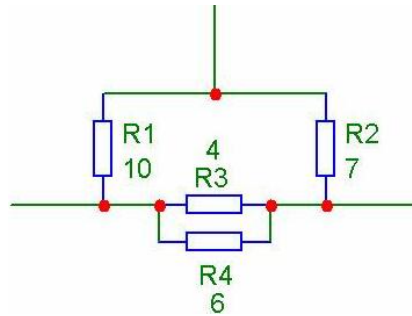
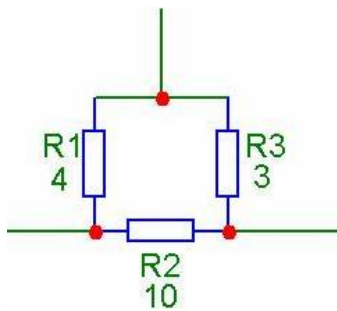
№2-topshiriq uchun variantlar

№ var	E_2 , V	R_2 , Om	R , Vt	n , sht		№ var	E_2 , V	R_2 , Om	R , Vt	n , sht
1	10	8,5	5	2		51	8,7	2,5	2,5	5
2	8	4,8	3	4		52	7,8	2,8	3	3
3	9	3	2	6		53	7,5	4	2	2
4	11	5	1	7		54	9	3,5	1	4
5	6	4,5	1	8		55	10,2	3,8	0,5	6
6	5	6	2	7		56	9,8	4,2	0,5	7
7	7,5	5,8	3	5		57	7,2	5,6	1	6
8	4,8	6,2	5	3		58	6,8	7,2	0,5	8
9	8	3,8	4	2		59	10	3,2	0,5	10
10	7	5,2	3	4		60	11	3,5	2	5
11	10,5	6	1	3		61	8	4,2	2,5	4
12	11,2	6,5	1,2	5		62	7	2,8	2	3
13	8,7	8	2	6		63	8,5	2,5	3	3
14	7,5	10	1	8		64	9	3	2	5
15	7,8	4	1	10		65	9,5	2,6	1,5	6
16	9,2	3	2	5		66	10	8,5	2,5	5
17	6,7	2	2,5	4		67	8	4,8	3	3
18	7,8	1	3	2		68	9	3	2	2
19	6,5	2,5	2	6		69	11	5	1	4
20	7	3,2	3	3		70	6	4,5	0,5	6
21	5,8	2,8	2,5	5		71	5	6	0,5	7
22	8,7	4	3,5	7		72	7,5	5,8	1	6
23	9,2	2	2,5	8		73	4,8	6,2	0,5	8
24	10	3	2	9		74	8	3,8	0,5	10

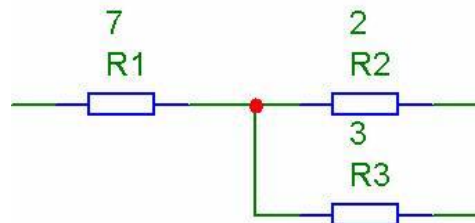
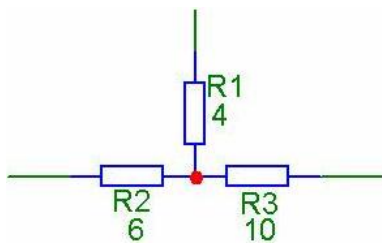
25	11	1,8	2,5	6		75	7	5,2	2	5
26	10,5	8	6	3		76	10,2	3,8	3	4
27	8,5	6	2	5		77	9,8	4,2	1	3
28	9	4	3	6		78	7,2	5,6	1,2	5
29	11	7,5	2	8		79	6,8	7,2	2	6
30	6	6	1	9		80	10	3,2	1	8
31	5	7,6	2,5	4		81	11	3,5	1	10
32	4,8	3,5	2	10		82	8	4,2	2	5
33	7,5	4,5	1	12		83	7	2,8	2,5	4
34	10,5	4	1,5	6		84	8,5	2,5	3	2
35	11,2	3	2	4		85	9	3	2	6
36	10,5	6	1	3		86	8	4,2	2,5	4
37	11,2	6,5	1,2	5		87	7	2,8	2	3
38	8,7	8	2	6		88	8,5	2,5	3	3
39	7,5	10	1	8		89	9	3	2	5
40	7,8	4	1	10		90	9,5	2,6	1,5	6
41	9,2	3	2	5		91	10	8,5	2,5	5
42	6,7	2	2,5	4		92	8	4,8	3	3
43	7,8	1	3	2		93	9	3	2	2
44	6,5	2,5	2	6		94	11	5	1	4
45	7	3,2	3	3		95	6	4,5	0,5	6
46	5,8	2,8	2,5	5		96	5	6	0,5	7
47	8,7	4	3,5	7		97	7,5	5,8	1	6
48	9,2	2	2,5	8		98	4,8	6,2	0,5	8
49	10	3	2	9		99	8	3,8	0,5	10
50	11	1,8	2,5	6		100	7	5,2	2	5

IV. Mustaqil ishlar uchun topshiriqlar

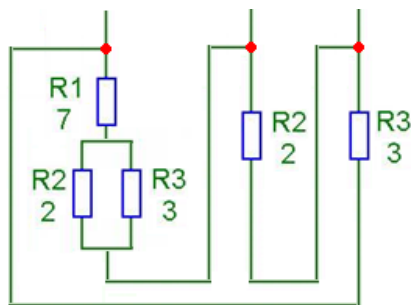
1. «Uchburchak» sxemani ekvivalent «yulduz» sxemaga almashtiring.



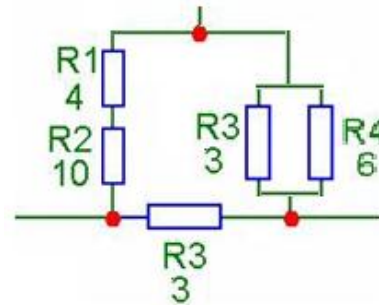
2. «YUlduz» sxemani ekvivalent «uchburchak» sxemaga almashtiring.



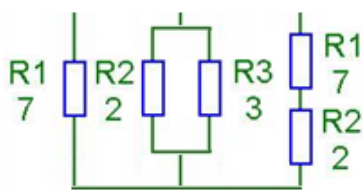
3. YUqorida berilan qarshiliklar asosida quyidagi sxemalarni almashtiring.



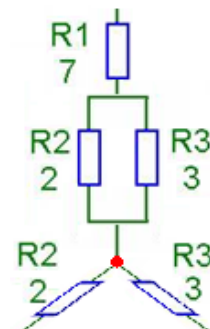
a)



b)

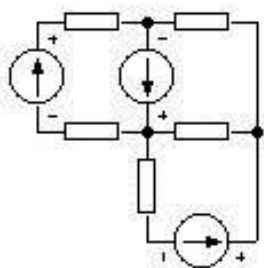


v)

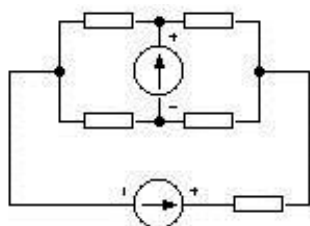


g)

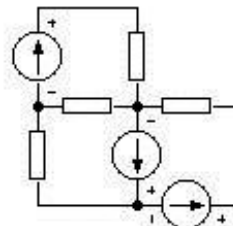
3. Quyida keltirilgan sxemalar uchun belgilashlar kiriting. Kirxgof qonunlaridan foydalanib tenglamalar sistemasini yozing.



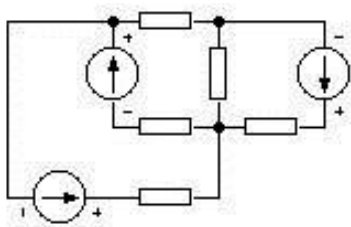
1 – rasm



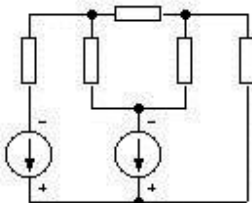
2 – rasm



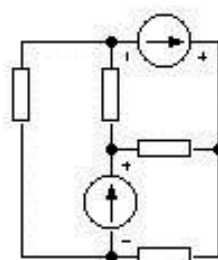
3 - rasm



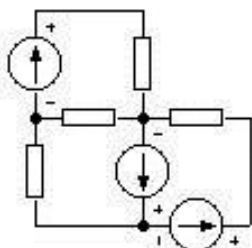
4 – rasm



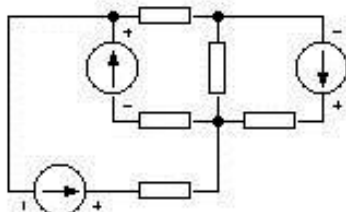
5 – rasm



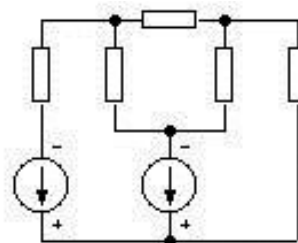
6 - rasm



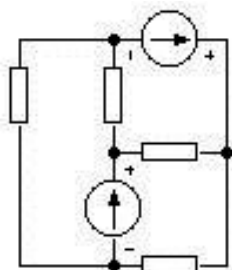
7 – rasm



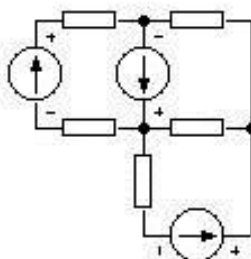
8 – rasm



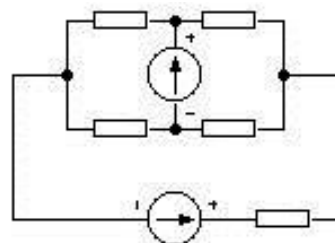
9 - rasm



10 – rasm

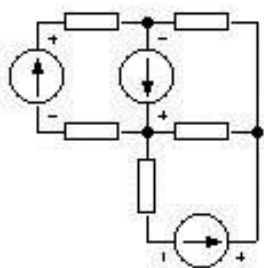


11 – rasm

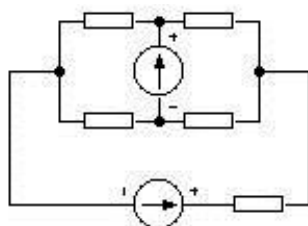


12 - rasm

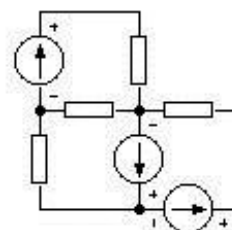
4. Quyida keltirilgan sxemalar uchun belgilashlar kiriting. Kontur toklar usulidan foydalanib matritsa ko‘rinishidagi tenglamalar sistemasini yozing.



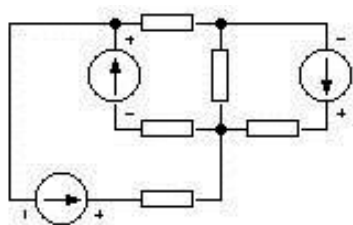
1 – rasm



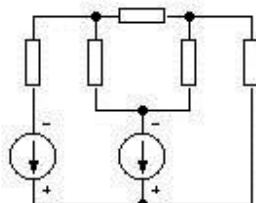
2 – rasm



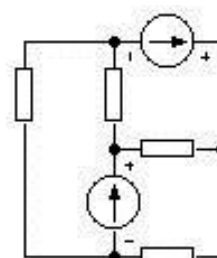
3 - rasm



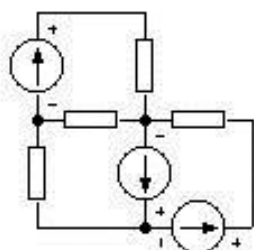
4 – rasm



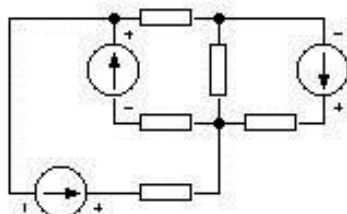
5 – rasm



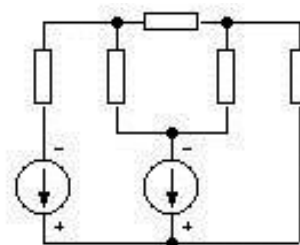
6 - rasm



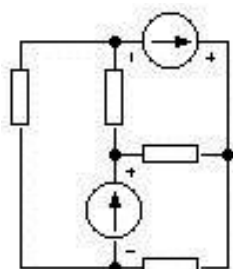
7 – rasm



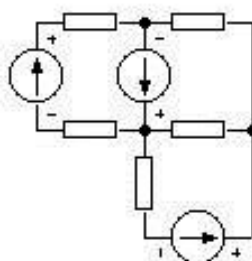
8 – rasm



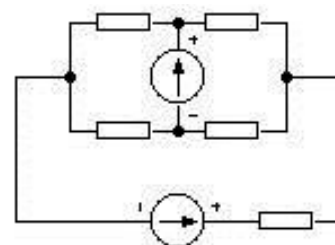
9 - rasm



10 – rasm



11 – rasm



12 - rasm

Foydalanilgan adabiyotlar ruyxati

1. John Bird. “Electrical and Electronic Principles and Technology” LONDON AND NEW YORK, 2014.-455 p.
2. Каримов А.С. ва бошқ. “Электротехника ва электроника асослари”. Дарслик. Т.: Ўқитувчи нашриёти, 1995 й. - 448 с.
3. Abdullayev B. va boshqalar. Elektrotexnika va elektronika asoslari fanidan laboratoriya ishlarini bajarishga o'quv-uslubiy qo'llanma. Toshkent, ToshDTU, 2011. -136 b.
4. Abdullayev B., Begmatov Sh.E., Xalmanov D.X. Elektrotexnika va elektronika fanidan virtual laboratoriya ishlarini bajarishga uslubiy ko'rsatmalar. Toshkent, ToshDTU, 2016. -86 b.
5. Alimxodjayev K., Abdullayev B., Abidov Q., Ibadullayev M.. Elektr texnikaning nazariy asoslari. Darslik. 1-qism. -T.: “Fan va texnologiya”, 2015, 320 bet.
6. Бегматов Ш.Э., Абдуллаев Б. «Электротехника и основы электроники». Методические электронное пособие к выполнению виртуальных лабораторных работ. Ташкент. 2015. - 84 с.
7. Amirov S.F., Yoqubov M.S., Jabborov N.G. Elektrotexnikaning nazariy asoslari. Oliy o'quv yurtlari talabalari uchun o'quv qo'llanma, T.: ToshTYML, 2007. - 128 b.
8. Karimov A.S. va b. Elektrotexnika. Masalalar to'plami. Toshkent – «O'qituvchi», 1975. – 208b.
6. Rekus G.G., Belousov A.I. Sbornik zadach i uprajneniy po elektrotexnike i osnovam elektroniki. – M.: Vysshaya shkola, 2002. - 416s.

Mundarija

I. Qisqacha nazariy ma'lumotlar	3
1.Elektr zanjir va uning elementlari.....	3
2.Om qonuni.....	8
3.Potensial diagramma.....	9
4.Elektr zanjirida quvvatlar balansi.....	9
5. Kirxgof qonunlari.....	10
6. Kontur toklar usuli.....	12
II. Masala echish namunalari	14
1.Elektr zanjir va uning elementlariga doir.....	14
2.Om qonuniga doir.....	15
3.Potensial diagrammaga doir.....	18
4.Elektr zanjirlarida quvvatlar balansiga doir.....	20
5. Kirxgof qonunlariga doir.....	21
6. Kontur toklar usuliga doir.....	22
III.O'zgarmas tok zanjiri bo'yicha nazorat ishiga topshiriq	24
Nazorat uchun №1-topshiriq sharti	24
Nazorat uchun №2-topshiriq sharti.....	28
IV. Mustaqil ishlar uchun topshiriqlar	32
Foydalanilgan adabiyotlar ro'yxati	34

Bepul tarqatiladi

Muharrir:

Nashrga ruxsat etildi
Qog'oz bichimi 60x84 1/16.

Hajmi
Adadi____ nusxa.

b.t.
Buyurtma№

TDTU bosmaxonasi.

