TTYMI

ENERGETIKANING MATEMATIK MASALALARI

Uslubiy ko'rsatma

Toshkent-2010

“O‘zbekiston temir yo‘llari” DATK

Toshkent temir yo‘l muhandislari instituti

ENERGETIKANING MATEMATIK MASALALARI

5520200 − Elektroenergetika yo‘nalishi bo‘yicha ta’lim olayotgan bakalavriat talabalari uchun amaliy, shaxsiy hisob grafik ishlari va mustaqil mashg‘ulotlarga oid uslubiy ko‘rsatma

Toshkent – 2010

UDK 621.31

Uslubiy ko‘rsatmada “Energetikaning matematik masalalari” fani bo‘yicha ko‘p hollarda uchraydigan amaliy masalalarni yechish usullari ko‘rsatilgan.

Uslubiy ko‘rsatma 2-bosqich 5520200 – “Elektroenergetika” yo‘nalishidagi bakalavr talabalar uchun mo‘ljalangan. Elektr zanjirlarning barqaror normal rejimlari, ehtimollar nazariyasi usullarini energetikada qo‘llash hamda energetik tizimlarning avtomatik rostlash va boshqarish masalalari bo‘yicha shug‘ullanadigan mutaxassislar uchun foydali bo‘ladi.

Institut O‘quv-uslubiy kengashi tomonidan nashirga tavsiya etilgan.

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Kirish

Uslubiy ko‘rsatma “Energetikaning matematik masalalari” fanining dasturiga mos holda tuzilgan bo‘lib, murakkab elektr tarmoqlar ishchi rejimlarini matritsa usulida umumlashgan holda yechish va energetik masalalarni yechishda ehtimollar nazariyasi usullaridan foydalanish hamda elektroenergetikadagi avtomatik tizim masalalarini yechish va tahlil qilishdan iborat.

Hozirgi vaqtda elektr tarmoqlarni ishchi rejimlarini hisoblash ayniqsa ularni joriy ishlatish jarayonida ko‘p uchraydi. Faqat shunday hisoblashlar negizida elektr ta’minot iqtisodini yuksalishiga mos asoslangan tadbirlar qabul qilish mumkin. Bu yerda kuchlanishni rostlash, berk tarmoqlarda yuklamalarni qayta taqsimlash va reaktiv quvvatni ularni manbalari orasida oqilona taqsimlash orqali ishchi rejimlarni EHM yordamida optimallash masalasi turadi.

Mazkur uslubiy ko‘rsatmaning shu bobida asosan, matritsalar hamda graflarning topologik nazariyasida qo‘llanilayotgan atamalardan foydalanilgan.

Ma’lumki, elektroenergetik tizim elektr energiyani generatsiyalovchi, uzatuvchi, o‘zgartiruvchi va taqsimlovchi texnik qurilmalardan iborat bo‘lib, ularning ish sharoitlari tasodifiy ta’sir etuvchi hodisalar, tasodifiy kattaliklar va jarayonlarga bog‘liq. Bunday tasodifiy hodisalar bir-biriga ustma-ust sodir etilishi natijasida energotizimda elektr quvvatiga bo‘lgan ehtiyoj o‘zgarib turadi. Tasodifiy hodisalarni ehtimollik xarakteristikalarini bilgan holda quvvatga bo‘lgan zarur energiya quvvati zahirasini aniqlash mumkin. Shularga ko‘ra uslubiy ko‘rsatmada ehtimollar nazariyasi usullarini elektroenergetik masalalarda qo‘llashga doir misollar keltirilgan.

“Energetikaning matematik masalalari” fanining ishchi dasturida elektr tarmoqlardagi o‘tkinchi jarayonining kerakli xossalarga ega bo‘lishi uchun qo‘llaniladigan avtomatik rostlash va boshqarish tizimlarini ifodalovchi differensial tenglamalar yechimini tahlil qilish masalasida tizim tarkibiga kiruvchi dinamik bo‘g‘inlar, strukturali sxemalarning tuzilishi hamda turg‘unlik mezonlarini aniqlash vazifasi kiradi. Shu bois ko‘rsatmada elektr sistemaning statik turg‘unligiga, ularda o‘tadigan o‘tkinchi jarayonlarning o‘tish xarakterini aniqlashga doir misol va masalalar kiritilgan.

1. Elektr zanjirlarni matritsa shaklida analitik ifodalash

Amaliy masalalarni yechishda elektr sxema shoxobchalarining ulanish xarakterini ikki usul bilan ifodalash lozim bo‘ladi: tugunlarda va bog‘lanmagan konturlarda.

Shuni aytish joizki shoxobchalarning bunday ulanishi o‘zaro bir-biriga bog‘liqdir. Ma’lum sxema shoxobchalarining ulanishini ifodalash uchun ulanish insidensiyalarning matritsasi qo‘llaniladi. Barcha kattaliklarni hisoblashda musbat yo‘nalishlarni muvofiqlashtirish katta ahamiyatga ega. Musbat yo‘nalishlar nafaqat shxobchalardagi toklarni, balki sxemaning barcha EYuK va kuchlanishlar yo‘nalishlarini belgilaydi. Musbat yo‘nalishlar shartli bo‘lib ixtiyoriy qabul qilinadi.

Shoxobchalar yo‘nalishlari belgilangan har qanday sxema-yo‘naltirilgan graf deyiladi.

Har bir shoxobchaning yo‘nalishi u boshlang‘ich uchidan (tugundan) oxirgi uchigacha hisoblanadi.

Bog‘lanishlarning (insidensiyalarning) birinchi matritsasi.

Sxema holatining har qanday $i-$ tuguni uchun Kirxgofning matritsa shaklidagi birinchi tenglamasi.

$$M\underline{I} = \underline{Y},$$

bunda: $M-$ matritsa sxema tuguniga ulangan shoxobchalarning ulanishini aks ettiradi. Bu matritsa zanjir holatining birinchi tenglamasini tuzish uchun kerak bo‘ladi. Bu matritsa bog‘lanishlarning birinchi matritsasi deyiladi.

Shoxobcha yo‘nalishlari belgilangan bo‘lsa, M matritsasini tuzish mumkin. Bu matritsaning har qanday $i-$ qatori sxemaning bog‘lanmagan xuddi shu $i-$ tartib raqamlari tuguniga to‘g‘ri keladi.

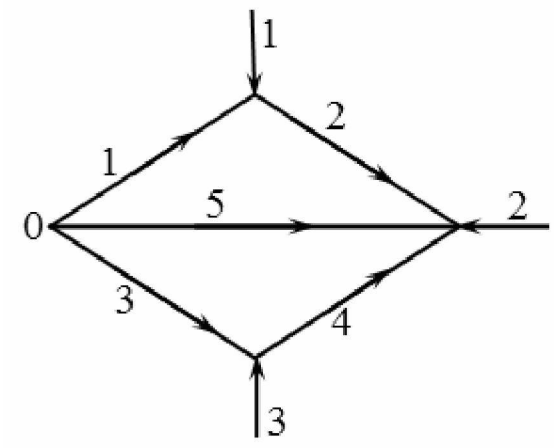
Shu matritsaning har qanday $j-$ ustuni xuddi shu $j-$ tartib raqamlari shoxobchaga to‘g‘ri keladi. Matritsaning $i-$ qatori va $j-$ ustuni kesishgan o‘rniga +1 yoziladi, agar $j-$ shoxobcha $i-$ tugun bilan boshlang‘ich uchi orqali ulangan, ya’ni yo‘nalishi $i-$ tugundan boshlangan bo‘lsa, $i-$ qator va $j-$ ustun kesishgan joyda “–1” qo‘yiladi, agar $j-$ shoxobcha $i-$ tugunga qarab yo‘nalgan, ya’ni ohirgi uchi bilan ulangan bo‘lsa. Nihoyat $i-$ qator va $j-$ ustun kesishgan joyda *0* qo‘yiladi, agar $j-$ shoxobcha $i-$ tugun bilan bevosita bog‘lanmagan bo‘lsa.

M matritsa to‘laligicha elektr sxemani ifodalaydi va masalani analitik yechishga imkon beradi. Matritsaning har bir qatorida bittadan kam bo‘lmagan musbat yoki manfiy bir bo‘lish lozim. Aks holda bu tugun tizimning boshqa qismi bilan ulanmagan bo‘ladi. Qatordagi musbat birlar soni shu tugunga nechta shoxobcha ulanganini ko‘rsatadi. Manfiy birlar soni shu tugunga ohirgi uchlari bilan ulangan shoxobchalar soniga teng bo‘ladi.

M-matritsaning har bir ustunida faqat bitta “+1” va “–1” bo‘lishi mumkin. Birlar yig‘indisi bitta yoki ikkita bo‘lishi mumkin. Agar ustunda faqat bitta bir bo‘lsa (musbat yoki manfiy) bu shoxobchaning boshqa uchi bazis tugun bilan ulanganini bildiradi.

M matritsa to‘g‘ri burchakli bo‘ladi. Uning qatorining soni sxemadagi bog‘lanmagan tugunlar soniga teng bo‘ladi, ustunlar soni esa shoxobchalar soniga teng bo‘ladi.

1.10-rasmda beshta shoxobcha va uchta bog‘lanmagan tugunga ega sxema tasvirlangan. Demak sxemaning *M*– matritsasi uchta qator va beshta ustunga ega bo‘lishi kerak. Agar shoxobchalarning yo‘nalishi 1.10-rasmda ko‘rsatilganidek bo‘lsa, matritsa quyidagi ko‘rinishga ega bo‘ladi.



1.1-rasm

sh o x o b ch a

$$M = \begin{matrix} mу \\ гу \\ н \end{matrix}\begin{Vmatrix} -1 & 1 & 0 & 0 & 0 \\ 0 & -1 & 0 & -1 & -1 \\ 0 & 0 & -1 & 1 & 0 \end{Vmatrix}$$

Birinchi tugunga mos keladigan 1-qatorning 1-ustunida manfiy bir joylashgan, 2-ustunda esa ─ musbat bir, chunki birinchi tugun shoxobcha bilan birinchi shoxobcha o‘zini ohirgi uchi bilan ulangan, ikkinchi shoxobcha esa boshlang‘ich uchi bilan ulangan. Boshqa ustunlarda esa nollar joylashgan. 2-qatorda esa manfiy birlar 2, 4, 5-ustunlarda joylashgan, chunki mos shoxobchalar 2-tugunga ohirgi uchlari bilan ulangan va hokazo.

M matritsa tugun kattaliklari orasidagi munosabatlarni aniqlash, ya'ni bu matritsa sxemaning har bir bog'lanmagan tugun va uning bazis tuguni orasidagi U_Δ kuchlanishlar tushishi bo'yicha sxema shoxobchalaridagi kuchlanish pasayishlarining U_β matritsasini aniqlash uchun qo'llaniladi. Bu munosabat quyidagicha ifodalanadi:

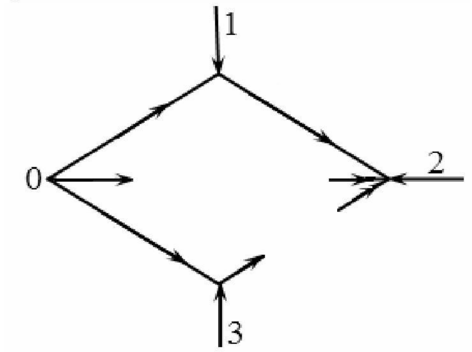
$$\underline{U}_\beta = M_t U_\Delta$$

bunda M_t – transponirlangan matritsa.

M_t – matritsani U_Δ matritsaga o'ng tomondan ko'paytirsa sxemaning har bir shoxobchasi uchun kuchlanish ayirmasi hosil bo'ladi, ya'ni shoxobchaning boshlang'ich va ohirgi uchlari orasidagi kuchlanishlar farqi chiqadi.

Ochiq zanjirga kvadratli M matritsa to'g'ri keladi, chunki ochiq zanjirni har bir shoxobchasi bazis tugunni yangi tugun bilan ulaydi.

Misol uchun, 1.2-rasmdagi uchta bog'lanmagan tugunli va uchta shoxobchali ochiq zanjirning birinchi bog'lanish (insidentsiya) matritsasi quyidagi ko'rinishga ega bo'ladi:



1.2 –rasm

sh o x o b ch a

$$M_p = \begin{matrix} ту \\ гу \\ н \end{matrix}\begin{Vmatrix} -1 & 1 & 0 \\ 0 & -1 & 0 \\ 0 & 0 & -1 \end{Vmatrix}$$

Bu matritsa berk zanjir matritsasi kabi tuzildi.

Ochiq zanjirlarning bog'lanish matritsasi M_p berilma toklar shoxobchalarda hosil qiladigan toklarni aniqlanishda qo'llaniladi.

$$\underline{I} = M_p^{-1} \underline{J}$$

Xuddi shunga o'xshash:

$$\underline{I} = C_0 \overline{J},$$

chunki,

$$M_p^{-1} = C_0,$$

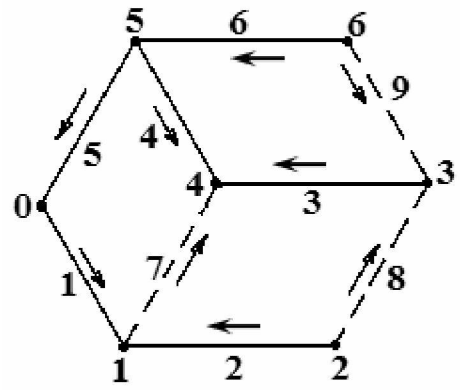
bunda, C_0 – taqsimlanish koeffitsientlarining matritsasi.

C_0 – matritsaning har bir i ustuni, xuddi shu raqami bog‘lanmagan tugunga mos keladi, har bir j– qator esa j– shoxobcha to‘g‘ri keladi. C_p matritsaning har bir ustuni sxemaning bog‘lanmagan tugunidan balans tuguniga qadar yo‘lni aniqlaydi. Grafning belgilangan yo‘liga kiradigan shoxobcha birlar bilan belgilanadi, ishorasi esa – musbat yoki manfiy – mos ravishda shoxobchaning yo‘nalishi graf yo‘li bilan mos kelsa, unga qarama-qarshi bo‘lganini ko‘rsatadi.

C_p matritsaning har bir qatori shu shoxobcha grafning qanday yo‘llariga (qanday tugunlariga) kirishini ko‘rsatadi. Matritsaning i-qatori va j-ustuni kesishgan joydagi “0” grafning j-tugunidan sxemaning balans tugunigacha bo‘lgan yo‘l tarkibiga i–shoxobcha kirmasligini ko‘rsatadi.

Shunday qilib, C_p matritsani bevosita ajratilgan sxema bo‘yicha tuzish mumkin.

Misol tariqasida 1.3-rasm uchun tuzilgan taqsimlanish koeffitsientlari C_0 matritsasi quyida keltirilgan.



1.3-rasm

$$C_0 = \begin{Vmatrix} -1 & -1 & 0 & 0 & 0 & 0 \\ 0 & 1 & 0 & 0 & 0 & 0 \\ 0 & 0 & 1 & 0 & 0 & 0 \\ 0 & 0 & -1 & -1 & 0 & 0 \\ 0 & 0 & 1 & 1 & 1 & 1 \\ 0 & 0 & 0 & 0 & 0 & 1 \end{Vmatrix}$$

Ma’lumki murakkab sxemaning shoxobchalaridagi toklarni aniqlash uchun shoxobchalarning tartibli tenglamalar tizimini yechish shart emas, chunki, agar sxema tugunlaridagi berilma toklar ma’lum bo‘lsa, ular o‘zaro mustaqil bo‘lmaydi.

Bundan kelib chiqadiki, avval qandaydir tenglamalarni birgalikda yechib vatarlardagi toklarni aniqlash kerak bo‘ladi, keyin quyidagi formuladan foydalanib, sxemaning boshqa shoxobchalaridagi toklari aniqlanadi.

$$I_\alpha = M_\alpha^{-1}\left(J - M_\beta I_\beta\right),$$

bunda:

I_α – daraxt shoxobchalaridagi toklar;

J – berilma toklar;

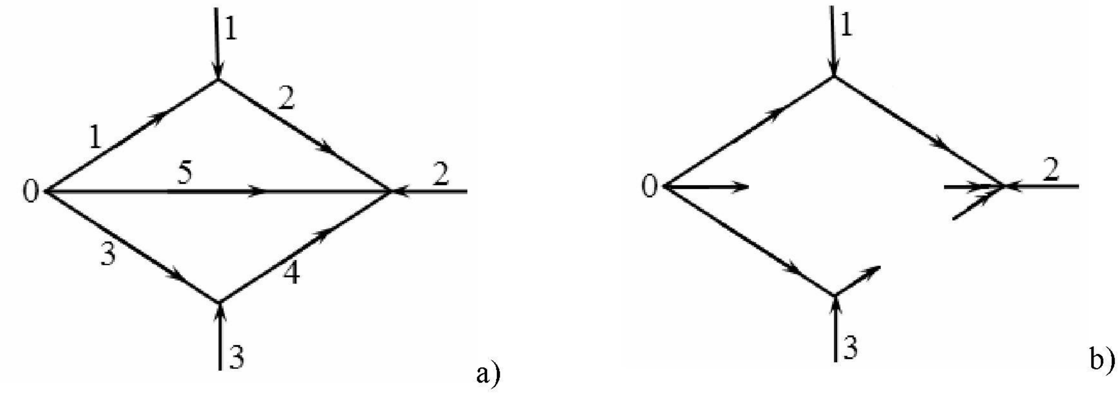
M_β – vatar tugunlarining bog‘lanish matritsasi;

I_β – vatar shoxobchalarining toklari matritsasi.

1-1-misol. 1.4-rasmdagi sxema uchun vatarning 5 va 4 shoxobchalaridagi toklar aniqlansin:

$$I_\beta = \begin{Vmatrix} 0{,}5211 \\ -1{,}0704 \end{Vmatrix}$$

Bu holda sxemani daraxt ko‘rinishida tasvirlab uni soddalashtirish mumkin.



1.4-rasm

Sxemaning boshqa barcha shoxobchalaridagi toklarni bevosita topamiz. Buning uchun quyidagi formuladan foydalaniladi:

$$\overline{I}_\alpha = C_o\left(\underline{J} - \underline{M}_\beta \underline{I}_\beta\right).$$

Bu formulada $\overline{I}_\alpha$ matritsani M_β matritsasiga chap tomondan ko‘paytirish, vatarlardagi toklarni berilma toklarning mos yig‘indisi bilan almashtirilganligini aniqlatadi:

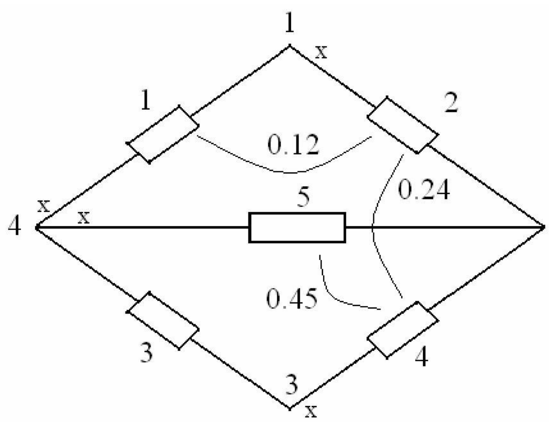
$$M_\beta I_\beta = \begin{Vmatrix} 0 & 0 \\ -1 & -1 \\ 1 & 0 \end{Vmatrix} \cdot \begin{Vmatrix} 0{,}5211 \\ -1{,}0704 \end{Vmatrix} = \begin{Vmatrix} 0 \\ 0{,}5493 \\ 0{,}5211 \end{Vmatrix}$$

Yuqoridagi formulada bu toklar sxemadagi berilma toklar bilan algebraik ravishda qo‘shiladi:

$$\underline{Y} - M_\beta \underline{I}_\beta = \begin{Vmatrix} 1 \\ 2 \\ 3 \end{Vmatrix} - \begin{Vmatrix} 0 \\ 0{,}5493 \\ 0{,}5211 \end{Vmatrix} = \begin{Vmatrix} 1 \\ 1{,}4507 \\ 2{,}4789 \end{Vmatrix}$$

1-2-misol. Almashlash sxemasi 1.5-rasmda tasvirlangan tarmoq uchun qarshiliklar matritsasi yozilsin («X» – ishorasi bilan shoxobchadagi tok yo‘nalishi belgilangan). O‘z qarshiligidan tashqari, sxema 1 va 2, 2 va 4, 4 va 5 shoxobchalar orasida o‘zaro qarshiliklarga ega. Matritsa yozilishi oson bo‘lishi uchun qarshiliklarning qiymatlari shoxobchalar raqami bilan bog‘langan: $Z_{12} = Z_{21} = 0.12\,; Z_{42} = Z_{24} = 0.24\,; Z_{45} = Z_{54} = 0.45$.

Yechilishi:



1.5-rasm

$$\underline{Z}_b = \begin{Vmatrix} 1 & 0.12 & 0 & 0 & 0 \\ 0.12 & 2 & 0 & 0.24 & 0 \\ 0 & 0 & 3 & 0 & 0 \\ 0 & 0.24 & 0 & 4 & 0.45 \\ 0 & 0 & 0 & 0.45 & 5 \end{Vmatrix}$$

Umumiy holda ikki o‘lchamli matritsa to‘g‘ri burchakli bo‘ladi. To‘g‘ri burchakli matritsada qatorlar soni ustunlar soniga teng bo‘lmasligi, ya’ni ko‘p yoki kam bo‘lishi mumkin bo‘lgan chiziqli matritsani xususiy holidir. Misol uchun, ustunli matritsada ustunlar soni birga teng, kvadrat matritsada qatorlar soni ustunlar soniga teng.

1-3-misol. Ikkita matritsa ko‘paytmasini hisoblang:

$$\underline{A} = \begin{Vmatrix} 0 & 1 & 2 \\ 3 & 4 & 5 \\ 6 & 7 & 8 \\ 9 & 10 & 11 \end{Vmatrix} \quad \text{va} \quad \underline{B} = \begin{Vmatrix} 12 & 15 \\ 13 & 16 \\ 14 & 17 \end{Vmatrix}$$

Yechilishi:

$$\underline{D} = \underline{A}\underline{B} = \begin{Vmatrix} 0 & 1 & 2 \\ 3 & 4 & 5 \\ 6 & 7 & 8 \\ 9 & 10 & 11 \end{Vmatrix} \bullet \begin{Vmatrix} 12 & 15 \\ 13 & 16 \\ 14 & 17 \end{Vmatrix} = \begin{Vmatrix} 0\cdot12+1\cdot13+2\cdot14 & 0\cdot15+1\cdot16+2\cdot17 \\ 3\cdot12+4\cdot13+5\cdot4 & 3\cdot15+4\cdot16+5\cdot17 \\ 6\cdot12+7\cdot13+8\cdot14 & 6\cdot15+7\cdot16+8\cdot17 \\ 9\cdot12+10\cdot13+11\cdot14 & 9\cdot15+10\cdot16+11\cdot17 \end{Vmatrix} =$$

$$= \begin{Vmatrix} 41 & 50 \\ 158 & 189 \\ 275 & 338 \\ 392 & 482 \end{Vmatrix}$$

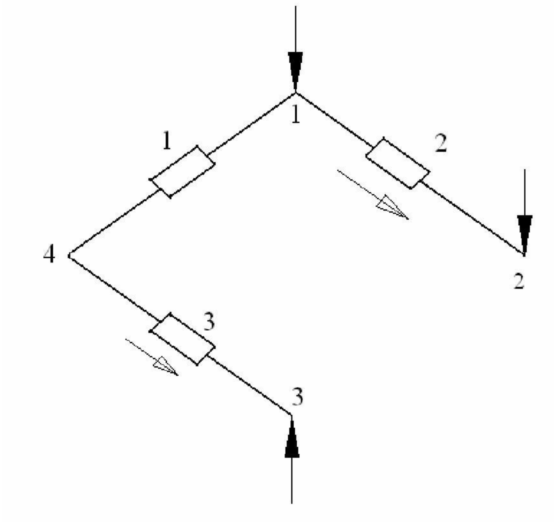
Muhim xususiyatga e’tibor berish kerak: matritsalarni ko‘paytirish – o‘rin almashtirish xususiyatga ega emas. Misol uchun, agar $\underline{A}$ va $\underline{B}$

ko‘paytma matritsalar – kvadratli va bir tartibli bo‘lsa, umumiy holda $\underline{AB}$ va $\underline{BA}$ har xil natijalar beradi:

$$\underline{AB} \neq \underline{BA}$$

Shuning uchun $\underline{A}$ matritsani $\underline{B}$ matritsaga ko‘paytirishni chap tomondan $C = \underline{BA}$, va o‘ng tomondan $D = \underline{AB}$ farqlanadi.

***1-4-misol**.* 1.6-rasmda tasvirlangan sxema uchun balans tuguni 4 bilan belgilangan, berilma toklarni matritsasi



$$\underline{J} = \begin{Vmatrix} 1 \\ 2 \\ 3 \end{Vmatrix}$$

1.6-rasm

va taqsimlanish koeffitsientlarining matritsasi

$$\underline{C} = \begin{Vmatrix} -1 & 0 & 0 \\ 0 & -1 & 0 \\ 0 & 0 & -1 \end{Vmatrix}$$

Shu sxemada balans tugunini 1-tugunga o‘zgartirilganda $\underline{J}$ $\underline{C}$ matritsalarni aniqlash kerak. Yechilishini aniqlash kerak bo‘lgan matritsalarni yozish uchun 1 va 4 tugunlarni o‘zaro o‘zgartiramiz. Unda berilma toklarning matritsasi

$$\underline{J} = \begin{Vmatrix} -6 \\ 2 \\ 3 \end{Vmatrix}$$

va taqsimlanish koeffitsientlarni matritsasi

$$\underline{C} = \begin{Vmatrix} 1 & 0 & 1 \\ 0 & -1 & 0 \\ 0 & 0 & -1 \end{Vmatrix}$$

1-5-misol. Dastlabki matritsa.

$$\underline{Z}_B = \begin{Vmatrix} 1,5 & -0,5 & 0 \\ -0,5 & 0,95 & -0,25 \\ 0 & -0,25 & 0,5833 \end{Vmatrix}$$

Shu matritsaga teskari bo‘lgan matritsani aniqlash uchun, uning taqribiy diagonal matritsasini yozamiz:

$$\widetilde{Z}_{в} = \begin{Vmatrix} 1,5 & & \\ & 0,95 & \\ & & 0,5833 \end{Vmatrix}$$

Taqribiy (diagonal) teskari matritsa

$$\underline{\widetilde{Y}}_B^1 = \begin{Vmatrix} \frac{1}{1,5} & & \\ & \frac{1}{0,95} & \\ & & \frac{1}{0,5833} \end{Vmatrix} = \begin{Vmatrix} 0,6667 & & \\ & 1,0526 & \\ & & 1,7144 \end{Vmatrix}$$

Birinchi aniqlashtirishdan so‘ng formula $Y_B^{11} = 2\widetilde{Y}_B - \widetilde{Y}_B' \, \underline{Z}_B \widetilde{Y}_B'$ yordamida quyidagini hisoblash mumkin:

$$\widetilde{Y}_B^{II} = \begin{Vmatrix} 0,6667 & 0,3508 & 0 \\ 0,3509 & 1,0526 & 0,4512 \\ 0 & 0,4511 & 1,7144 \end{Vmatrix}$$

Ikkinchi aniqlashtirishdan so‘ng:

$$\widetilde{Y}_B^{III} = \begin{Vmatrix} 0,7837 & 0,4520 & 0,1504 \\ 0,4521 & 1,3561 & 0,5813 \\ 0 & 0,4511 & 1,7144 \end{Vmatrix}$$

Uchinchi yaqinlashtirish amaldagiga yaqin javob beradi:

$$\widetilde{Y}_B^{IV} = \begin{Vmatrix} 0,8271 & 0,4895 & 0,2063 \\ 0,4897 & 1,4688 & 0,6296 \\ 0,2062 & 0,6296 & 1,9796 \end{Vmatrix}$$

Haqiqatda olingan teskari matritsani dastlabki matritsaga ko‘paytmasi quyidagini beradi:

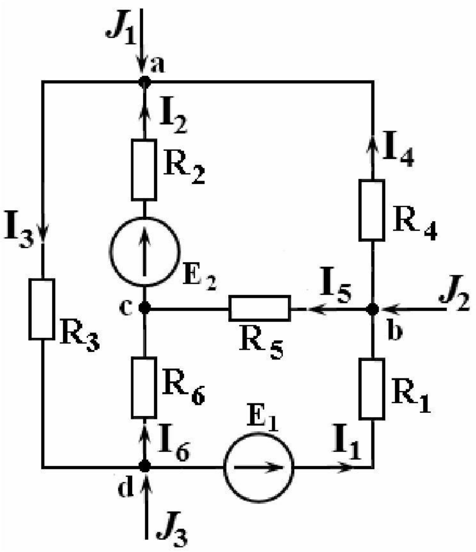
$$\tilde{Y}_B^{IV}\underline{Z}_B = \begin{Vmatrix} 0{,}9959 & 0{,}0001 & 0{,}0021 \\ -0{,}0001 & 0{,}9931 & 0{,}0000 \\ -0{,}0055 & 0{,}0001 & 0{,}9973 \end{Vmatrix},$$

ya’ni birlik diagonal matritsaga yaqin bo‘lgan matritsani beradi.

1-6-misol. Berilgan elektr sxema (1.7-rasm) toklarini holat tenglamalari usulida aniqlang.

$E_1 = 12$ В; $E_2 = 24$В; $R_1 = 5{,}8$Ом; $R_2 = 12{,}4$Ом; $R_3 = 16{,}6$ Ом; $R_4 = 12{,}4$ *Ом*;

$R_5 = 5{,}8$ Ом; $R_6 = 6{,}2$ Ом; $J_1 = 4$ А; $J_2 = 3$ А; $J_3 = 4$ А.



1.7-rasm

Yechish:

1. Berilma toklarning matritsasini tuzamiz:

$$J = \begin{Vmatrix} 4 \\ 3 \\ 4 \end{Vmatrix};$$

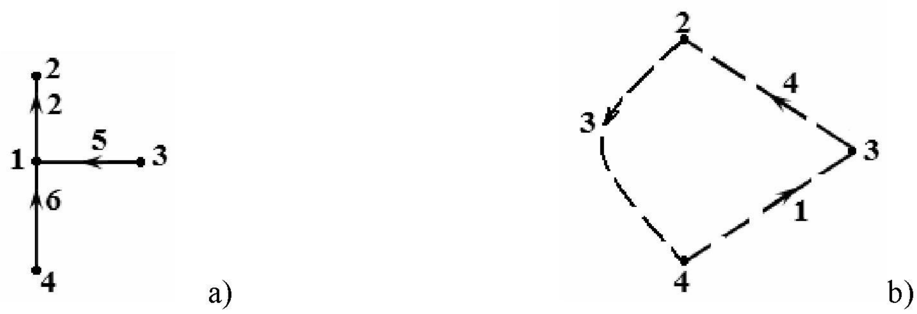
2. Shoxobchalar qarshiliklarining matritsasini tuzamiz:

$$Z = \begin{Vmatrix} 5{,}8 & 0 & 0 & 0 & 0 & 0 \\ 0 & 12{,}4 & 0 & 0 & 0 & 0 \\ 0 & 0 & 16{,}6 & 0 & 0 & 0 \\ 0 & 0 & 0 & 4 & 0 & 0 \\ 0 & 0 & 0 & 0 & 5{,}8 & 0 \\ 0 & 0 & 0 & 0 & 0 & 6{,}2 \end{Vmatrix};$$

3. EYuK lar matritsasini tuzamiz:

$$E_{ij} = \begin{Vmatrix} 12 \\ 24 \\ 0 \\ 0 \\ 0 \\ 0 \end{Vmatrix};$$

Sxema grafining daraxti: a) va vatarga b) ajratamiz. Ma'lumki, bunda daraxt tarkibida barcha tugunlar bo'lishi kerak.



1.8-rasm
Elektr sxemaning daraxti: a) va vatari b).

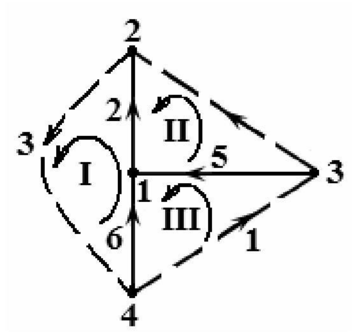
4. Daraxt $Z_{\alpha\alpha}$ va vatarlar $Z_{\beta\beta}$ shoxobchalarining qarshiliklari matritsalarini tuzamiz:

$$Z_{\alpha\alpha} = \begin{Vmatrix} 12{,}4 & 0 & 0 \\ 0 & 5{,}8 & 0 \\ 0 & 0 & 6{,}2 \end{Vmatrix}; \qquad Z_{\beta\beta} = \begin{Vmatrix} 5{,}8 & 0 & 0 \\ 0 & 1{,}6 & 0 \\ 0 & 0 & 4 \end{Vmatrix};$$

5. Vatar tugunlarining bog'lanish (insidensiyalarning) birinchi matritsasini tuzamiz:

$$\begin{matrix} & & \text{shoxobchalar №} \\ & \text{ту} & \\ M_{\beta} = & \text{гун} & \begin{Vmatrix} 0 & 1 & -1 \\ -1 & 0 & 1 \\ 1 & -1 & 0 \end{Vmatrix}; \\ & \text{лар№} & \end{matrix}$$

6. Sxema daraxti uchun konturlar (insidensiyalar) matritsasining bloki tarkibiga kiruvchi shoxobchalar hisobga olinsin, 1.9-rasm. Matritsalar tuzamiz:



1.9-rasm

$$\begin{array}{r} \\ \\ кон\ I \\ N_\alpha = тур\ II \\ лар\ III \end{array} \begin{array}{c} \text{shoxobchalar№} \\ \begin{array}{ccc} 2 & 5 & 6 \end{array} \\ \left\| \begin{array}{ccc} 1 & 0 & 1 \\ 0 & 1 & -1 \\ -1 & -1 & 0 \end{array} \right\| \end{array};$$

7. Sxema daraxti uchun taqsimlanish koeffitsientlarining matritsasi:

$$\begin{array}{r} \\ \\ шо\ \ 2 \\ C_{o\alpha} = хобча\ \ 5 \\ лар\ \ 6 \end{array} \begin{array}{c} \text{tugunlar№} \\ \begin{array}{ccc} 2 & 3 & 4 \end{array} \\ \left\| \begin{array}{ccc} -1 & 0 & 0 \\ 0 & 1 & 0 \\ 0 & 0 & 1 \end{array} \right\| \end{array};$$

8. To‘la sxema uchun konturlar insidensiyalarning ikkinchi matritsasi:

$$\begin{array}{r} \\ \\ кон\ I \\ N = тур\ II \\ лар\ III \end{array} \begin{array}{c} \text{sh a x o b ch a l a r №} \\ \begin{array}{cccccc} 1 & 2 & 3 & 4 & 5 & 6 \end{array} \\ \left\| \begin{array}{cccccc} 0 & 1 & 1 & 0 & 0 & 1 \\ 1 & 0 & 0 & 0 & 1 & -1 \\ 0 & -1 & 0 & 1 & -1 & 0 \end{array} \right\| \end{array};$$

9. Vatardagi toklar matritsasini quyidagi formuladan aniqlaymiz:

$$\mathrm{I}_{\beta} = (Z_{\beta\beta} + N_{\alpha} Z_{\alpha\alpha} N_{\alpha\, t})^{-1} \cdot (NE - N_{\alpha} Z_{\alpha\alpha} C_{o\,\alpha} J) =$$

$$\qquad Z_{\beta\beta} \qquad\qquad N_{\alpha} \qquad\qquad\qquad Z_{\alpha\alpha} \qquad\qquad N_{\alpha\, t}$$

$$= \left(+ \begin{Vmatrix} 5{,}8 & 0 & 0 \\ 0 & 1{,}6 & 0 \\ 0 & 0 & 0 \end{Vmatrix} \cdot \begin{Vmatrix} 1 & 0 & 1 \\ 0 & 1 & -1 \\ -1 & -1 & 0 \end{Vmatrix} \cdot \begin{Vmatrix} 12{,}4 & 0 & 0 \\ 0 & 5{,}8 & 0 \\ 0 & 0 & 6{,}2 \end{Vmatrix} \cdot \begin{Vmatrix} 1 & 0 & -1 \\ 0 & 1 & -1 \\ 1 & -1 & 0 \end{Vmatrix} \right)^{-1} \cdot$$

$$\qquad N \qquad\qquad E \qquad\qquad N_{\alpha} \qquad\qquad\qquad Z_{\alpha\alpha} \qquad\qquad\qquad C_0 \qquad\quad Y$$

$$\cdot \left(\begin{Vmatrix} 1 & 0 & 1 \\ 0 & 1 & -1 \\ -1 & -1 & 0 \end{Vmatrix} \cdot \begin{Vmatrix} 12 \\ 24 \\ 0 \\ 0 \\ 0 \\ 0 \end{Vmatrix} - \begin{Vmatrix} 1 & 0 & 1 \\ 0 & 1 & -1 \\ -1 & -1 & 0 \end{Vmatrix} \cdot \begin{Vmatrix} 12{,}4 & 0 & 0 \\ 0 & 5{,}8 & 0 \\ 0 & 0 & 6{,}2 \end{Vmatrix} \cdot \begin{Vmatrix} -1 & 0 & 0 \\ 0 & 1 & 0 \\ 0 & 0 & 1 \end{Vmatrix} \cdot \begin{Vmatrix} 4 \\ 3 \\ 4 \end{Vmatrix} \right) = \begin{Vmatrix} -5{,}3 \\ -1 \\ -6{,}7 \end{Vmatrix}$$

Matritsalar ustida amallar bajarish quyida ko‘rsatilgan:

$$\text{a)} \begin{Vmatrix} 1 & 0 & 1 \\ 0 & 1 & -1 \\ -1 & -1 & 0 \end{Vmatrix} \cdot \begin{Vmatrix} 12{,}4 & 0 & 0 \\ 0 & 5{,}8 & 0 \\ 0 & 0 & 6{,}2 \end{Vmatrix} = \begin{Vmatrix} 12{,}4 & 0 & 6{,}2 \\ 0 & 5{,}8 & -6{,}2 \\ -12{,}4 & -5{,}8 & 0 \end{Vmatrix};$$

$$\text{b)} \begin{Vmatrix} 12{,}4 & 0 & 6{,}2 \\ 0 & 5{,}8 & -6{,}2 \\ -12{,}4 & -5{,}8 & 0 \end{Vmatrix} \cdot \begin{Vmatrix} 1 & 0 & -1 \\ 0 & 1 & -1 \\ 1 & -1 & 0 \end{Vmatrix} = \begin{Vmatrix} 18{,}6 & -6{,}2 & -12{,}4 \\ -6{,}2 & 12 & -5{,}8 \\ -12{,}4 & -5{,}8 & 18{,}2 \end{Vmatrix};$$

$$\text{v)} \begin{Vmatrix} 5{,}8 & 0 & 0 \\ 0 & 16{,}6 & 0 \\ 0 & 0 & 4 \end{Vmatrix} + \begin{Vmatrix} 18{,}6 & -6{,}2 & -12{,}4 \\ -6{,}2 & 12 & -5{,}8 \\ -12{,}4 & -5{,}8 & 18{,}2 \end{Vmatrix} = \begin{Vmatrix} 24{,}4 & -6{,}2 & -12{,}4 \\ -6{,}2 & 28{,}6 & -5{,}8 \\ -12{,}4 & -5{,}8 & 22{,}2 \end{Vmatrix};$$

Teskari matritsa hisoblashda quyidagi formuladan foydalanamiz:

$$A^{-1} = \frac{1}{D} \cdot \begin{Vmatrix} \begin{vmatrix} A_{22} & A_{23} \\ A_{32} & A_{33} \end{vmatrix} & -\begin{vmatrix} A_{12} & A_{13} \\ A_{32} & A_{33} \end{vmatrix} & \begin{vmatrix} A_{12} & A_{13} \\ A_{22} & A_{23} \end{vmatrix} \\ -\begin{vmatrix} A_{21} & A_{23} \\ A_{31} & A_{33} \end{vmatrix} & \begin{vmatrix} A_{11} & A_{13} \\ A_{31} & A_{33} \end{vmatrix} & -\begin{vmatrix} A_{11} & A_{13} \\ A_{21} & A_{23} \end{vmatrix} \\ \begin{vmatrix} A_{21} & A_{22} \\ A_{31} & A_{32} \end{vmatrix} & -\begin{vmatrix} A_{11} & A_{12} \\ A_{31} & A_{32} \end{vmatrix} & \begin{vmatrix} A_{11} & A_{12} \\ A_{21} & A_{22} \end{vmatrix} \end{Vmatrix}$$

Demak,

$$\begin{Vmatrix} 24{,}4 & -6{,}2 & -12{,}4 \\ -6{,}2 & 28{,}6 & -5{,}8 \\ -12{,}4 & -5{,}8 & 22{,}2 \end{Vmatrix} = \frac{1}{8528{,}5}\begin{Vmatrix} -601 & 210 & 391 \\ 210 & 388 & 218 \\ 391 & 218 & 659 \end{Vmatrix}$$

Keyingi amallar:

$$g)\ \begin{Vmatrix} 0 & 1 & 1 & 0 & 0 & 1 \\ 1 & 0 & 0 & 0 & 1 & -1 \\ 0 & -1 & 0 & 1 & -1 & 0 \end{Vmatrix} \cdot \begin{Vmatrix} 12 \\ 24 \\ 0 \\ 0 \\ 0 \\ 0 \end{Vmatrix} = \begin{Vmatrix} 24 \\ 12 \\ -24 \end{Vmatrix}; \quad d)\ \begin{Vmatrix} 1 & 0 & 1 \\ 0 & 1 & -1 \\ -1 & -1 & 0 \end{Vmatrix} \cdot \begin{Vmatrix} 12{,}4 & 0 & 6{,}2 \\ 0 & 5{,}8 & -6{,}2 \\ -12{,}4 & -5{,}8 & 0 \end{Vmatrix};$$

$$e)\ \begin{Vmatrix} -1 & 0 & 0 \\ 0 & 1 & 0 \\ 0 & 0 & 1 \end{Vmatrix} \cdot \begin{Vmatrix} 12{,}4 & 0 & 6{,}2 \\ 0 & 5{,}8 & -6{,}2 \\ -12{,}4 & -5{,}8 & 0 \end{Vmatrix} = \begin{Vmatrix} -12{,}4 & 0 & -6{,}2 \\ 0 & 5{,}8 & -6{,}2 \\ -12{,}4 & -5{,}8 & 0 \end{Vmatrix};$$

$$j)\ \begin{Vmatrix} -12{,}4 & 0 & -6{,}2 \\ 0 & 5{,}8 & -6{,}2 \\ -12{,}4 & -5{,}8 & 0 \end{Vmatrix} \cdot \begin{Vmatrix} 4 \\ 3 \\ 4 \end{Vmatrix} = \begin{Vmatrix} -74{,}4 \\ -7{,}4 \\ -67 \end{Vmatrix}$$

$$z)\ \begin{Vmatrix} 24 \\ 12 \\ -24 \end{Vmatrix} - \begin{Vmatrix} -74{,}4 \\ -7{,}4 \\ -67 \end{Vmatrix} = \begin{Vmatrix} 98{,}4 \\ 19{,}4 \\ 43 \end{Vmatrix}$$

$$i)\ \frac{1}{8528{,}5}\begin{Vmatrix} -601 & 210 & 391 \\ -210 & 388 & 218 \\ -391 & 218 & 659 \end{Vmatrix} \cdot \begin{Vmatrix} 98{,}4 \\ 19{,}4 \\ 43 \end{Vmatrix} = \frac{1}{8528{,}5}\begin{Vmatrix} -59138{,}4 & +4074 & +16813 \\ -20664 & +7527{,}2 & +9374 \\ -38474{,}4 & +4229{,}2 & +28337 \end{Vmatrix} =$$

$$= \frac{1}{8528{,}5}\begin{Vmatrix} -45201 \\ -8528 \\ -57141 \end{Vmatrix} = \begin{Vmatrix} -5{,}3 \\ -1 \\ -6{,}7 \end{Vmatrix}$$

10. Sxema daraxtining shoxobchalaridagi toklarni hisoblaymiz:

$$I_\alpha = C_0(\underline{J} - M_\beta I_\beta) = \begin{Vmatrix} -1 & 0 & 0 \\ 0 & 1 & 0 \\ 0 & 0 & 1 \end{Vmatrix} \cdot \left(\begin{Vmatrix} 4 \\ 3 \\ 4 \end{Vmatrix} - \begin{Vmatrix} 0 & 1 & -1 \\ -1 & 0 & 1 \\ 1 & -1 & 0 \end{Vmatrix} \cdot \begin{Vmatrix} -5{,}3 \\ -1 \\ -6{,}7 \end{Vmatrix} \right) = \begin{Vmatrix} 1{,}7 \\ 4{,}4 \\ 8{,}3 \end{Vmatrix}$$

$$a)\begin{Vmatrix} 0 & 1 & -1 \\ -1 & 0 & 1 \\ 1 & -1 & 0 \end{Vmatrix}\begin{Vmatrix} -5,3 \\ -1 \\ -6,7 \end{Vmatrix} = \begin{Vmatrix} 5,7 \\ -1,4 \\ -4,3 \end{Vmatrix};\ b)\begin{Vmatrix} 4 \\ 3 \\ 4 \end{Vmatrix} - \begin{Vmatrix} 5,7 \\ -1,4 \\ -4,3 \end{Vmatrix} = \begin{Vmatrix} -1,7 \\ 4,4 \\ 8,3 \end{Vmatrix};\ v)\begin{Vmatrix} -1 & 0 & 0 \\ 0 & 1 & 0 \\ 0 & 0 & 1 \end{Vmatrix} \cdot \begin{Vmatrix} -1,7 \\ 4,4 \\ 8,3 \end{Vmatrix} = \begin{Vmatrix} 1,7 \\ 4,4 \\ 8,3 \end{Vmatrix};$$

$$I_\beta = \begin{Vmatrix} -5,3 \\ -1 \\ -6,7 \end{Vmatrix}\begin{matrix} I_1 \\ I_3 \\ I_4 \end{matrix} \qquad I_\alpha = \begin{Vmatrix} 1,7 \\ 4,4 \\ 8,3 \end{Vmatrix} = \begin{matrix} I_2 \\ I_5 \\ I_6 \end{matrix} \qquad I = \begin{matrix} 1 \\ 2 \\ 3 \\ 4 \\ 5 \\ 6 \end{matrix}\begin{Vmatrix} -5,3 \\ 1,7 \\ -1 \\ -6,7 \\ 4,4 \\ 8,3 \end{Vmatrix}\begin{matrix} I_1 \\ I_2 \\ I_3 \\ I_4 \\ I_5 \\ I_6 \end{matrix}$$

Bazisli tugunning toklarini tekshirish:

$I_6 + I_5 - I_2 = 8,3 + 4,4 - 1,7 = \quad J_1 + J_2 + J_3 = 4 + 3 + 4 = 11;$

2-tugun toklarini tekshirish:

$-I_3 + I_2 + I_4 + J_1 = 1 + 1,7 - 6,7 + 4 = 0;$

3-tugun toklarini tekshirish:

$-I_4 - I_5 + I_1 + J_2 = 6,7 - 4,4 - 5,3 + 3 = 0;$

4-tugun toklarini tekshirish:

$I_3 - I_1 - I_6 + J_3 = -1 + 5,3 - 8,3 + 4 = 0.$

1-7-misol. O'zgaruvchan tok elektr sxemaning shoxobchalaridagi kompleks toklar aniqlansin.

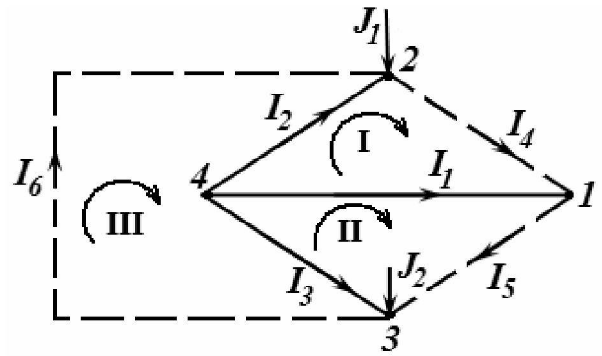
Sxemada EYuK berilmagan.

$$J_1 = 12e^{j30^0}A;\ J_2 = 24e^{j60^0}A;\qquad Z_1 = 2e^{j0}Ом;\ Z_2 = 4e^{j60^0}Ом;\ Z_3 = j3Ом;$$

$$Z_4 = 2e^{j30}\ Ом;\ \ Z_5 = -j3\ Ом;\ Z_6 = 1j2\ Ом.$$

$z_1,\ z_2,\ z_3$ – daraxt qarshiliklari;

$z_4,\ z_5,\ z_6$ – vatar qarshiliklari.



1.9-rasm

Mos ravishda graf daraxti va vatari qarshiliklari matritsalari:

$$Z_{\alpha\alpha} = \begin{Vmatrix} 2e^{j0} & 0 & 0 \\ 0 & 4e^{j60} & 0 \\ 0 & 0 & j3 \end{Vmatrix}; \qquad Z_{\beta\beta} = \begin{Vmatrix} 2e^{j30} & 0 & 0 \\ 0 & -j3 & 0 \\ 0 & 0 & j2 \end{Vmatrix}$$

Berilma toklar matritsasi:

$$J = \begin{Vmatrix} 0 \\ 12e^{j30} \\ 24e^{j60} \end{Vmatrix}$$

Daraxt uchun taqsimlanish koeffitsientlari matritsasi:

$$\begin{matrix} & \text{t u g u n} \\ C_o = \begin{matrix} шо \\ хоб \\ ча \end{matrix} & \begin{Vmatrix} -1 & 0 & 0 \\ 0 & -1 & 0 \\ 0 & 0 & -1 \end{Vmatrix}; \end{matrix}$$

Graf uchun kontur bog‘lanishlar (intsidentsiyalarning ikkinchi) to‘la matritsasi:

$$\begin{matrix} & \begin{matrix} \text{sh} & \text{o} & \text{x} & \text{o} & \text{b} & \text{ch} & \text{a} \\ 1 & 2 & 3 & 4 & 5 & 6 \end{matrix} \\ N = \begin{matrix} кон\ I \\ ту\ II \\ р\ III \end{matrix} & \begin{Vmatrix} -1 & 1 & 0 & 1 & 0 & 0 \\ 1 & 0 & -1 & 0 & 1 & 0 \\ 0 & -1 & 1 & 0 & 0 & 1 \end{Vmatrix} \end{matrix}$$

Graf daraxti uchun mos ravishda N_{α} va transponirlangan $N_{\alpha t}$ konturlar matritsalar:

$$\begin{matrix} & \begin{matrix} \text{sh o x o b ch a} \\ 1 \quad 2 \quad 3 \end{matrix} \\ N_{\alpha} = \begin{matrix} кон \\ ту \\ р \end{matrix} & \begin{Vmatrix} -1 & 1 & 0 \\ 1 & 0 & -1 \\ 0 & -1 & 1 \end{Vmatrix} \end{matrix} \qquad N_{\alpha t} = \begin{Vmatrix} -1 & 1 & 0 \\ 1 & 0 & -1 \\ 0 & -1 & 1 \end{Vmatrix}$$

Vatar shoxobchalaridagi toklarni hisoblaymiz:

$$I_{\beta} = \left(Z_{\beta\beta} + N_{\alpha} \cdot Z_{\alpha\alpha} \cdot N_{\alpha t}\right)^{-1}\left(NE - N_{\alpha} Z_{\alpha\alpha} \cdot C_o J\right);$$

Matritsalarni formulaga qo‘yib amallarni bajaramiz:

$$N_\alpha Z_{\alpha\alpha} = \begin{Vmatrix} -1 & 1 & 0 \\ 1 & 0 & -1 \\ 0 & -1 & 1 \end{Vmatrix} \cdot \begin{Vmatrix} 2e^{j0} & 0 & 0 \\ 0 & 4e^{j60} & 0 \\ 0 & 0 & j3 \end{Vmatrix} = \begin{Vmatrix} -2e^{j0} & 4e^{j60} & 0 \\ 2e^{j0} & 0 & -j3 \\ 0 & -4e^{j60} & j3 \end{Vmatrix};$$

$$N_\alpha Z_{\alpha\alpha} \cdot N_{\alpha t} = \begin{Vmatrix} -2e^{j0} & 4e^{j60} & 0 \\ 2e^{j0} & 0 & -j3 \\ 0 & -4e^{j60} & j3 \end{Vmatrix} \cdot \begin{Vmatrix} -1 & 1 & 0 \\ 1 & 0 & -1 \\ 0 & -1 & 1 \end{Vmatrix} = \begin{Vmatrix} 4+j3{,}46 & -2 & -2-j3{,}46 \\ -2 & 2+j3 & -j3 \\ -2-j3{,}46 & -j3 & 2 \end{Vmatrix};$$

$$Z_{\beta\beta} + N_\alpha Z_{\alpha\alpha} \cdot N_{\alpha t} = \begin{Vmatrix} -2e^{j30} & 0 & 0 \\ 0 & -j3 & 0 \\ 0 & 0 & j2 \end{Vmatrix} = \begin{Vmatrix} 4+j3{,}46 & -2 & -2-j3{,}46 \\ -2 & 2+j3 & -j3 \\ -2-j3{,}46 & -j3 & 2 \end{Vmatrix} =$$

$$= \begin{Vmatrix} 1{,}7+j1 & 0 & 0 \\ 0 & -j3 & 0 \\ 0 & 0 & 2 \end{Vmatrix} + \begin{Vmatrix} 4+j3{,}46 & -2 & -2-j3{,}46 \\ -2 & 2+j3 & -j3 \\ -2-j3{,}46 & -j3 & 2 \end{Vmatrix} = \begin{Vmatrix} 5{,}7+j4{,}46 & -2 & -2-j3{,}46 \\ -2 & 2 & -j3 \\ -2-j3{,}46 & -j3 & 2+j2 \end{Vmatrix}$$

Shu matritsaning teskarisini hisoblaymiz:

$$\Delta\ 7{,}23e^{j38^0} \cdot 2 \cdot 2{,}82^{j45^0} \cdot -2 \cdot 3e^{j90^0} \cdot 3{,}99 \cdot e^{j60^0} - 2 \cdot 3e^{j90^0} \cdot 3{,}99 \cdot e^{j60^0} - 2 \cdot 3{,}99e^{j60^0} \cdot$$

$$\cdot 3{,}99 \cdot e^{j60^0} - 3e^{j90^0} \cdot 7{,}23e^{j38^0} - 4 \cdot 2{,}82e^{j45^0} = 40{,}77e^{j83^0} - 23{,}94e^{j150^0} - 23{,}94e^{j150^0} -$$

$$-31{,}84e^{j12^0} - 65{,}07e^{j218^0} - 11{,}28e^{j45^0} = 4{,}90 + j40{,}46 + 20{,}73 - j11{,}97 + 20{,}73 - j11{,}97 +$$

$$+15{,}92 - j27{,}57 + 51{,}27 + j40{,}06 - 7{,}9 - j7{,}9 = 105{,}65 + j21{,}11 = 107{,}73e^{j11{,}3^0}.$$

$$\left\|\begin{matrix} \begin{vmatrix} 2 & -j3 \\ -j3 & 2+j2 \end{vmatrix} & -\begin{vmatrix} -2 & -j3 \\ -2-j3{,}46 & 2+j2 \end{vmatrix} & \begin{vmatrix} -2 & 2 \\ -2-3{,}46 & -j3 \end{vmatrix} \\ -\begin{vmatrix} -2 & -2-j3{,}46 \\ -j3 & 2+j2 \end{vmatrix} & \begin{vmatrix} 5{,}7+j4{,}46 & -2-j3{,}46 \\ -2-j3{,}46 & 2+j2 \end{vmatrix} & -\begin{vmatrix} 5.7+j4{,}46 & -2 \\ -2-j3{,}46 & -j3 \end{vmatrix} \\ \begin{vmatrix} -2 & -2-j3{,}46 \\ 2 & -j3 \end{vmatrix} & -\begin{vmatrix} 5{,}7+j4{,}46 & -2-j3{,}46 \\ -2 & 2+j2 \end{vmatrix} & \begin{vmatrix} 5{,}7+j4{,}46 & -2 \\ -2-j3{,}46 & -j3 \end{vmatrix} \end{matrix}\right\| =$$

$$= \left\|\begin{matrix} 12{,}98+j3{,}98 & 14{,}34-j2 & -3{,}99-j12{,}9 \\ 14{,}34-j2 & 10{,}49+j6{,}88 & 9{,}36-j24 \\ -3{,}99-j12{,}9 & -8{,}63-j15{,}54 & 7{,}39+j89 \end{matrix}\right\|;$$

$$\frac{1}{107{,}73e^{j11.3}}\left\|\begin{matrix} 13{,}57e^{j17^0} & -14{,}47e^{j172.5^0} & 13{,}51e^{j72.8^0} \\ 14{,}47e^{j172.5^0} & 12{,}4e^{j33^0} & 25{,}76e^{j111..3^0} \\ 13{,}51e^{j72.8^0} & 17{,}77e^{j11^0} & 85{,}3e^{j85.3^0} \end{matrix}\right\| = \left\|\begin{matrix} 0{,}125e^{j57^0} & 0{,}134e^{j161.2^0} & 0{,}125e^{j11.5^0} \\ 0{,}134e^{j161.2^0} & 0{,}116e^{j21.7^0} & 0{,}239e^{j100^0} \\ 0{,}125e^{j4.5^0} & 0{,}164e^{j49.7^0} & 0{,}791e^{j74^0} \end{matrix}\right\| =$$

$$= \left\|\begin{matrix} 0{,}125e^{j5.7^0} & 0{,}134e^{j161.2^0} & 0{,}125e^{j61.5^0} \\ 0{,}134e^{j161.2^0} & 0{,}116e^{j21.7^0} & 0{,}164e^{j161.2^0} \\ 0{,}125e^{j61.5^0} & 0{,}239e^{j100^0} & 0{,}791e^{j74^0} \end{matrix}\right\|;$$

$(-1)\ N_\alpha Z_{\alpha\alpha}\cdot C_0\cdot J -$ amallarni bajaramiz:

$$N_\alpha Z_{\alpha\alpha}\cdot C_0 = \left\|\begin{matrix} -2e^{j0^0} & 4e^{j60^0} & 0 \\ 2e^{j0^0} & 0 & -j3 \\ 0 & -4e^{j60^0} & j3 \end{matrix}\right\| \cdot \left\|\begin{matrix} -1 & 0 & 0 \\ 0 & -1 & 0 \\ 0 & 0 & -1 \end{matrix}\right\| = \left\|\begin{matrix} 2e^{j0^0} & -4e^{j60^0} & 0 \\ -2e^{j0} & 0 & j3 \\ 0 & 4e^{j60^0} & -j3 \end{matrix}\right\|$$

$$-N_\alpha Z_{\alpha\alpha}\cdot C_0\cdot J = \left\|\begin{matrix} 2e^{j0^0} & -4e^{j60^0} & 0 \\ -2e^{j0^0} & 0 & j3 \\ 0 & 4e^{j60^0} & -j3 \end{matrix}\right\| \cdot \left\|\begin{matrix} 0 \\ 12e^{j30^0} \\ 24e^{j60^0} \end{matrix}\right\| = \left\|\begin{matrix} 48e^{j90^0} \\ -72e^{j150^0} \\ -45e^{j90^0} \end{matrix}\right\|$$

Amallarini ohiriga etkazamiz:

$$I_\beta = \begin{Vmatrix} 0.125e^{j5.7^0} & 0.134e^{j161.2^0} & 0.125e^{j61.5^0} \\ 0.134e^{j161.2^0} & 0.116e^{j21.7^0} & 0.164e^{j161.2^0} \\ 0.125e^{j61.5^0} & 0.239e^{j100^0} & 0.791e^{j74^0} \end{Vmatrix} \cdot \begin{Vmatrix} 48e^{j90} \\ -72e^{j150} \\ -45e^{j90} \end{Vmatrix} =$$

$$= \begin{Vmatrix} 6e^{j95.7} - 9.648e^{j311.2} - 5.625e^{j151.5} \\ 6.432e^{j251} - 8.352e^{j171.7} - 7.38e^{j251.2} \\ 6e^{j151..5} + 17.208e^{j250} - 35.599e^{j164} \end{Vmatrix} = \begin{Vmatrix} -2 + j10.47 \\ 8.63 - j0.3 \\ 23.06 - j3.55 \end{Vmatrix} = \begin{Vmatrix} 10.85e^{j100.8^0} \\ 8.635e^{-j2} \\ 23.33e^{-j16.5} \end{Vmatrix} \begin{matrix} I_4 \\ I_5 \\ I_6 \end{matrix}$$

8. Daraxt shoxobchalaridagi toklarni topamiz:

shoxobchalar№

$$\underline{I}_\alpha = \underline{C}_0 \left(\underline{J} - \underline{M}_\beta \cdot \underline{I}_\beta \right) \qquad M_\beta = \begin{matrix} ту \\ гун \\ лар\ № \end{matrix} \begin{Vmatrix} -1 & 1 & 0 \\ 1 & 0 & -1 \\ 0 & -1 & 1 \end{Vmatrix}$$

$$M_\beta \cdot I_\beta = \begin{Vmatrix} -1 & 1 & 0 \\ 1 & 0 & -1 \\ 0 & -1 & 1 \end{Vmatrix} \cdot \begin{Vmatrix} 2 + j10,47 \\ 8,63 - j0,3 \\ 23,06 - j3,55 \end{Vmatrix} = \begin{Vmatrix} 2 - j10,47 + 8,63 - j0,3 \\ -2 + j10,47 - 23,06 + j3,55 \\ -8,63 + j0,3 + 23,06 - j3,55 \end{Vmatrix} = \begin{Vmatrix} 10,63 - j10,77 \\ -25,06 + j14,02 \\ 14,43 - j3,25 \end{Vmatrix}$$

$$J - M_\beta \cdot I_\beta = \begin{Vmatrix} 0 \\ 10,39 + j6 \\ 12 + j20,78 \end{Vmatrix} - \begin{Vmatrix} 10,63 - j10,77 \\ -25,06 + j14,02 \\ 14,43 - j3,25 \end{Vmatrix} = \begin{Vmatrix} -10,63 + j10,77 \\ 35,45 - j8,02 \\ -2,43 + j24,03 \end{Vmatrix}$$

$$I_\alpha = \begin{Vmatrix} -1 & 0 & 0 \\ 0 & -1 & 0 \\ 0 & 0 & -1 \end{Vmatrix} \cdot \begin{Vmatrix} -10,63 + j10,77 \\ +35,45 - j8,02 \\ -2,43 + j24,03 \end{Vmatrix} = \begin{Vmatrix} 10,63 - j10,77 \\ -35,45 + j8,02 \\ 2,43 - j24,03 \end{Vmatrix} = \begin{Vmatrix} 15,13e^{-j45,4} \\ 36e^{j167,5} \\ 24,15e^{-j84,2} \end{Vmatrix} \begin{matrix} I_1 \\ I_2 \\ I_{3.} \end{matrix}$$

Tekshirish

1. Birinchi tugun toklarini tekshirish:

$I_4 + I_1 - I_5 = 0 \qquad -2 + j10,47 + 10,63 - j10,77 - 8,63 + j0,3 = 0.$

2. Ikkinchi tugun toklarini tekshirish:

$I_2 + I_6 - I_4 + J_1 = 0 \qquad -35,45 + j8,02 + 23,06 - j3,55 + 2 - j10,47 + 10,39 + j6 = 0.$

3. Uchinchi tugun toklarini tekshirish:

$I_3 + I_5 + J_2 - I_6 = 0 \qquad 2,43 - j24,03 + 8,63 - j0,3 + 12 + j20,78 - 23,06 + j3,55 \approx 0.$

4. Balans tugun toklarini tekshirish, ya'ni $-I_1 - I_2 - I_3 = J_1 + J_2$

Haqiqatdan:

$-I_1 - I_2 - I_3 = -10,63 + j10,72 + 35,45 - j8,02 - 2,43 + j24,03 = 22,39 + j26,78.$

$J_1 + J_2 = 12e^{j30^0} + 24e^{j60^0} = 10,32 + j6 + 12 + j20,78 = 22,39 + j26,78A.$

2. Energetik masalalarda ehtimollar nazariyasini qo‘llashga doir misollar

2-1-misol. Ketma-ket ulangan bug‘ qozonidan, bug‘ turbina va elektr generatordan iborat energetik blok ishdan chiqishi ehtimolligi aniqlansin. Bug‘ qozoni barcha bug‘ni bug‘ turbinasiga uzatadi. Generator turbina bilan bir o‘qqa o‘rnatilgan, ya’ni uning barcha quvvatidan foydalaniladi. Blokning alohida elementlarining bunga mos ravishda qozon, turbina va generator ishdan chiqishi q ehtimolligi ma’lum, q q= 0,02; $q_T = 0{,}01$ va $q_T = 0{,}01$,

Yechish. Ma’lumki, blokning ishdan chiqishi (avariya), tarkibidagi elementlarning hech bo‘lmaganda, bittasining ishdan chiqishiga bog‘liq. Blok elementlarining har birini ishdan chiqmaslik ehtimolligi ($P_к = 1 - q_к$) bo‘yicha aniqlanadi:

$$p_к = 1 - 0{,}02 = 0{,}98; \quad p_T = 1 - 0{,}02 = 0{,}99; \quad p_г = 1 - 0{,}001 = 0{,}999.$$

Blok elementlarining barchasi ishdan chiqmasligi ehtimolligini, ya’ni blok shikastsiz ishlashini topamiz.

Har bir elementning avariya holatida boshqa elementlarga bog‘lanmaganligini e’tiborga olib blokning ishlash ehtimolligini quyidagidan aniqlaymiz:

$$p_{бл} = p_к \cdot p_T \cdot p_г = 0{,}98 \cdot 0{,}99 \cdot 0{,}999 = 0{,}9693.$$

Blokni ishdan chiqishi uni ishdan chiqmasligiga teskari bo‘lgani uchun, ishdan chiqish ehtimolligiga teng:

$$q_{бл} = 1 - 0{,}9693 = 0{,}0307$$

2-2-misol. Iste’molchi ikki zanjirli uzatish liniyasidan ta’minlanadi. Liniyaning har bir zanjirini ishdan chiqishining ehtimolligi $q = 0{,}001$. Iste’molchi liniyaning har bir zanjiridan kerak bo‘lgan barcha quvvatni olishi mumkin.

Iste’molchi elektr ta’minotini saqlash ehtimoli qanday?

Yechish. Iste’molchi elektrta’minoti, faqat ikkala zanjir ham (avariya), ya’ni ishdan chiqqanida yo‘qoladi, buning ehtimoli $q = 0{,}001 \cdot 0{,}001 = 0{,}000001$ga teng.

$$p = 1 - q = 1 - 0{,}000001 = 0{,}999999.$$

2-3-misol. Uzatish liniyasining ihtiyoriy fazasi shikastlanishining statistik ehtimolligi 0,001 ga teng. Agar bir fazaning shikastlanishi sodir etilsa, boshqa ikkita fazaning statistik ishdan chiqishining ehtimolligi 0,2 bo‘lsa, ya’ni ikkinchi fazaning ishdan chiqishining shartli ehtimolligi 0,2 teng. Bundan tashqari, ikkita fazaning ishdan chiqishi sababli, uchinchi fazaning xuddi shunday ishdan chiqish ehtimolligi 0,5 teng bo‘lsin.

Avariya bir fazadan boshlangan deb, bir, ikki va uch fazali qisqa tutashlarning ehtimollik nisbatlari aniqlansin.

Yechish. Ikki fazaning ishdan chiqishi (avariya) ehtimolligi quyidagiga teng:

$$q_{2\varphi} = 0{,}2 \cdot 0{,}001 = 0{,}0002.$$

Uchta fazaning ishdan chiqishi (avariyasi):

$$q_{3\varphi} = 0{,}5 \cdot 0{,}0002 = 0{,}0001$$

Avariyaning rivojlanish shartli ehtimolligini, ya'ni boshqa fazalar ishdan chiqishining shartli ehtimolligini aniqlaymiz. Faraz qilaylik statistik kuzatishlar bo'yicha uzoq davom etgan davrda bir fazali qisqa tutashishlar soni 100 ta, shu jumladan 20 tasida ikkinchi faza ham qisqa tutashdi. Unda quyidagi formula asosida boshqa fazani ham ishdan chiqishining shartli ehtimolligini hisoblash mumkin:

$$q(A/B) = \frac{q(AB)}{q(B)} \approx \frac{20}{100} = 0{,}2$$

chunki avariyalar sonini ehtimollikka proporsional deyish mumkin.

Shunday qilib bir fazali, ikki fazali va uch fazali ishdan chiqishlarning ehtimolliklar nisbati 0,001; 0,0002; 0,0001 yoki taqriban 77%– bir fazali, 15%– ikki fazali va 8%– uch fazali bo'ladi.

2-4-misol. Energosistemada *n* ta bir xil turli va bir xil sharoitda ishlamaydigan agregatlar mavjud bo'lsin (misol uchun qozon yoki turbinalar). Agregatlarning to'g'ri ishlash holatining ehtimolligi *r* ga va qarama-qarshi holati, ya'ni agregatning ishlamaslik holatining ehtimolligi *q* ga teng.

Yechish. Ko'rsatilgan n agregatlardan m tasini ishga yaroqli holatining ehtimolligini topamiz, bunda *m* noldan *n* gacha o'zgaradi quyidagi formuladagi

$$(q+p)^n = q^n + nq^{(n-1)}p + \frac{n(n-1)}{1-2}q^{n-2}p^2 + \ldots + C_m^n q^{n-m} \cdot p^m + \ldots + p^n = 1$$

yoyish izlanayotgan ehtimollik qatorini aniqlaydi. Darhaqiqat, q^n- ma'lumki, barcha agregatlar ishdan chiqqanlikning ehtimolligidir va barcha agregatlar ishdan chiqqan va ishga yaroqli agregatlar soni nolga teng; $np \cdot q^{n-1}$ –faqat bitta agregat ishga yaroqligining ehtimolligi:

$$C_n^m p^m q^{n-m} = \frac{n!}{m!\,(n-m)!} p^m q^{n-m}$$

m ta– agregatlar ishga yaroqli holatining ehtimolligi; (p^n– barcha agregatlar ishga yaroqli holati ehtimolligi.

Agar ishga yaroqsiz holati emas balki turli agregatlarning avariya– ishdan chiqishi aniqlansa, unda shu qatorni quyidagi tartibda yozish kerak:

$$(p+q)^n = p^n + np^{n-1}q + \frac{n(n-1)^n}{1\cdot 2} p^{n-2}q^2 + \ldots + C_n^m p^{n-m} q^m + \ldots + q^n = 1,$$

bunda $(m+1)$ had ***m*** ta agregatlarni ishdan chiqishi ehtimolligi $C_n^m p^{n-m} q^m$ ga tengdir.

Misol uchun $n = 5,\ \ p = 0{,}98,\ \ q = 0{,}02$ bo‘lsa, avariya holatlar bo‘lmasligining ehtimolligi:

$$p^n = 0{,}98^2 \approx 0{,}905.$$

Bitta agregatning ishdan chiqish (avariya) ehtimolligi

$$n \cdot p^{n-1} \cdot 5 \cdot 0{,}98^4 \cdot 0{,}02 = 0{,}0923.$$

2-5-misol. Energotizimdagi qandaydir son agregatlarning ishdan chiqish ehtimolligini aniqlaymiz. Agar tizimda beshta guruhdan iborat bir xil turdagi ishdan chiqish ehtimolligi $q_1 \div q_5$ bo‘lgan $n_1 \div n_5$ agregatlar mavjud bo‘lsa, unda agregatlarni har qanday kombinatsiyali bir vaqtda ishdan chiqish ehtimolligini quyidagi ifodani yoyilishidan topish mumkin

$$(p_1 + q_1)^{n_1}(p_2 + q_2)^{n_2}(p_3 + q_3)^{n_3}(p_4 + q_4)^{n_4}(p_5 + q_5)^{n_5} = 1.$$

Misol uchun, 1-guruhdagi ikkita agregatni, 3-guruhdagi bitta agregatni va 5-guruhdagi bir agregatni ishdan chiqishining (avariya) ehtimolligi teng:

$$\left[\frac{n_1(n_1-1)}{1\cdot 2} p_1^{n_1-2} q^2\right] p_2^{n_2} \left[n_3 p_3^{n_3-1} q_3\right] p_4^{n_4} \left[n_5 p_5^{n_5-1} q_5\right]$$

2-6-miso. Energetik tizimda to‘rtta bir xil turdagi generator mavjud. Ularning bir nechtasini bir vaqtda ishdan chiqish ehtimolligini toping.

Har bir agregatni ishdan chiqishining ehtimolligi $q = 0{,}02$, ishchi holatining ehtimolligi esa $p = 0{,}98$. Tasodifiy kattalik deb, *m* ta avariya holatida bo‘lishligiga aytamiz. Bu kattalik diskret bo‘lib 0, 1, 2, 3, 4 qiymatlarni qabul qilishi mumkin.

Binominal taqsimlanish formulasidan foydalanib, agregatlarni ishdan chiqish ehtimolligini topish mumkin:

$$p_n^m = C_n^m p^{n-m} q^m.$$

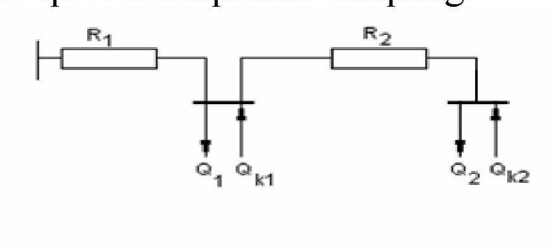
Bu formula bo‘yicha hisoblarni bajarib *m* ta avariya holatidagi agregatlar soni tasodifiy kattaliklar ehtimolligini hisoblashimiz mumkin:

Avariya holatidagi agregatlar soni	0	1	2	3	4
Ehtimollik	0,92237	0,075530	0,00230	0,00003	0,00000

Ehtimolliklar yig‘indisi 1 ga teng.

3. Energetik tizimlarda optimallash masalalarini yechish na'munalari

3-1-miso. Mavjud bo'lgan elektr ta'minot sxemasida (3.1-rasm) 1 va 2 tugunlarga ulanadigan va sarf xarajatlari minimum bo'lgan kompensatsiyalovchi qurilmalar Q_{k1} va Q_{k2} quvvatlarini hamda sxemada isrof bo'ladigan aktiv quvvat miqdorini aniqlang.



3.1-rasm

Berilgan:

Liniya kuchlanishi U = 10 kV;

liniya qarshiligi R_1 = 6 Om, R_2=4 Om;

1 va 2 tugunlarni reaktiv quvvatlari Q_1 = 600 kVar va Q_2 = 800 kVar; kompensatsiyalovchi qurilmalarni o'rnatish uchun sarf bo'ladigan solishtirma xarajatlar Z_0 = 0,5 shartli birlik/kVar;

aktiv quvvat isroflarni tiklash uchun solishtirma xarajatlar S_0 = 10 shartli birlik/kVt.

Yechish. Kompensatsiyalovchi qurilmalarni o'rnatish va sxemani aktiv quvvat isroflarini tiklash uchun ketadigan xarajatlarni ifodalaydigan maqsadli funksiya quyidagi ko'rinishga ega:

$$z = z_0(Q_{k1} + Q_{k2}) + a_1(Q_1 + Q_2 - Q_{k1} - Q_{k2})^2 + a_2(Q_2 - Q_{k2})^2 \rightarrow \min$$

bunda:

$$a_1 = R_1 c_0 \cdot 10^{-3} U^2 = 0.0006,$$

$$a_2 = R_2 c_0 \cdot 10^{-3} U^2 = 0.0004$$

Sonli koeffitsient 10^{-3} maqsadli funksiyani bir xil o'lchov birliklariga keltirish maqsadida kiritilgan.

Masalani yechish uchun koordinata bo'yicha tushish usulidan foydalanamiz.

Maqsadli funksiya Z ni Q_{k1} va Q_{k2} bo'yicha xususiy xosilalarini aniqlaymiz:

$$\partial z/\partial Q_{k1} = z_0 - 2a_1(Q_1 + Q_2 - Q_{k1} - Q_{k2});$$
$$\partial z/\partial Q_{k2} = z_0 - 2a_1(Q_1 + Q_2 - Q_{k1} - Q_{k2}) - 2a_2(Q_2 - Q_{k2})$$

Dastlabki yaqinlashtirish $Q_{k1}^0 = 0$; $Q_{k2}^0 = 0$ qabul qilamiz. Bu qiymatlar uchun maqsadli funksiyalarni va ularni xususiy xosilalarini hisoblaymiz:

$$z^0 = 0.5\cdot(0+0)+0.0006\cdot(600+800-0-0)^2+0.0004\cdot(800-0)^2 = 1432$$
$$\partial z/\partial Q_{k1} = 0.5-2\cdot 0.0006\cdot(600+800-0-0) = -1{,}18$$
$$\partial z/\partial Q_{k2} = 0.5-2\cdot 0.0006\cdot(600+800-0-0)-2\cdot 0.0004\cdot(800-0) = -1{,}8$$

shartli birlik

Hisoblangan qiymatlardan ma'lumki, Q_{k2} o'zgaruvchi yo'nalishida maqsadli funksiya Q_{k1} o'zgaruvchiga qaraganda tezroq kamayadi, chunki

$$|\partial z/\partial Q_{k2}| > |\partial z/\partial Q_{k1}|$$

O'zgaruvchan Q_{k2} yo'nalishida "tushishni" boshlaymiz. Qadam kattaligini $\lambda = 400$ kVar deb qabul qilamiz. Birinchi yaqinlashtirish (birinchi qadam) $Q_{k1}^1 = 0;\ Q_{k2}^1 = 400$ kVar bo'lsin. Maqsadli funksiyani qiymati:

$$z^1 = 0.5\cdot(0+400)+0.0006\cdot(600+800-0-400)\cdot 2+0.0004\cdot(800-400)\cdot 2 = 864$$

shartli birlik.

Ikkinchi qadam: $Q_{k1}^2 = 0;\ Q_{k2}^2 = 800$ kVar. Maqsadli funksiya $z^2 = 616$ sh.b.

Uchinchi qadam $Q_{k1}^3 = 0;\ Q_{k2}^3 = 1200$ kVar. Maqsadli funksiya $z_3 = 689$ sh.b.

Ravshanki Q_{k2} koordinata bo'yicha "tushishni" to'xtatish maqsadga muofiq, chunki $z^3 > z^2$, va ikkinchi qadamda olingan $Q_{k1}^2 = 0,\ Q_{k2}^2 = 800$ kVar qiymatlarga qaytish lozim.

Yangi uchinchi $\lambda = 400$ kVar qadamni boshqa o'zgaruvchi bo'yicha qabul qilamiz $Q_{k1};\ Q_{k1}^3 = 400$ kVar, $Q_{k2}^3 = 800$ kVar. Maqsadli funksiya $z^3 = 624$ sh.b. Q_{k1} yo'nalishdagi harakat maqsadga muofik emas, chunki $z^3 > z^2$. Koordinatalari $Q_{k1} = 0$ va $Q_{k2} =$ 800 kVar bo'lgan nuqta maqsadli funksiyaning minimumi atrofida joylashadi

$$\Delta P = 0.004(1500-Q_{k1}-Q_{k2}-Q_{k3})^2+0.005\cdot(500-Q_{k2})^2+0.006\cdot(400-Q_{k3})^2 =$$
$$= 0.004\cdot(1500-100-500-400)^2+0.005\cdot(500-500)^2+0.006\cdot(400-400)^2 = 2\kappa Bm$$

4. Energetikadagi avtomatik rostlashga doir masalalar

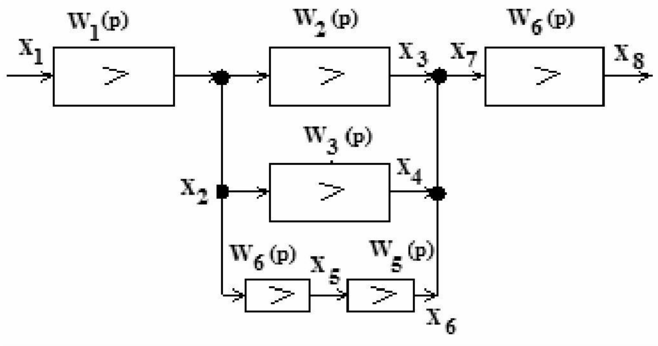
4-1-misol. Bir nechta ketma-ket va paralel ulangan tizimningning uzatish funksiyasini aniqlang (4.1-rasm): 1 va 2 – inersion, 3, 4, 5 differensialovchi, 6 – noinersion bo‘g‘inlar.

Ketma-ket va paralel ulangan bo‘g‘inlarning uzatish funksiyasini aniqlash qoidalaridan foydalanib, ajratilgan tizimningning uzatish funksiyasini yozamiz:

$$W(p) = W_1(p)[W_2(p) + W_3(p) + W_4(p)W_5(p)]\,W_6(p)$$

Namunaviy bo‘g‘inlarning uzatish funksiyasini yozib quyidagini hosil qilamiz:

$$W(p) = \frac{K_1 K_6}{1 + pT_1}\left[\frac{K_2}{1 + pT_2} + \frac{K_3 p}{1 + pT_3} + \frac{K_4 K_5 p^2}{(1 + pT_4)(1 + pT_5)}\right]$$



4.1-rasm

4-2-misol. Ikkita W_5 va W_6 o‘zaro kesishgan teskari bog‘lanishli murakkab strukturali sxemani (5.16-rasm) soddalashtiring.

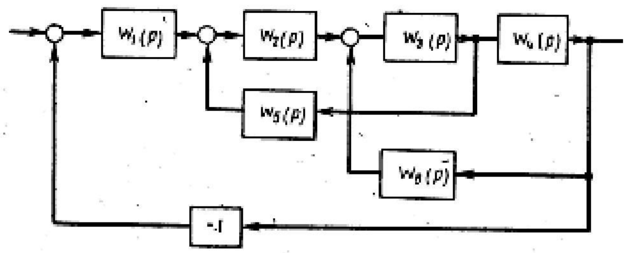
Jadvalning 3-bandida bayon etilgan qoidani $W_6(p)$ bo‘g‘in kirishiga tadbiq etib, 4.3-rasm, a da keltirilgan sxemani hosil qilamiz. Endi shu narsa ayonki, ikkita ketma-ket ulangan $W_4(p)$ va $W_6(p)$ bo‘g‘inlar bilan qamrab olingan $W_3(p)$ bo‘g‘inni uzatish funksiyasi:

$$W_{346}(p) = \frac{W_3(p)}{1 + W_3(p)W_4(p)W_6(p)}\ ,$$

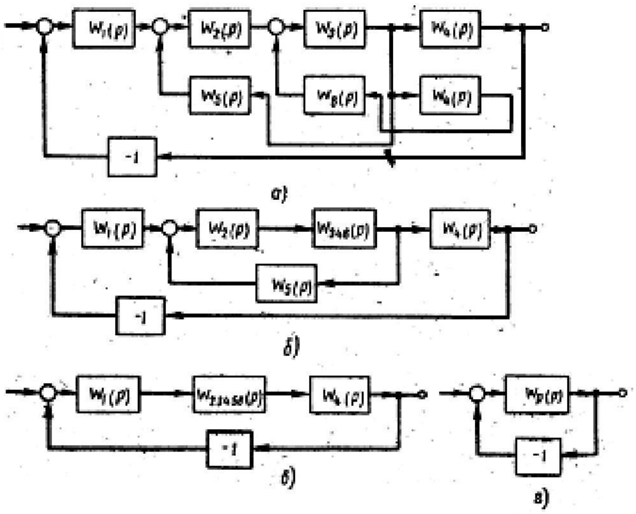
bo‘lgan bitta bo‘g‘in bilan almashtirish mumkin. Bu sxemani o‘z navbatida yana soddalashtirish mumkin. Buning uchun ketma-ket ulangan $W_2(p)$ va $W_{346}(p)$ bo‘g‘inlarni, uzatish funksiyasi $W_5(p)$ bo‘lgan bo‘g‘in bilan qamrab olamiz:

$$W_{23456}(p) = \frac{W_2(p)W_{346}(p)}{1 + W_2(p)W_{346}(p)W_5(p)}$$

Natijada sxema yana soddalashtiriladi (4.3-rasm, v, g).



4-2-rasm



4-3-rasm

4-3-miso3. Uzatish funksiyasi $W(p)=\dfrac{k}{1+Tp}$ bo'lgan inersion bo'g'in chastotali xarakteristikasi qurilsin va tahlil qilinsin.

Uzatish funksiyasiga $P=j\omega$ ni qo'yib kuchaytirishning kompleks koeffitsientini va tizimning chastotali xarakteristikasini hosil qilamiz:

$$W(j\omega)=\frac{k}{1+j\omega T}=\frac{K(1-j\omega T)}{1+\omega^2T^2}=\frac{K}{1+\omega^2T^2}-j\frac{K\omega T}{1+\omega^2T^2}=$$

$$=P(\omega)+jQ(\omega)=A(\omega)e^{j\varphi(\omega)}$$

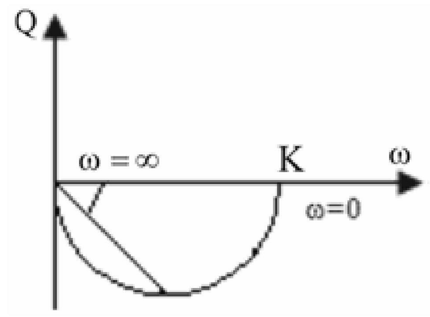
bunda

$$P(\omega)=\frac{K}{1+\omega^2T^2};\quad Q(\omega)=-\frac{K}{1+\omega^2T^2};$$

$$A(\omega)=\frac{K}{(1+j\omega T)}=\frac{K}{\sqrt{1+\omega^2T^2}};$$

$$=tg\varphi=-\omega T;\quad \varphi(\omega)=-arctgT\omega.$$

Ko'rsatish mumkinki, inersion bo'g'inning amplituda-chastotali xarakteristikasi, kompleks tekislikning pastki yarim tekisligida joylashgan yarim doiradir (4.4-rasm), uning diametri statik kuchaytirish koeffitsienti $W(0)=K$ ga tengdir.



4.4-rasm

4-4-misol. Uzatish funksiyasi $W(\rho)=\dfrac{K}{p^2+2\beta p+\omega_0^2}$ bo‘lgan tebranma bo‘g‘inning chastotali xarakteristikasini quring va tahlil qiling.

Kuchaytirishning kompleks koeffitsienti

$$W(j\omega)=\frac{K}{-\omega^2+\omega_0^2+2j\beta\omega}=A(\omega)e^{j\varphi(\omega)}$$

bunda

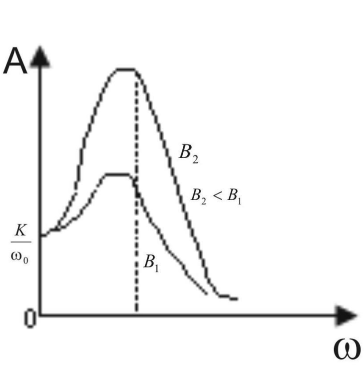
$$A(\omega)=\frac{K}{\sqrt{\left(\omega_0^2-\omega^2\right)^2+4\beta^2\omega^2}};$$

$$\varphi(\omega)=-arctg\frac{2\beta\omega}{\omega_0^2-\omega^2}.$$

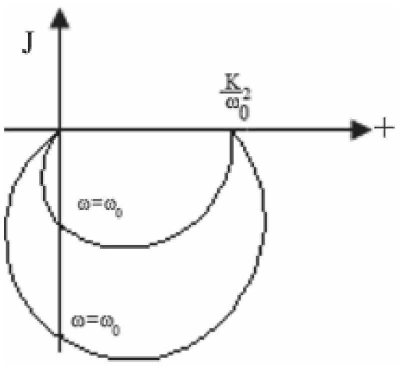
Berilgan sistemaning amplituda faza-chastotali xarakteristikasi (4.5-rasm) $\omega=0$ da haqiqiy o‘qda $\dfrac{K}{\omega_0^2}$ ga teng holda boshlanadi.

Amplituda chastotali xarakteristikasi (4.6-rasm) $\beta<<\omega_0$ bo‘lgan $\omega\approx\omega_0$ chastotada maksimumga erishadi.

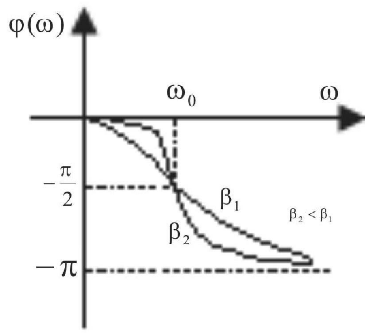
Faza-chastotali xarakteristika 4.7-rasmda tasvirlangan.



4.5-rasm



4.6-rasm



4.7-rasm

5. Shaxsiy hisob grafik ishlarining variantlari. Chiziqli o‘zgarmas tok elektr zanjirlarini hisoblash

1.10-rasmlarda keltirilgan elektr zanjirlari uchun 1-jadvalda berilgan kattaliklardan foydalanib quyidagilarni bajaring:

- sxema grafini daraxt va vatarlarga ajratib tasvirlang;

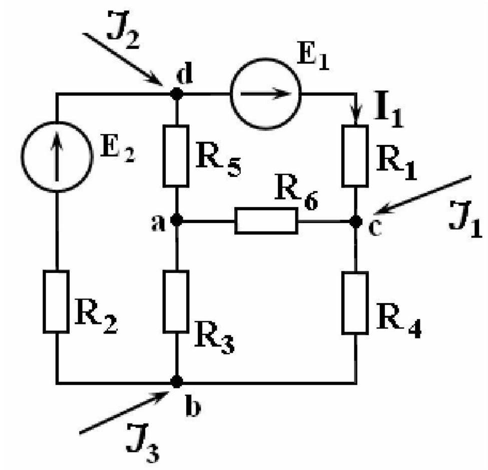
-barcha shoxobchalardagi toklarni umumlashgan holat tenglamalari usulida hamda umumlashgan kontur toklar tenglamalari usulida aniqlang;

- shoxobchalardagi mos toklarni taqqoslang;

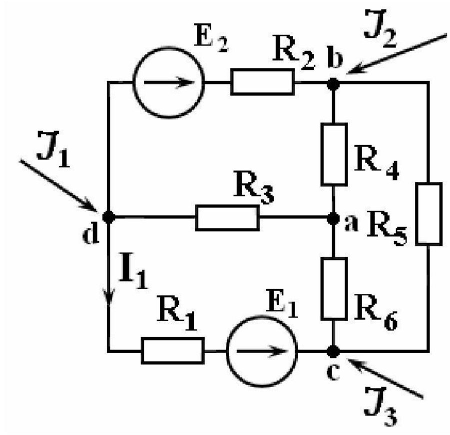
-barcha tugunlardagi toklarni Kirxgofning birinchi qonuni bo‘yicha va bog‘lanmagan konturlardagi kuchlanishlarni Kirxgofning ikkinchi qonuni bo‘yicha tekshiring.

1-jadval

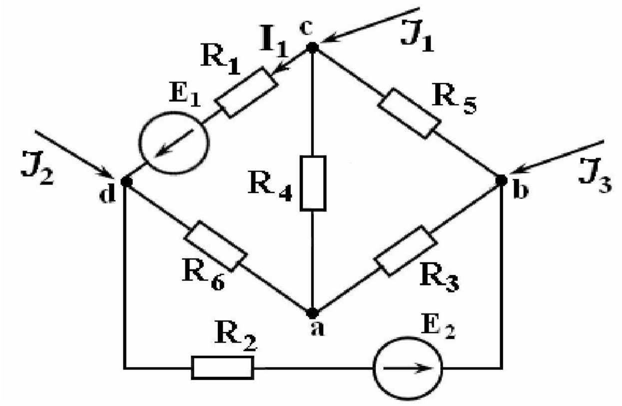
№	EYuK		Qarshiliklar						Tok manbalari		
	E_1	E_2	R_1	R_2	R_3	R_4	R_5	R_6	J1	J2	J3
	V	V	Om	Om	Om	Om	Om	Om	A	A	A
1	32	16	10	13	10	9	8	16	2	10	6
2	24	12	2	5	7	1	3	8	4	8	8
3	15	32	3	6	5	6	10	22	6	6	10
4	14	8	8	8	18	14	11	4	8	4	8
5	25	20	7	10	16	11	12	17	10	2	6
6	12	24	6	12	17	4	6	6	8	4	4
7	24	32	10	15	4	7	7	4	6	6	2
8	10	27	18	2	5	8	11	21	4	8	4
9	20	10	16	18	5	7	13	15	2	10	6
10	24	16	8	20	7	4	10	4	4	12	8



1.1- rasm



1.2-rasm



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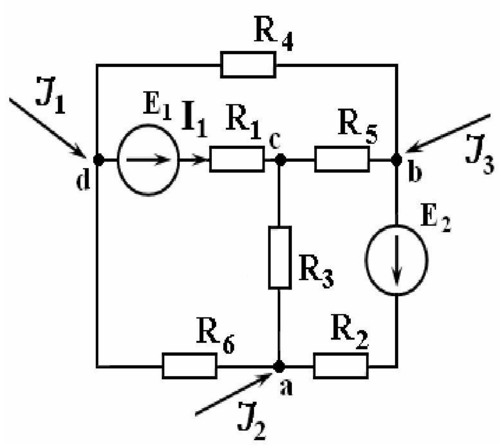

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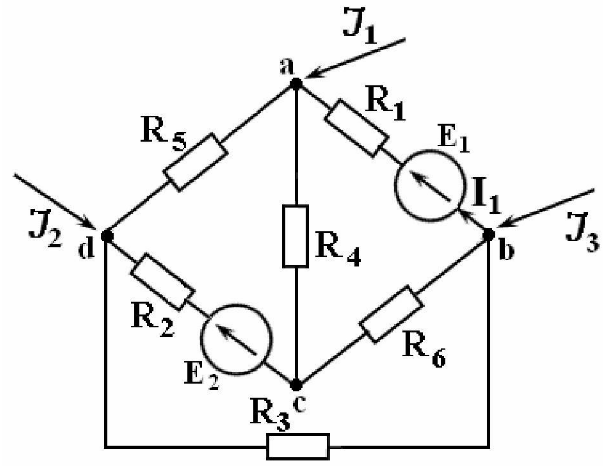

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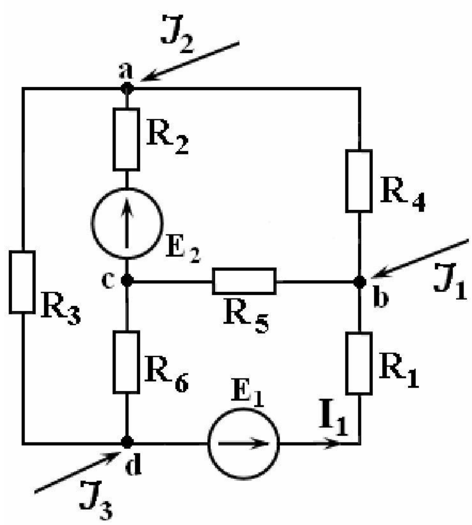
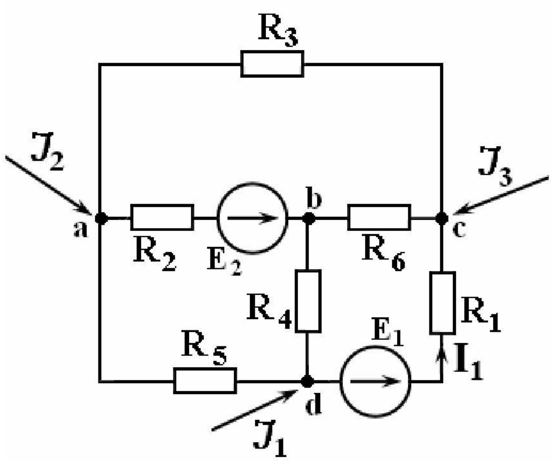
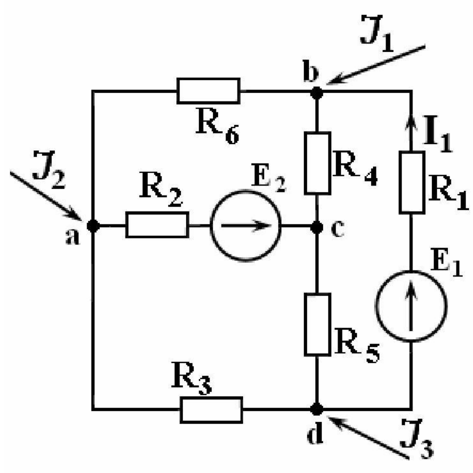


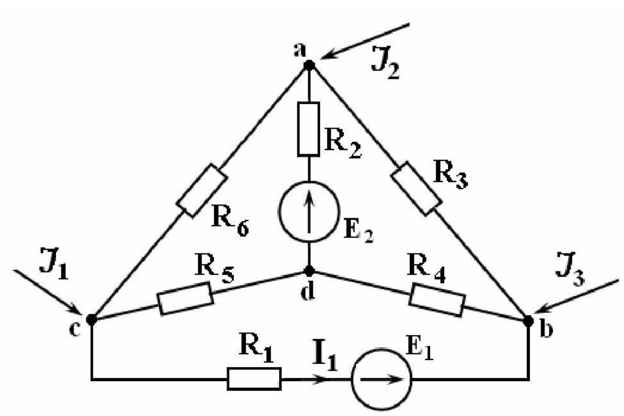
1.6-rasm



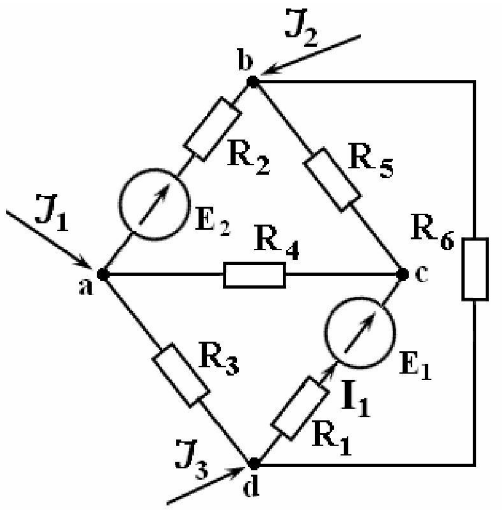
1.7-rasm



1.8-rasm



1.9-rasm



1.10-rasm

Adabiyotlar

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2. Ивашев В.И. Математические задачи энергетики. Ташкент «Ротаприпт», 1990. 82 с.
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Mundarija

Muharrir: T.I. Umurzoqova

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ToshTYMI bosmaxonasi Toshkent sh., Odilxo'jayev ko'chasi, 1