

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

**ABU RAYHON BERUNIY NOMIDAGI  
TOSHKENT DAVLAT TEXNIKA UNIVERSITETI**

**«ELEKTROTEXNIKANING NAZARIY ASOSLARI»**

fanining «**Uch fazali zanjirlar**»  
bo‘limi bo‘yicha hisob-grafik ishlarini bajarish  
yuzasidan uslubiy ko‘rsatma

**Toshkent – 2013**

Tuzuvchilar: Q.G'.Abidov, A.I.Raxmatullayev, R.Jo'rayev, I.V.Ernst, D.R.Qadirova. «Elektrotexnikaning nazariy asoslari» fanining «Uch fazali zanjirlar» bo'limi bo'yicha hisob-grafik ishlarini bajarish yuzasidan uslubiy ko'rsatma. –Toshkent, ToshDTU, 2013. 32 b.

Tavsiya etilayotgan ko'rsatmada «Elektrotexnikaning nazariy asoslari» fanining «Uch fazali zanjirlar» bo'limi bo'yicha hisob-grafik ishlarini bajarish namunalari ko'rsatilgan.

Uslubiy ko'rsatma bakalavriat yo'nalishida ta'lim oluvchi va «Elektrotexnikaning nazariy asoslari» fanini o'rganuvshi talabalarga mo'ljallangan.

Abu Rayhon Beruniy nomidagi Toshkent davlat texnika universiteti ilmiy-uslubiy kengashi qarori bilan nashr etildi.

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## KIRISH

Fan va texnikaning jadal rivojlanib borishi energetika, avtomatika, boshqaruv tizimi va boshqa ko'pgina sohalarda elektr zanjirlarini hisoblash bilan birga ularni analiz va sintez masalalari ham ko'rib chiqishni talab etadi.

Tavsiya etilayotgan ko'rsatmada «Elektrotexnikaning nazariy asoslari» fanini «Uch fazali zanjirlar» bo'limi bo'yicha yuklama qarshiliklari yulduz va uchburchakli shaklda ulanishda simmetrik hamda nosimmetrik holati uchun faza va liniya tok va kuchlanishlarini har xil ish holatlari uchun hisoblash usullari na'munaviy masalalar orqali ko'rsatilgan bo'lib, mos ravishda vektor diagrammalarni qurish usullari ham berilgan.

Bu talabalardan sinusoidal tokli uch fazali zanjirlarni turli yuklama holati uchun hisoblay olish usullarini o'rganishda ko'nikmalarga ega bo'lishga yordam beradi va barcha bakalavriat ta'lim yo'nalishidagi mutaxassisliklar uchun dasturulamal bo'lib xizmat qiladi.

Sinusoidal tokli uch fazali zanjirlarni hisoblash uchun mos ravishda bo'lgan 100 ta turli variantlar berilgan.

«Uch fazali zanjirlar» bo'limi bo'yicha hisob - garfik ishlarini bajarish uchun mo'ljallangan mazkur uslubiy ko'rsatma «Elektr energetikasi», «Elektr texnika, elektr mexanika va elektr texnologiyalar», «Kasbiy ta'lim (elektr energetikasi)», «Elektronika va asbobsozlik», «Radioelektron qurilmalar va tizimlar», «Kasbiy ta'lim (radioelektron qurilmalar va tizimlar)» bakalavriat ta'lim yo'nalishlarida tahsil oluvchi talabalarga mo'ljallangan.

## Hisob - grafik ishini bajarish bo'yicha

### TOPSHIRIQ

Uch fazali simmetrik genratorning faza kuchlanishlariga  $U_F$  liniya  $Z_L$  qarshiliklari orqali yulduz yoki uchburchakli shaklda yuklama  $Z_{IST}$  ulangan.

Yuklamaning yulduz yoki uchburchak ulangan shakli uchun quyidagilar hisoblansin:

1. Faza va liniya toklari, yuklamadagi faza kuchlanishlar, liniyadagi kuchlanish tushuvi va simmetrik yuklama bo'lganda liniyaning F.I.K.

2. Yuklamaning biror fazasida qisqa tutashuv bo'lgan holati uchun faza va liniya toklari, yuklamadagi faza kuchlanishlar, liniya simlaridagi kuchlanishlar tushuvi.

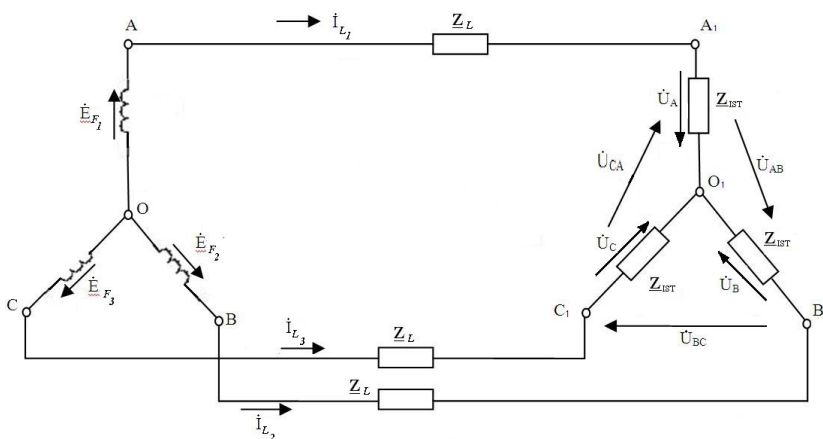
3. Yuklamaning biror fazasida uzilish bo'lgan holati uchun faza va liniya toklari, yuklamadagi faza kuchlanishlar, liniya simlaridagi kuchlanishlar tushuvi va uzilish simidagi hosil bo'lgan kuchlanish.

4. Yuqorida keltirilgan hamma holatlar uchun tok va kuchlanishlarning vektor diagrammalari qurilsin.

## NA'MUNAVIY MASALA

### YULDUZ - YULDUZ ULANISHNING SIMMETRIK HOLATI

Hisoblash quyidagi elektr zanjiri asosida amalga oshiriladi (1-rasm).



**1-rasm. Yulduz -yulduz ulanishning simmetrik holati**

Variant quyidagi uchta qiymat asosida beriladi. Birinchisi uch fazali generatorning  $U_F$  kuchlanishi, ikkinchisi liniya simlaridagi  $\underline{Z}_L$  qarshilik, uchinchi yuklamadagi iste'molchi  $\underline{Z}_{IST}$  qarshiligi. Shularni hisobga olgan holda quyidagi qiymatlar uchun hisoblashlar amalga oshiriladi:

$$U_F = 110 \text{ V},$$

$$\underline{Z}_L = 15 - j25 = 29e^{-j59^0} \text{ Om},$$

$$\underline{Z}_{IST} = 30 + j100 = 104,4e^{j73^0} \text{ Om}.$$

Uch fazali zanjirlarning analizi chiziqli zanjirlar nazariyasida keltirilgan har qanday usullar asosida olib borilishi mumkin. Lekin uch fazali zanjirlarning xususiyatlaridan kelib chiqib alohida hisoblash

uslubiyatini keltirib chiqarish mumkin. Bunda quydagi shartlarni hisobga olish kerak:

1. Iste'molchining yuklamasi statik ko'rinishga ega.

2. Generator chulg'amlarining ichki qarshiliklari inobatga olinmaydi yoki liniya qarshiliklarining ichiga qo'shib yuboriladi.

Generator (transformator) chulg'amlarining bir xilligini hisobga olib induksiyanayotgan E.Yu.K lar bir xil amplitudali va chastotali deb olinadi, lekin E.Yu.K lar bir - birlariga nisbat faza bo'yicha davrning uchdan bir qismiga siljigan bo'ladi. Shunda «A» birinchi faza deb hisoblanib, uning boshlang'ich fazasi nolga teng deb qabul qilinadi. Eslatib o'tamiz, bu to'g'ri ketma - ketlikdagi tizim hisoblanadi:

$$\dot{U}_{F1} = 110 V ,$$

$$\dot{U}_{F2} = 110e^{-j120^0} = -55 - j95,2 V ,$$

$$\dot{U}_{F3} = 110e^{j120^0} = -55 + j95,2 V .$$

Natijada generatorning faza kuchlanishlari sistemasi kelib chiqadi. Simmetrik yuklama holatida har bir faza Om qonuniga ko'ra alohida hisoblanishi mumkin. U holda tok va kuchlanishlarning simmetriyasi hosil bo'ladi va bunda bitta fazani ko'rib chiqsa bo'ladi. Faza qarshiligi liniyadagi qarshilik bilan qo'shib topilishi mumkin:

$$\underline{Z}_F = \underline{Z}_L + \underline{Z}_{IST} = 87,4e^{j59^0} \text{ Om} .$$

Om qonuniga asosan zanjirdagi liniya toklarini hisoblaymiz:

$$\dot{I}_{L1} = \frac{\dot{U}_{F1}}{\underline{Z}_L + \underline{Z}_{IST}} = \frac{110}{87,4e^{j59^0}} = 1,25e^{-j59^0} \text{ A} ,$$

$$\dot{I}_{L2} = \frac{\dot{U}_{F2}}{\underline{Z}_L + \underline{Z}_{IST}} = \frac{110e^{-j120^0}}{87,4e^{j59^0}} = 1,25e^{-j179^0} \text{ A} ,$$

$$\dot{I}_{L3} = \frac{\dot{U}_{F3}}{\underline{Z}_L + \underline{Z}_{IST}} = \frac{110e^{j120^0}}{87,4e^{j59^0}} = 1,25e^{-j61^0} \text{ A} .$$

Yuklama qarshiligidagi kuchlanish tushuvi hisoblanadi:

$$\begin{aligned}\dot{U}_{IST_1} &= \dot{I}_{L_1} \underline{Z}_{IST} = 1,25e^{-j59^0} \cdot 104,4e^{j73^0} = 130,5e^{j14^0} \text{ V}, \\ \dot{U}_{IST_2} &= \dot{I}_{L_2} \underline{Z}_{IST} = 1,25e^{-j179^0} \cdot 104,4e^{j73^0} = 130,5e^{-j106^0} \text{ V}, \\ \dot{U}_{IST_3} &= \dot{I}_{L_3} \underline{Z}_{IST} = 1,25e^{j61^0} \cdot 104,4e^{j73^0} = 130,5e^{j134^0} \text{ V}.\end{aligned}$$

Liniya qarshiligidagi kuchlanishlar tushuvi aniqlanadi:

$$\begin{aligned}\Delta \dot{U}_{L_1} &= \dot{I}_{L_1} \underline{Z}_L = 1,25e^{-j59^0} \cdot 29e^{-j59^0} = 36,25e^{-j119^0} \text{ V}, \\ \Delta \dot{U}_{L_2} &= \dot{I}_{L_2} \underline{Z}_L = 1,25e^{-j179^0} \cdot 29e^{-j59^0} = 36,25e^{-j238^0} \text{ V}, \\ \Delta \dot{U}_{L_3} &= \dot{I}_{L_3} \underline{Z}_L = 1,25e^{j61^0} \cdot 29e^{-j59^0} = 36,25e^{j2^0} \text{ V}.\end{aligned}$$

Manba generatoridagi aktiv quvvatni hisoblaymiz:

$$P_{GEN} = 3U_{F_1} \cdot I_{L_1} \cos(U_{F_1} \wedge I_{L_1}) = 3 \cdot 110 \cdot 1,25 \cos 59^0 = 212,4 \text{ W}.$$

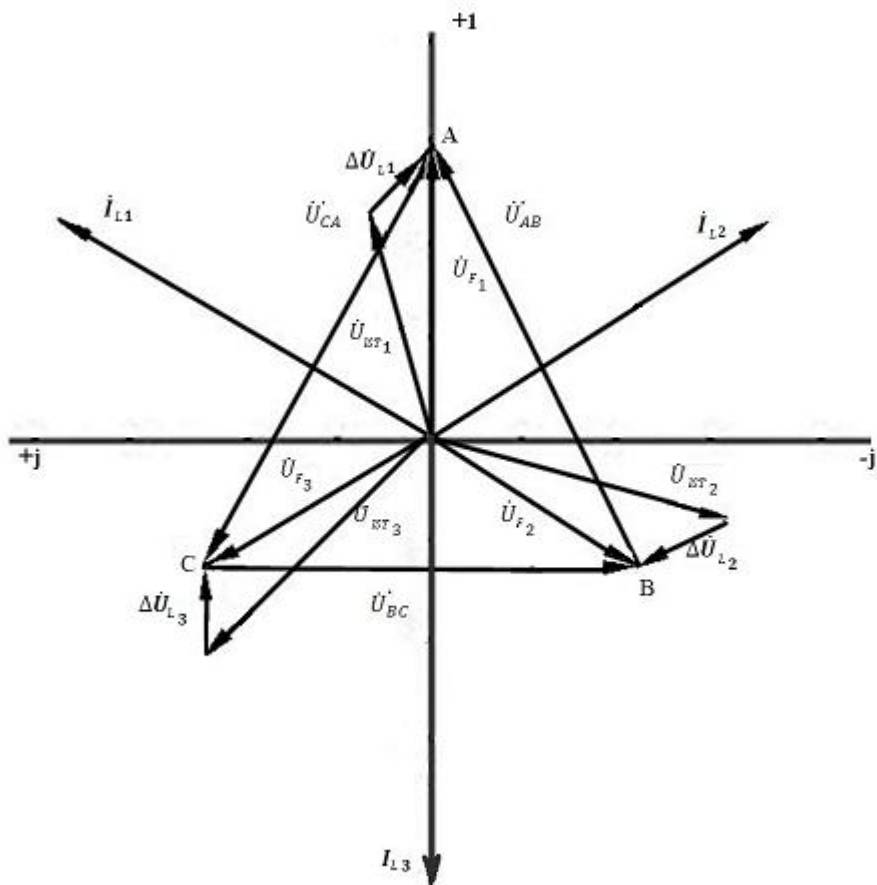
Iste'molchining aktiv quvvati:

$$P_{IST} = 3U_{IST_1} I_{L_1} \cos(U_{IST_1} \wedge I_{L_1}) = 3 \cdot 130 \cdot 1,25 \cos(14^0 + 59^0) = 140,1 \text{ W}.$$

Uch fazali sistemaning foydali ish koeffitsienti hisoblanadi:

$$\eta = \frac{P_{IST}}{P_{GEN}} \cdot 100\% = 65,9\%.$$

Hisoblangan qiymatlar asosida masshtab bo'yicha kuchlanish va toklarning topografik diagrammasi kompleks tekisligida quriladi (2-rasm):



2-rasm. Kuchlanish va toklarning topografik diagrammasi.

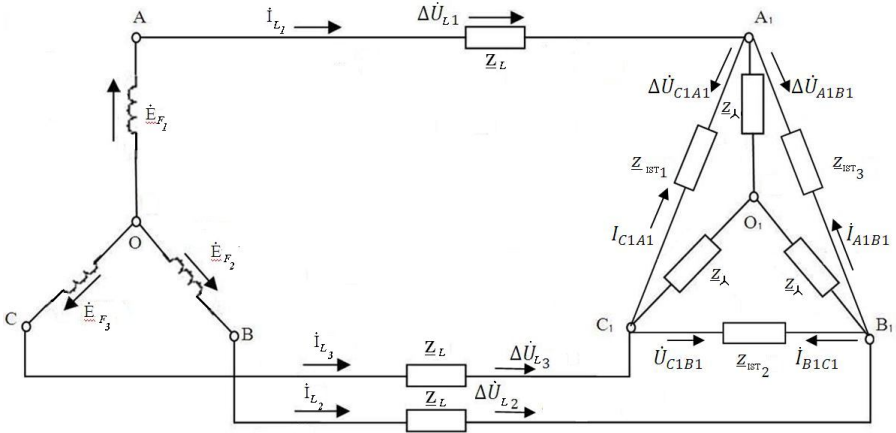
Masshtab

$m_U : 1\text{sm} / \text{V}$

$m_I : 1\text{sm} / \text{A}$



## YULDUZ - UCHBURCHAKLI ULANISHNING SIMMETRIK HOLATI



**3-rasm. Yulduz – uchburchakli ulanishning simetrik holati**

Liniya simlaridagi qarshiliklar uchburchak tarmoqlardagi tokni topishga imkon bermaydi. Shuning uchun uchburchakni ekvivalent yulduzga almashtirib olish mumkin (3-rasm). Yulduz nurlarining qarshiliklari quyidagicha topiladi:

$$\underline{Z}_{\lambda} = \frac{Z_{\text{BT}}}{3} = \frac{104,4e^{j73^{\circ}}}{3} = 34,8e^{j73^{\circ}} \text{ Om.}$$

Liniya simidagi qarshilikni qo‘shib, faza qarshiligi aniqlanadi:

$$\underline{Z}_{\lambda} + \underline{Z}_{L} = 10 + j33,3 + 15 - j25 = 25 + j8,3 = 26,3e^{j19^{\circ}} \text{ Ohm.}$$

Uch fazali zanjirning liniya toklari

$$\dot{I}_{L1} = \frac{\dot{U}_{F1}}{\underline{Z}_{\lambda} + \underline{Z}_{L}} = \frac{110}{26,3e^{j19^{\circ}}} = 4,1e^{-j19^{\circ}} \text{ A,}$$

$$\dot{I}_{L2} = \frac{\dot{U}_{F2}}{\underline{Z}_{\lambda} + \underline{Z}_{L}} = \frac{110e^{-j120^{\circ}}}{26,3e^{j19^{\circ}}} = 4,1e^{-j139^{\circ}} \text{ A,}$$

$$\dot{I}_{L3} = \frac{\dot{U}_{F3}}{\underline{Z}_{\lambda} + \underline{Z}_{L}} = \frac{110e^{j120^{\circ}}}{26,3e^{j19^{\circ}}} = 4,1e^{j102^{\circ}} \text{ A.}$$

Yulduzli ulanish holatidagi faza kuchlanishi

$$\dot{U}_{A_0'} = I_{L1} \cdot \underline{Z}_{\lambda} = 4,1e^{-j19^{\circ}} \cdot 34,8e^{j73^{\circ}} = 142,68e^{j54^{\circ}} \text{ V,}$$

$$\dot{U}_{B_1 0'} = I_{L2} \cdot \underline{Z}_{\lambda} = 4,1e^{-j139^{\circ}} \cdot 34,8e^{j73^{\circ}} = 142,68e^{-j66^{\circ}} \text{ V,}$$

$$\dot{U}_{C_1 0'} = I_{L3} \cdot \underline{Z}_{\lambda} = 4,1e^{j102^{\circ}} \cdot 34,8e^{j73^{\circ}} = 142,68e^{j175^{\circ}} \text{ V.}$$

Uchburchakli ulanish holati uchun liniya kuchlanishi quydagicha aniqlanadi:

$$\dot{U}_{A_1 B_1} = \dot{U}_{A_1 0'} - \dot{U}_{B_1 0'} = 84,1 + j114,5 - 57,6 + j129,4 = 246,5e^{j83^{\circ}25'} \text{ V,}$$

$$\dot{U}_{B_1 C_1} = \dot{U}_{B_1 0'} - \dot{U}_{C_1 0'} = 246,5e^{-j36^{\circ}12'} \text{ V,}$$

$$\dot{U}_{C_1 A_1} = \dot{U}_{C_1 0'} - \dot{U}_{A_1 0'} = 246,5e^{j203^{\circ}25'} \text{ V.}$$

Uchburchakli ulanishdagi faza toklari

$$\dot{I}_{A_1B_1} = \frac{\dot{U}_{A_1B_1}}{\underline{Z}_{IST_1}} = \frac{246,5e^{j83^{\circ}25'}}{104,4e^{j73^{\circ}}} = 2,46e^{j10^{\circ}25'} \text{ A},$$

$$\dot{I}_{B_1C_1} = \frac{\dot{U}_{B_1C_1}}{\underline{Z}_{IST_2}} = \frac{246,5e^{-j36^{\circ}12'}}{104,4e^{j73^{\circ}}} = 2,46e^{-j109^{\circ}12'} \text{ A},$$

$$\dot{I}_{C_1A_1} = \frac{\dot{U}_{C_1A_1}}{\underline{Z}_{IST_3}} = \frac{246,5e^{j203^{\circ}25'}}{104,4e^{j73^{\circ}}} = 2,46e^{j130^{\circ}25'} \text{ A}.$$

Manbaning aktiv quvvati

$$P_{GEN} = 3U_{FI}I_{LI} \cos(\dot{U}_{FI} \wedge \dot{I}_{LI}) = 3 \cdot 110 \cdot 4,1 \cos 19^{\circ} = 1270 \text{ W}.$$

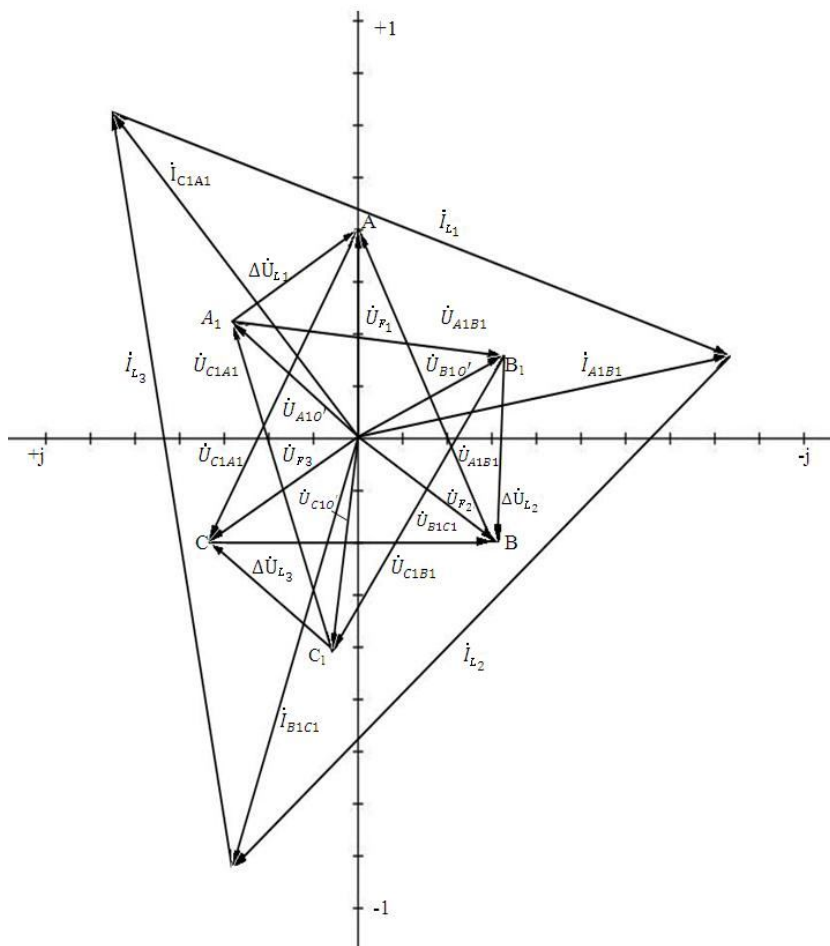
Iste'molchining aktiv quvvati

$$P_{IST} = 3U_{A_1B_1}I_{A_1B_1} \cos(U_{A_1B_1} \wedge I_{A_1B_1}) = 3 \cdot 246,5 \cdot 2,46 \cos 73^{\circ} = 544,5 \text{ W}.$$

Uch fazali sistemaning foydali ish koeffitsenti quyidagicha hisoblanadi:

$$\eta = \frac{P_{IST}}{P_{GEN}} \cdot 100\% = 43\%.$$

Hisoblangan qiymatlar asosida masshtab bo'yicha kuchlanish va toklarning topografik diagrammasi kompleks tekislikda quriladi (4-rasm).



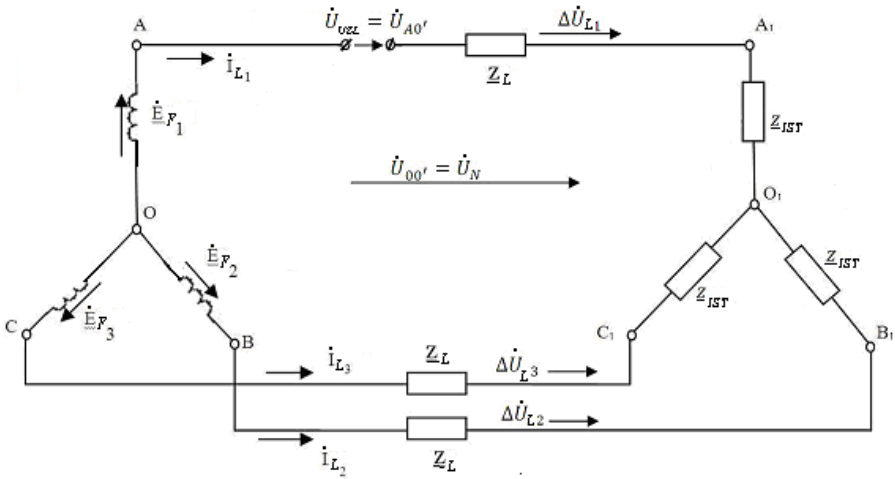
**4-rasm. Kuchlanish va toklarning topografik diagrammasi**

Masshtab  
 $m_U: 1\text{sm} / \text{V}$   
 $m_I: 1\text{sm} / \text{A}$

# YULDUZ - YULDUZ ULANISHNING NOSIMMETRIK HOLATI

## «A» FAZANING LINIYA SIMIDAGI UZILISH

«A» fazada uzilish hosil qilinsa zanjir nosimmetrik ko‘rinishga keladi(5-rasm).



5-rasm. «A» fazada uzilish hosil qilish

$$Y_1 = 0,$$

$$\dot{U}_{00'} = \frac{\dot{U}_{F_1} \cdot Y_1 + \dot{U}_{F_2} \cdot Y_2 + \dot{U}_{F_3} \cdot Y_3}{Y_1 + Y_2 + Y_3} = \frac{\dot{U}_{F_1}}{2} = -55 \text{ V},$$

$$\dot{U}_{A0'} = \dot{U}_{uzl} = \dot{U}_{F_1} - \dot{U}_{00'} = 1,5\dot{U}_{F_1} = 165 \text{ V},$$

$$\dot{U}_{B0'} = \dot{U}_{F_2} - \dot{U}_{00'} = -55 - j95,2 + 55 = 95,2e^{-j90^\circ} \text{ V},$$

$$\dot{U}_{C0'} = \dot{U}_{F_3} - \dot{U}_{00'} = -55 + j95,2 + 55 = 95,2e^{j90^\circ} \text{ V}.$$

Liniya toklari hisoblanadi:

$$\begin{aligned} \dot{I}_{L_1} &= 0, \\ \dot{I}_{L_2} &= \frac{\dot{U}_{B0'}}{\underline{Z}_L + \underline{Z}_{IST}} = \frac{95,2e^{-j90^\circ}}{87,4e^{j59^\circ}} = 1,08e^{-j149^\circ} \text{ A}, \\ \dot{I}_{L_3} &= \frac{\dot{U}_{C0'}}{\underline{Z}_L + \underline{Z}_{IST}} = \frac{95,2e^{j90^\circ}}{87,4e^{j59^\circ}} = 1,08e^{j31^\circ} \text{ A}. \end{aligned}$$

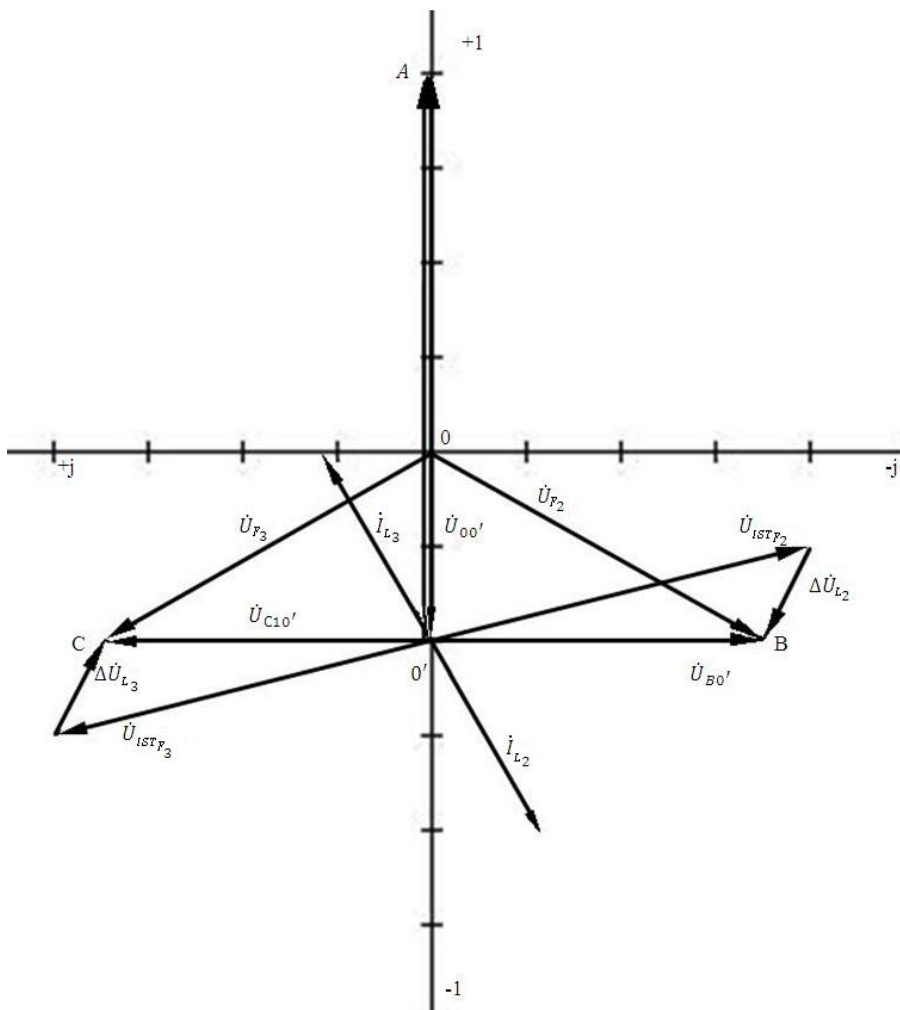
Liniya simlaridagi kuchlanish isrofi

$$\begin{aligned} \Delta \dot{U}_{L_1} &= \dot{I}_{L_1} \underline{Z}_L = 0 \text{ V}, \\ \Delta \dot{U}_{L_2} &= \dot{I}_{L_2} \underline{Z}_L = 1,08e^{-j149^\circ} \cdot 29e^{-j59^\circ} = 31,2e^{-j208^\circ} \text{ V}, \\ \Delta \dot{U}_{L_3} &= \dot{I}_{L_3} \underline{Z}_L = 1,08e^{j31^\circ} \cdot 29e^{-j59^\circ} = 31,2e^{-j28^\circ} \text{ V}. \end{aligned}$$

Iste'molchi qarshiligidagi kuchlanish

$$\begin{aligned} \dot{U}_{IST_1F_1} &= \dot{I}_{L_1} \underline{Z}_{IST} = 0 \text{ V}, \\ \dot{U}_{IST_2F_2} &= \dot{I}_{L_2} \underline{Z}_{IST} = 1,08e^{-j149^\circ} \cdot 104,4e^{j73^\circ} = 112,7e^{-j75^\circ} \text{ V}, \\ \dot{U}_{IST_3F_3} &= \dot{I}_{L_3} \underline{Z}_{IST} = 1,08e^{j31^\circ} \cdot 104,4e^{j73^\circ} = 112,7e^{j104^\circ} \text{ V}. \end{aligned}$$

Hisoblangan qiymatlar asosida masshtab bo'yicha kuchlanish va toklarning topografik diagrammasi kompleks tekislikda quriladi (6-rasm).



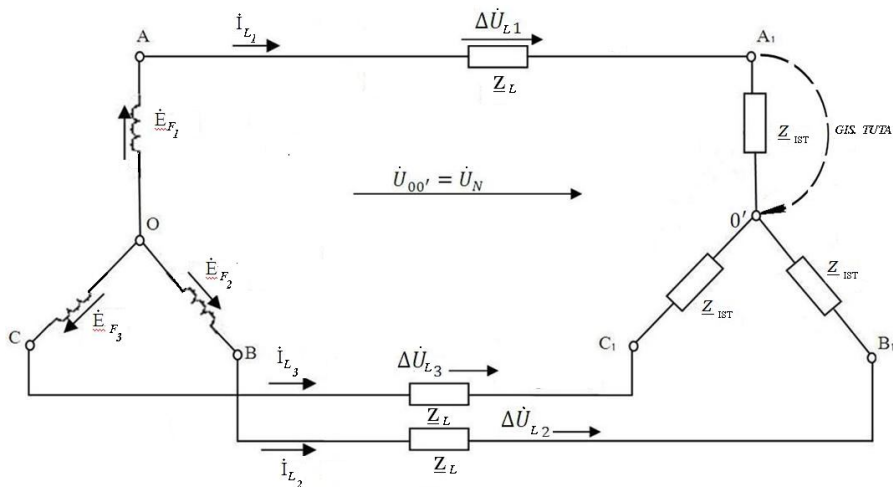
**6-rasm. Kuchlanish va toklarning topografik diagrammasi**

Masshtab

$m_U: 1\text{sm} / \text{V}$

$m_I: 1\text{sm} / \text{A}$

## «A» FAZADA QISQA TUTASHUV



**7-rasm. «A» fazada qisqa tutashuv.**

Nejtral simdagi kuchlanishni aniqlash (7-rasm):

$$\dot{U}_{00'} = \dot{U}_N = \frac{\dot{U}_{F_1} \cdot \underline{Z}_{IST}}{3\underline{Z}_L + \underline{Z}_{IST}} = \frac{110 \cdot 104,4e^{j73^0}}{3 \cdot 29e^{-j59^0} + 104,4e^{j73^0}} = \frac{11484e^{j73^0}}{79e^{j19^0}} =$$

$$= 145e^{j54^0} = 85,23 + j117,3 \text{ V},$$

$$\dot{U}_{A_0'} = \dot{U}_{F_1} - \dot{U}_{00'} = 110 - (85,23 + j117,3) = 24,77 - j117,3 = 120e^{-j78^0} \text{ V},$$

$$\dot{U}_{B_0'} = \dot{U}_{F_2} - \dot{U}_{00'} = -55 - j95,2 - (85,23 + j117,3) = -140,23 - j212,5 = 254e^{j236^0} \text{ V},$$

$$\dot{U}_{C_0'} = \dot{U}_{F_3} - \dot{U}_{00'} = -55 + j95,2 - (85,23 + j117,3) = -140,23 + j22,1 = 142,8e^{j189^0} \text{ V}.$$



Liniya toklari

$$\dot{i}_{L_1} = \frac{\dot{U}_{A_0'}}{\underline{Z}_L} = \frac{120e^{-j78^\circ}}{29e^{-j59^\circ}} = 4,2e^{j19^\circ} \text{ A},$$

$$\dot{i}_{L_2} = \frac{\dot{U}_{B_0'}}{\underline{Z}_L + \underline{Z}_{IST}} = \frac{254e^{j236^\circ 10' /}}{87,4e^{j59^\circ}} = 2,91e^{j177^\circ} \text{ A},$$

$$\dot{i}_{L_3} = \frac{\dot{U}_{C_0'}}{\underline{Z}_L + \underline{Z}_{IST}} = \frac{142e^{j189^\circ}}{87,4e^{j59^\circ}} = 1,62e^{j130^\circ} \text{ A}.$$

Liniya simidagi kuchlanish isrofi

$$\Delta \dot{U}_{L_1} = \dot{U}_{A_0'} = 120e^{-j78^\circ} \text{ V},$$

$$\Delta \dot{U}_{L_2} = \dot{i}_{L_2} \underline{Z}_L = 84,4e^{j118^\circ} \text{ V},$$

$$\Delta \dot{U}_{L_3} = \dot{i}_{L_3} \underline{Z}_L = 47e^{j71^\circ} \text{ V}.$$

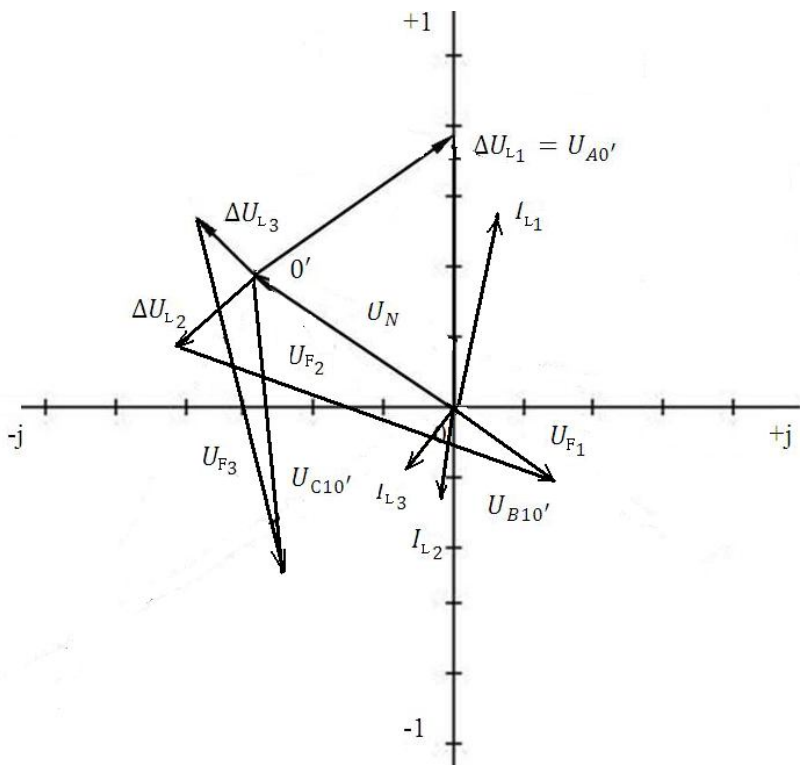
Yuklamada iste'mol qilinayotgan kuchlanish

$$\dot{U}_{A_0'} = 0,$$

$$\dot{U}_{B_0'} = \dot{i}_{L_2} \underline{Z}_{IST} = 303,8e^{j250^\circ 20' /} \text{ V},$$

$$\dot{U}_{C_0'} = \dot{i}_{L_3} \underline{Z}_{IST} = 169e^{j203^\circ 20' /} \text{ V}.$$

Hisoblangan qiymatlar asosida masshtab bo'yicha kuchlanish va toklarning topografik diagrammasi kompleks tekislikda quriladi (8-rasm).

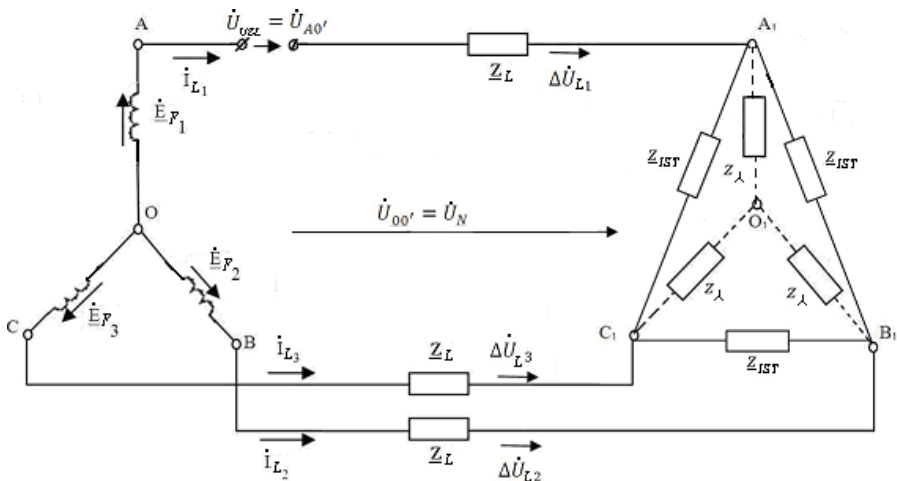


**8-rasm. Kuchlanish va toklarning topografik diagrammasi**

Masshtab  
 $m_U: 1\text{sm} / \text{V}$   
 $m_I: 1\text{sm} / \text{A}$

## YULDUZ - UCHBURCHAKLI ULANISHNING NOSIMMETRIK HOLATI

### «A» FAZASINING LINIYA SIMIDA UZILISH HOSIL BO‘LISHI



**9-rasm. Liniya simida uzilish hosil bo‘lishi**

$$Z_{\lambda} = \frac{Z_{IS\Gamma}}{3} = 34,8e^{j73^{\circ}} \text{ Om.}$$

Liniyadagi kuchlanish(9-rasm)

$$U_{00'} = \frac{U_{F_1}}{2} = -55 \text{ V,}$$

$$\dot{U}_{A0'} = \dot{U}_{uzl} = \dot{U}_{F_1} - \dot{U}_{00'} = 1,5\dot{U}_{F_1} = 165 \text{ V,}$$

$$\dot{U}_{B0'} = \dot{U}_{F_2} - \dot{U}_{00'} = 95,2e^{-j90^{\circ}} \text{ V,}$$

$$\dot{U}_{C0'} = \dot{U}_{F_3} - \dot{U}_{00'} = 95,2e^{j90^{\circ}} \text{ V.}$$

Liniya toklari

$$\begin{aligned} \dot{I}_{L_1} &= 0 \quad A, \\ \dot{I}_{L_2} &= \frac{\dot{U}_{B0'}}{\underline{Z}_\lambda + \underline{Z}_{\text{BT}}} = \frac{95,2e^{-j90^\circ}}{26,3e^{j19^\circ}} = 3,6e^{-j109^\circ} \quad A, \\ \dot{I}_{L_3} &= \frac{\dot{U}_{C0'}}{\underline{Z}_\lambda + \underline{Z}_{\text{BT}}} = \frac{95,2e^{j90^\circ}}{26,3e^{j19^\circ}} = 3,6e^{j71^\circ} \quad A. \end{aligned}$$

Liniya kuchlanishlari

$$\begin{aligned} \Delta \dot{U}_{L_1} &= 0 \quad V, \\ \Delta \dot{U}_{L_2} &= \dot{I}_{L_2} \underline{Z}_L = 3,6e^{-j109^\circ} \cdot 29e^{-j59^\circ} = 104,4e^{-j168^\circ} = -101,9 - j21,7 \quad V, \\ \Delta \dot{U}_{L_3} &= \dot{I}_{L_3} \underline{Z}_L = 3,6e^{j71^\circ} \cdot 29e^{-j59^\circ} = 104,4e^{j12^\circ} = 102 + j21,7 \quad V. \end{aligned}$$

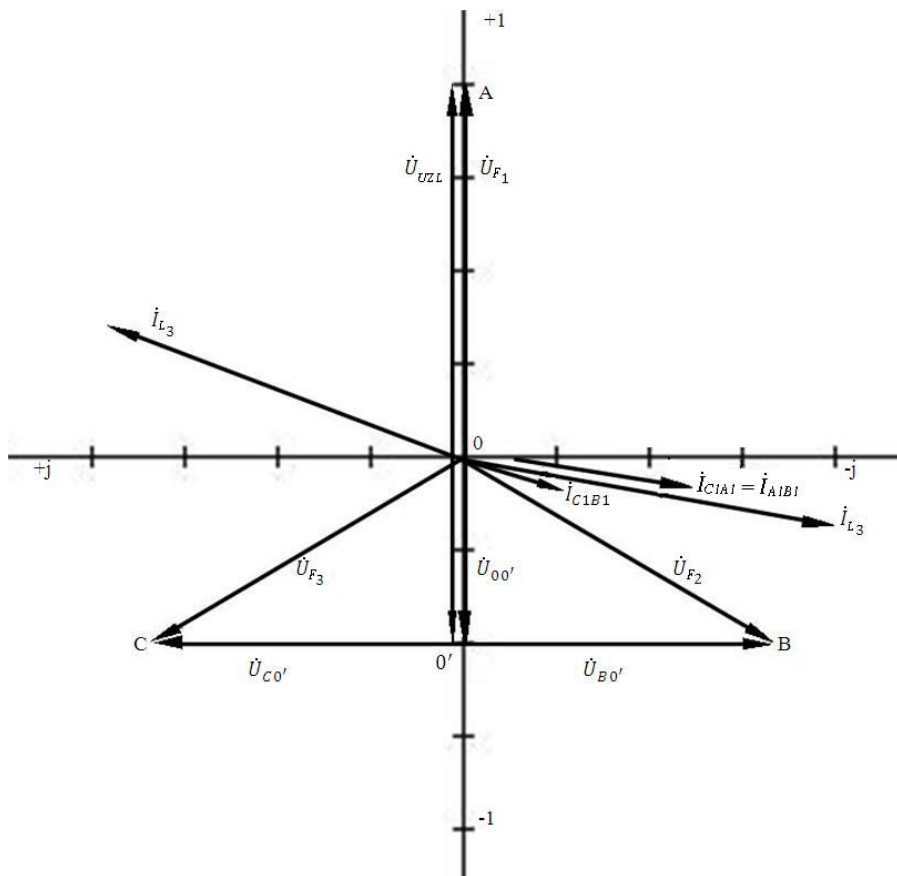
Iste'molchi kuchlanishi

$$\begin{aligned} \dot{U}_{\text{IST}F_1} &= 0 \quad V, \\ \dot{U}_{\text{IST}F_2} &= U_{B0'} = U_{B0} - \Delta U_{L_2} = -j95,2 + 101,9 + j21,7 = 101,9 - j73,5 = 126e^{-j36^\circ} \quad V, \\ \dot{U}_{\text{IST}F_3} &= U_{C0'} = U_{C0} - \Delta U_{L_3} = j95,2 - 102,5 - j21,7 = -102 + j73,5 = 126e^{j44^\circ} \quad V. \end{aligned}$$

Iste'molchi qarshiligidagi faza toklari hisoblanadi:

$$\begin{aligned} \dot{I}_{C_1A_1} &= \dot{I}_{A_1B_1} = \frac{\dot{I}_{L_2}}{3} = 1,2e^{-j109^\circ} \quad A, \\ \dot{I}_{C_1B_1} &= \frac{2\dot{I}_{L_2}}{3} = 2,4e^{-j109^\circ} \quad A. \end{aligned}$$

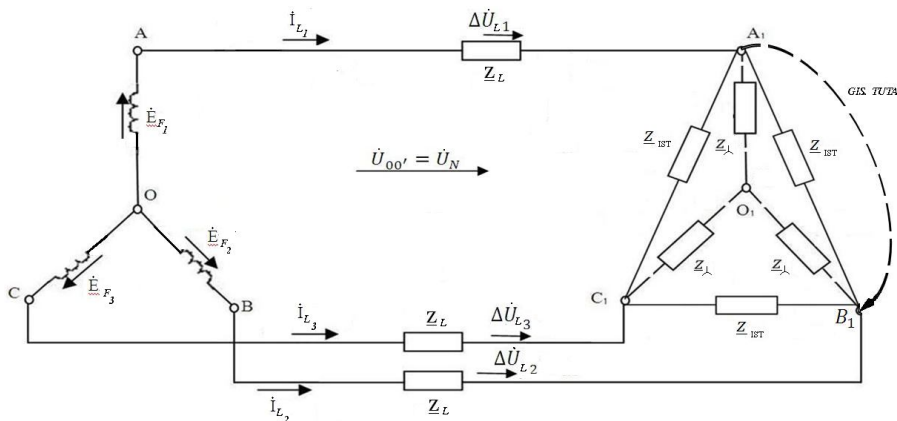
Hisoblangan qiymatlar asosida masshtab bo'yicha kuchlanish va toklarning topografik diagrammasi kompleks tekislikda quriladi (10-rasm).



**10-rasm. Kuchlanish va toklarning topografik diagrammasi**

Masshtab  
 $m_U: 1\text{sm} / \text{V}$   
 $m_I: 1\text{sm} / \text{A}$

## $A_1$ va $B_1$ TUGUNLAR ORASIDA QISQA TUTASHUV



**11-rasm. Tugunlar orasida qisqa tutashuv**

$$\underline{Z}_{AB} = 0,$$

$$\underline{Z} = \underline{Z}_{\text{ISTA}} = 0,$$

$$\underline{Z} = \underline{Z}_{\lambda} = \frac{\underline{Z}_{\text{IST}}}{2} = \frac{104,4e^{j73^0}}{2} = 52,2e^{j73^0} = 15 + j49,9 \quad \text{Om}.$$

$$\begin{aligned} \underline{Z}_C &= -\frac{U_{F_3} \cdot \underline{Z}_{\text{IST}}}{6\underline{Z}_L + 2\underline{Z}_{\text{IST}}} = -\frac{110e^{j120^0} \cdot 104,4e^{j73^0}}{6 \cdot 29e^{-j59^0} + 2 \cdot 104,4e^{j73^0}} = \\ &= -\frac{11484e^{j193^0}}{174e^{-j59^0} + 208,8e^{j73^0}} = -\frac{11484e^{j193^0}}{158e^{j19^0}} = 72,6e^{j173^0 30'} = -72,2 + j6,9 \quad \text{Om}. \end{aligned}$$

$\dot{U}_{00'} - 00'$  nuqtadagi neytral kuchlanish

Liniya simlaridagi kuchlanish isrofi hisoblanadi:

$$\dot{U}_{00'} + \Delta\dot{U}_{L_2} - \dot{E}_{F_1} = 0 \quad V,$$

$$\Delta\dot{U}_{L_1} = \dot{U}_{F_1} - \dot{U}_{00'} = 110 - (-72,2 + j6,9) = 182,2 - j6,9 = 182,3e^{-j2^\circ} \quad V,$$

$$\Delta\dot{U}_{L_1} = \dot{U}_{A0'} \quad V,$$

$$\dot{U}_{00'} + \Delta\dot{U}_{L_2} - \dot{E}_{F_2} = 0 \quad V,$$

$$\Delta\dot{U}_{L_2} = \dot{U}_{F_2} - \dot{U}_{00'} = (-55 - j95,2) - (-72,2 + j6,9) = 17,2 - j102,1 = 103,2e^{-j80^\circ} \quad V$$

$$\Delta\dot{U}_{L_2} = \dot{U}_{B0'} \quad V,$$

$$\Delta\dot{U}_{L_3} = \dot{U}_{F_3} - \dot{U}_{00'} = (-55 + j95,2) - (-72,2 + j6,9) = 17,2 + j88,3 = 89,9e^{j75^\circ} \quad V,$$

$$\Delta\dot{U}_{L_3} = \dot{U}_{C0'} \quad V.$$

Liniya toklari hisoblanadi:

$$\dot{I}_{L_1} = \frac{\Delta\dot{U}_{L_1}}{\underline{Z}_L} = \frac{182,3e^{-j2^\circ}}{29e^{-j59^\circ}} = 6,2e^{j57^\circ} \quad A,$$

$$\dot{I}_{L_2} = \frac{\Delta\dot{U}_{L_2}}{\underline{Z}_L} = \frac{103,2e^{-j80^\circ}}{29e^{-j59^\circ}} = 3,5e^{-j20^\circ} \quad A,$$

$$\dot{I}_{L_3} = \frac{\Delta\dot{U}_{L_3}}{\underline{Z}_L} = \frac{89,9e^{j75^\circ}}{29e^{-j59^\circ}} = 3,1e^{j134^\circ} \quad A.$$

Iste'molchi qarshiligidagi kuchlanish tushuvi

$$\dot{U}_{A_1C_1} = \dot{U}_{C_10'} = \dot{I}_{L3} \underline{Z}_\lambda = 3,1e^{j134^0} \cdot 52,2e^{j73^0} = 161,2e^{j207^0} \quad V,$$

$$\dot{U}_{A_1B_1} = 0 \quad V,$$

$$\dot{U}_{B_1C_1} = \dot{U}_{C_10'} = 161,2e^{j207^0} \quad V.$$

Iste'molchi qarshiligidagi faza toklari hisoblanadi:

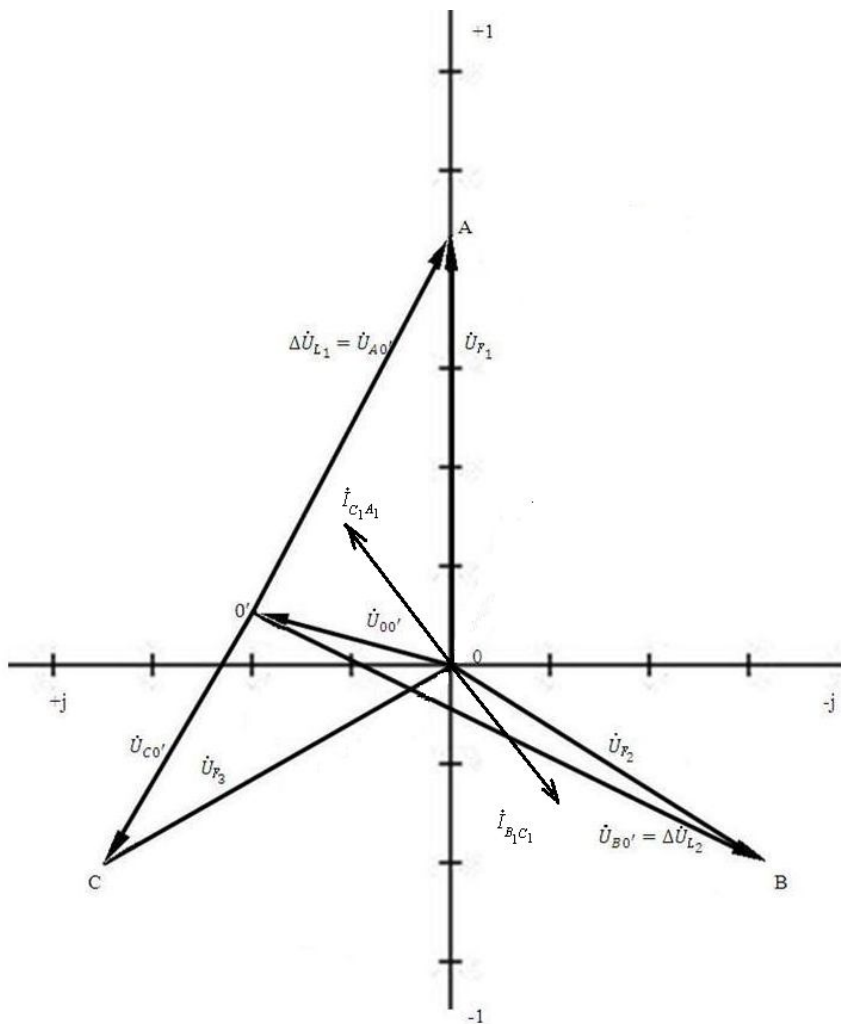
$$\dot{I}_{A_1B_1} = 0,$$

$$\dot{I}_{C_1A_1} = \frac{\dot{U}_{A_1C_1}}{\underline{Z}_{A_1C_1}} = \frac{\dot{U}_{A_1C_1}}{\underline{Z}_{IST}} = 3e^{j134^0} \quad A,$$

$$\dot{I}_{C_1B_1} = -\dot{I}_{C_1A_1} = 3e^{j134^0} \quad A.$$

Hisoblangan qiymatlar asosida masshtab bo'yicha kuchlanish va toklarning topografik diagrammasi kompleks tekislikda quriladi (11-rasm).





**12-rasm. Kuchlanish va toklarning topografik diagrammasi**

Masshtab

$m_U: 1\text{sm} / \text{V}$

$m_I: 1\text{sm} / \text{A}$

## VARIANTLAR

<b>Variant</b>	$U_F$	$\underline{Z}_L$	$\underline{Z}_{IST}$	<b>Variant</b>	$U_F$	$\underline{Z}_L$	$\underline{Z}_{IST}$
1	115	20+j5	20+j20	30	127	5+j15	50+j40
2	115	20+j10	20+j30	31	127	5+j20	50+j50
3	115	20+j15	20+j40	32	127	5-j5	50+j60
4	115	20+j20	20+j50	33	127	5-j10	50+j70
5	115	20-j5	20+j60	34	127	5-j15	50+j80
6	115	20-j10	20+j70	35	127	5-j20	50+j90
7	115	20-j15	20+j80	36	127	5-j25	50+j100
8	115	20-j20	20+j90	37	127	25+j5	60+j20
9	115	20-j25	20+j100	38	127	25+j10	60+j30
10	115	15+j5	30+j20	39	127	25+j15	60+j40
11	115	15+j10	30+j30	40	127	25+j20	60+j50
12	115	15+j15	30+j40	41	220	25+j25	60+j60
13	115	15+j20	30+j50	42	220	25-j5	60+j70
14	115	15-j5	30+j60	43	220	25-j10	60+j80
15	115	15-j10	30+j70	44	220	25-j15	60+j90
16	115	15-j15	30+j80	45	220	25-j20	60+j100
17	115	15-j20	30+j90	46	220	20+j5	70+j20
18	115	15-j25	30+j100	47	220	20+j10	70+j30
19	115	10+j5	40+j20	48	220	20+j15	70+j40
20	115	10+j10	40+j30	49	220	20-j20	60+j50
21	127	10+j15	40+j40	50	220	20-j5	70+j60
22	127	10+j20	40+j50	51	220	20-j10	70+j70
23	127	10-j5	40+j60	52	220	20-j15	70+j80
24	127	10-j10	40+j70	53	220	20-j20	70+j90
25	127	10-j15	40+j80	54	220	20-j25	70+j100
26	127	10-j20	40+j90	55	220	15+j5	80+j20
27	127	10-j25	40+j100	56	220	15+j10	80+j30
28	127	5+j5	50+j20	57	220	15+j15	80+j40
29	127	5+j10	50+j30	58	220	15+j20	80+j50

<b>Variant</b>	$U_F$	$\underline{Z}_L$	$\underline{Z}_{IST}$	<b>Variant</b>	$U_F$	$\underline{Z}_L$	$\underline{Z}_{IST}$
59	220	15-j5	80+j60	80	380	5-j20	100+j90
60	220	15-j10	80+j70	81	110	10+j5	10+j10
61	380	15-j15	80+j80	82	110	10+j10	10+j15
62	380	15-j20	80+j90	83	110	10+j15	10+j20
63	380	15-j25	80+j100	84	110	10+j20	10+j25
64	380	10+j5	90+j20	85	110	10-j5	10+j30
65	380	10+j10	90+j30	86	110	10-j10	10+j35
66	380	10+j15	90+j40	87	110	10-j15	10+j40
67	380	10+j20	90+j50	88	110	10-j20	10+j45
68	380	10-j15	90+j60	89	110	10-j25	10+j50
69	380	10-j10	90+j70	90	110	7,5+j5	15+j10
70	380	10-j15	90+j80	91	110	7,5+j10	15+j15
71	380	10-j20	90+j90	92	110	7,5+j15	15+j20
72	380	10-j25	90+j100	93	110	7,5+j20	15+j25
73	380	5+j5	100+j20	94	110	7,5-j5	15+j30
74	380	5+j10	100+j30	95	110	7,5+j10	15+j35
75	380	5+j15	100+j40	96	110	7,5+j15	15+j40
76	380	5+j20	100+j50	97	110	7,5+j20	15+j45
77	380	5-j5	100+j60	98	110	7,5+j5	15+j50
78	380	5-j10	100+j70	99	110	7,5+j10	15+j55
79	380	5-j15	100+j80	100	110	7,5+j15	15+j60

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Qaydlar uchun

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