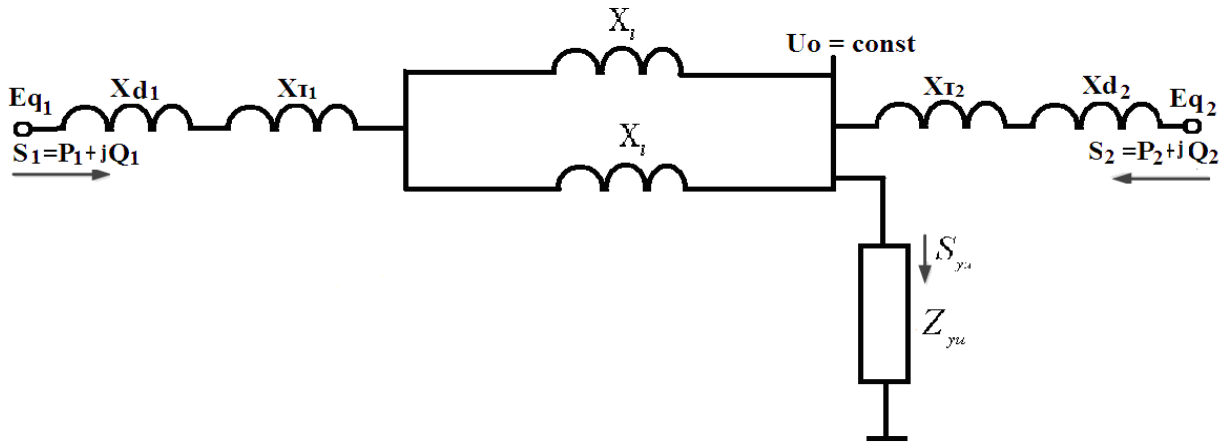
O‘ZBEKISTON RESPUBLIKASI OLIY VA O‘RTA MAXSUS TA’LIM VAZIRLIGI

ABU RAYHON BERUNIY NOMIDAGI TOSHKENT DAVLAT TEXNIKA UNIVERSITETI

O‘ T K I N CH I J A R A YO N L A R

fanidan kurs ishini bajarishga oid

USLUBIY KO‘RSATMALAR



Toshkent -2016

«O‘tkinchi jarayonlar» fanidan kurs ishini bajarish uchun uslubiy ko‘rsatmalar, Xaydarov S. D., – t. f. n., «Elektr stansiyalari, tarmoqlari va tizimlari» kafedrasi dotsenti; Abdubannayev J.X. «Elektr stansiyalari, tarmoqlari va tizimlari» kafedrasi assistenti. – Toshkent: ToshDTU, 2016 – 88 b.

Ushbu uslubiy ko‘rsatmalarda «O‘tkinchi jarayonlar» fanidan kurs ishini bajarish bo‘yicha topshiriqlar, ularni bajarish tartibi, kerakli nazariy ma’lumotlar hamda katalog ma’lumotlari keltirilgan.

Uslubiy ko‘rsatmalar «5310200 – Elektr energetikasi» va «5140900 – Kasb ta’limi (5310200 - elektr energetika)» ta’lim yo‘nalishi talabalari uchun mo‘ljallangan bo‘lib, keltirilgan kurs ishining tarkibi va bajarish tartibi mazkur fanning namunaviy dasturiga muvofiq keladi.

Abu Rayhon Beruniy nomidagi Toshkent davlat texnika universiteti ilmiy-uslubiy kengashi qaroriga muvofiq chop etildi.

Taqrizchilar:

Xamidov Sh. V. – Koordinatsion dispetcherlik markazi yetakchi mutaxassisi, t.f.n., dotsent;
Taslimov A. D. – ToshDTU «Elektr ta’minoti» kafedrasi mudiri, t.f.n., dotsent.

Toshkent davlat texnika universiteti,2016

Kirish

Elektr tarmoqlarida bajariladigan kommutatsiya paytida (sistema elementlarini qo‘shish va o‘chirish), sistemada sodir bo‘ladigan qisqa tutashuvlarni o‘chirishda sistemada kechadigan o‘tkinchi jarayonlarini o‘rganish ularning texnik iqtisodiy ko‘rsatkichlarini baholashda muhim o‘rin tutadi.

Ushbu o‘quv - uslubiy ko‘rsatmalar bakalavriatning «5310200- Elektr energetikasi» va «5111000 - Kasb ta’limi (5310200 - Elektr energetikasi)» ta’lim yo‘nalishlarida tahsil oluvchi talabalar uchun «O‘tkinchi jarayonlar» fanidan kurs ishini bajarishga mo‘ljallangan. Uslubiy ko‘rsatmalar «O‘tkinchi jarayonlar» fanining na’munaviy dasturiga muvofiq keladi.

Kurs ishi ikki qismdan iborat bo‘lib uning birinchi qismida talaba berilgan sistemaning kompleks almashtirish sxemasidan foydalanib sodir bo‘ladigan simmetrik va nosimmetrik qisqa tutashuv uchun simmetrik tashkil etuvchilar usulidan foydalanib, tokning tegishli ketma-ketliklarini aniqlaydi.

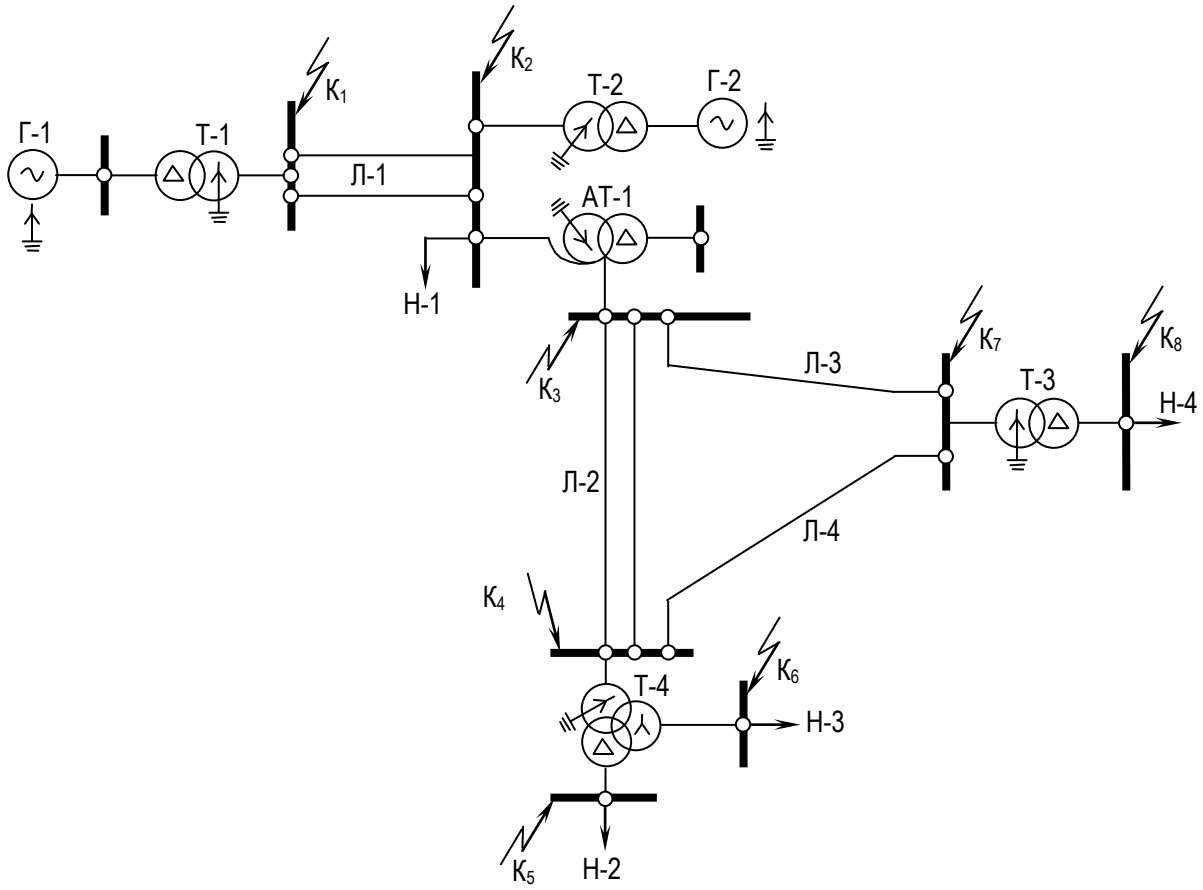
Kurs ishining ikkinchi qismini bajarishda talaba sistemaning asosiy elementlarida kechadigan elektromexanik o‘tish jarayonlarni tahlil qilib, sistemaga uzatiladigan aktiv quvvatning chegaraviy qiymatini aniqlaydi va sistemaning statik va dinamik turg’unligini baholaydi.

Kurs ishi doirasida talaba sistemaning statik va dinamik turg’unligiga tizim avtomatikasining (qo’zg’atishni avtomatik rostlagich (QAR) va avtomatik qayta ulagich (AQU)) ta’sirini baholaydi.

I. «O‘tkinchi jarayonlar» fanidan kurs ishini bajarishga topshiriq

1.1. Kurs ishining birinchi qismini bajarishga oid vazifalar.

Quyidagi 1-rasmda keltirilgan elektr sistemaning prinsipial sxemasini qaraymiz.



1-rasm. O‘tkinchi jarayoni tahlil qilinayotgan elektr uzatishning prinsipial sxemasi.

Bu prinsipial sxemada keltirilgan elektr sistemaning almashtirish sxemasi tuzilib, nuqtalarda tahliliy metod bilan $K^{(3)}$ nuqtasida uch fazali qisqa tutashuv toki davriy tashkil etuvchisining boshlang‘ich qiymatini va uning zarbaviy tokini aniqlang:

a) Transformatorlarning haqiqiy transformatsiya koeffitsiyentlarini hisobga olib yechimni nomlangan birliklarda bajaring;

b) Elektr tizimi uchun $K^{(3)}$ nuqtasida uch fazali qisqa tutashuv toki davriy tashkil etuvchisining boshlang‘ich qiymatini 1-rasmda ko‘rsatilgan sxemadan foydalanib analitik usulda aniqlaymiz. Uch fazali qisqa tutashuvning zarbaviy tokini aniqlaymiz. Almashtirish sxemasidan foydalanib yechimni nisbiy birliklarda bajaring;

v) Elektr tizimi uchun avariya bo‘lgan joydagi $K^{(n)}$ nuqtasida yerga nosimmetrik qisqa tutashuv tokining boshlang‘ich qiymatini keltirilgan sxemadan foydalanib analitik usulda aniqlaymiz;

Berilgan qisqa tutashuv bo‘lgan nuqta uchun toklar va kuchlanishlarning vektor diagrammalari qurilsin. Yuklamalarni hisobga olmasdan almashtirish sxemasidan foydalanib yechimni nomlangan birliklarda bajaring.

Kurs ishini bajarish uchun kerak bo‘lgan ma’lumotlar raqamli to‘plamdan aniqlanadi: 1. – generator va transformatorlar parametrlari;

2. – EUL parametrlari; 3. – yuklamalar parametrlari; 4. Barcha variantlar uchun qabul qiluvchi sistema cheksiz quvvatli sistema deb qabul ($S_{nom.sis} = \infty$, $X_S = 0$)qilinsin.

Induvidual variantlar bo‘yicha elektr uzatish liniyasining parametrlari

1-jadval.

Havo elektr uzatish liniyasining uzunliklari va markalari.

	HEUL	**L-1**	**L-2**	**L-3**	***L-4***
1	Uzunligi, km Markasi	120 2*AC-240	60 2*AC-240	40 AC-185	*40* AC-185
2	Uzunligi, km Markasi	95 2*AC-240	75 2*AC-185	60 AC-240	60 AC-240
3	Uzunligi, km Markasi	160 2*AC-240	50 2*AC-240	40 AC-185	40 AC-185
4	Uzunligi, km Markasi	160 2*AC-300	60 2*AC-185	35 AC-240	35 AC-240
5	Uzunligi, km Markasi	120 2*AC-240	65 2*AC-185	50 AC-240	50 AC-240
6	Uzunligi, km Markasi	140 2*AC-240	70 2*AC-185	60 AC-240	*60* AC-240

2-jadval.

Generatorlar va transformatorlar parametrlari.

1	T1	3*ТДЦ-125000/220	**2**	T1	2*ТДЦ-200000/220
	Г1	3*СВ-835/180-36		Г1	2*СВ-1430/175-72
	T2	4*ТДЦ-400000/220		АТ 1	2*АТДЦТН-200000/220/110
	Г2	4*ТГВ-300		Г2	3*ТГВ-300

	AT1	2*АТДЦТН-250000/220/110		T2	3*ТДЦ-400000/220
	T3	2*ТДЦН-80000/110		T3	2*ТРДН-40000/110
	T4	ТДТН-80000/110		T4	ТДТН-80000/110
3	T1	4*ТДЦ-125000/220	**4**	T1	2*ТД-80000/220
	Г1	4*СВ-835/180-36		Г1	2*СВ-395/250-12
	Г2	4*ТВВ-200-2		AT1	2*АТДЦТН-63000/220/110
	T2	4*ТДЦ-250000/220		Г2	3*ТГВ-300
	AT1	2*АТДЦТН-200000/220/110		T2	3*ТДЦ-400000/220
	T3	2*ТДН-63000/110		T3	ТДН-63000/110
	T4	2*ТДТН-63000/110		T4	ТДТН-80000/110
5	T1	2*ТДЦ-200000/220	**6**	T1	2*ТЦ-160000/220
	Г1	2*СВФ-1500/130-88		Г1	2*СВ-1500/200-88
	AT1	2*АТДЦТН-200000/220/110		AT1	2*АТДЦТН-200000/220/110
	Г2	4*ТВВ-320-2ЕУ3		Г2	3* ТВВ-320-2ЕУ3
	T2	4*ТДЦ-400000/220		T2	3*ТДЦ-400000/220
	T3	2*ТДН-63000/110		T3	2*ТДН-63000/110
	T4	ТДТН-80000/110		T4	2*ТДТН-80000/110

3-jadval.

Yuklamalarning parametrlari.

VARIANTLAR		P (MVT)	Cos(j)	Po (MVt)	tkz	t apv			P (MVT)	Cos(j)	Po (MVt)	t kz	t apv
1	Y1	500	0,85	200			**2**	Y1	700	0,83	150		
	Y2	40	0,9		0,25	0,3		Y2	25	0,8		0,25	0,3
	Y3	30	0,85					Y3	30	0,88			
	Y4	120	0,88					Y4	60	0,85			
3	Y1	600	0,8	220			**4**	Y1	600	0,87	100		
	Y2	50	0,85		0,25	0,3		Y2	30	0,9		0,25	0,3
	Y3	60	0,83					Y3	30	0,8			
	Y4	90	0,85					Y4	50	0,9			
5	Y1	700	0,85				**6**	Y1	800	0,88			

	Y2	35	0,9	250	0,25	0,3		Y2	65	0,9	200	0,25	0,3
	Y3	30	0,89					Y3	70	0,9			
	Y4	80	0,85					Y4	110	0,86			

Eslatma:

1) Generatorlar G-1 va transformatorlar T-1 o‘rniga quvvati uch marta ko‘paytirilgan ekvivalent - bitta generator va transformatorga almashtiramiz

2) Generatorlar G-2 va transformatorlar T-2 o‘rniga quvvati to’rt marta ko’paytirilgan ekvivalent bitta generator va transformatorga almashtiramiz.

3) Ikkta transformatorlar AT-1 o‘rniga quvvati ikki marta ko‘paytirilgan ekvivalent - bitta transformatorga almashtiramiz.

4) Ikkita transformatorlar T-3 o‘rniga quvvati ikki marta ko‘paytirilgan ekvivalent - bitta transformatorga almashtiramiz

Sxema elementlarining texnik parametrlari

4-jadval.

1. Generatorlar katalog parametrlari.

	Generatorlar turlari	Nomin. quvvati		Un, kV	Cos φ	Generator qarshiliklari *					Soni
		Tuliq MVA	Aktiv MVt			X’’d	X’d	Xd	Xq	X_2	
1-G.	CB-850/190-40	100	90	10,5	0,9	0,19	0,27	0,75	0,46	0,3	3
2-G.	ТГВ-200	235,3	200	18	0,8	0,185	0,297	1,896	1,896	0,226	4

5-jadval.

2.Transformatorlar katalog parametrlari.

	Transformatorlar turlari	Sн, MVA	Chulg‘amning kuchlanishi, kV			Uк, %			Soni
			BH	CH	HH	B-C	B-H	C-H	
1-T	ТДЦ-125000/220	125	242	-	10,5	-	11	-	3

2-T	ТДЦ-250000/220	250	242	-	18	-	11	-	4
3-T	ТД-63000/110	63	115	-	38,5	-	10,5	-	2
4-T	ТДТН-80000/110	80	115	38,5	11	11	18,5	7	1
AT	АТДЦТН-200000/220/110	200	230	121	6,6	11	32	20	2

6-jadval.

3. Havo uzatish liniyalari (HEUL) katalog parametrlari.

	EUL parametrlari	L-1	L-2	L-3	L-4
1.	Kuchlanishi, kV	220	110	110	110
2.	Liniya markasi	AC-240	AC-185	AC-240	AC-240
3.	Uzunligi, km	210	70	60	60
4.	Solishtirma qarshiligi, Om/km	0,435	0,413	0,405	0,405

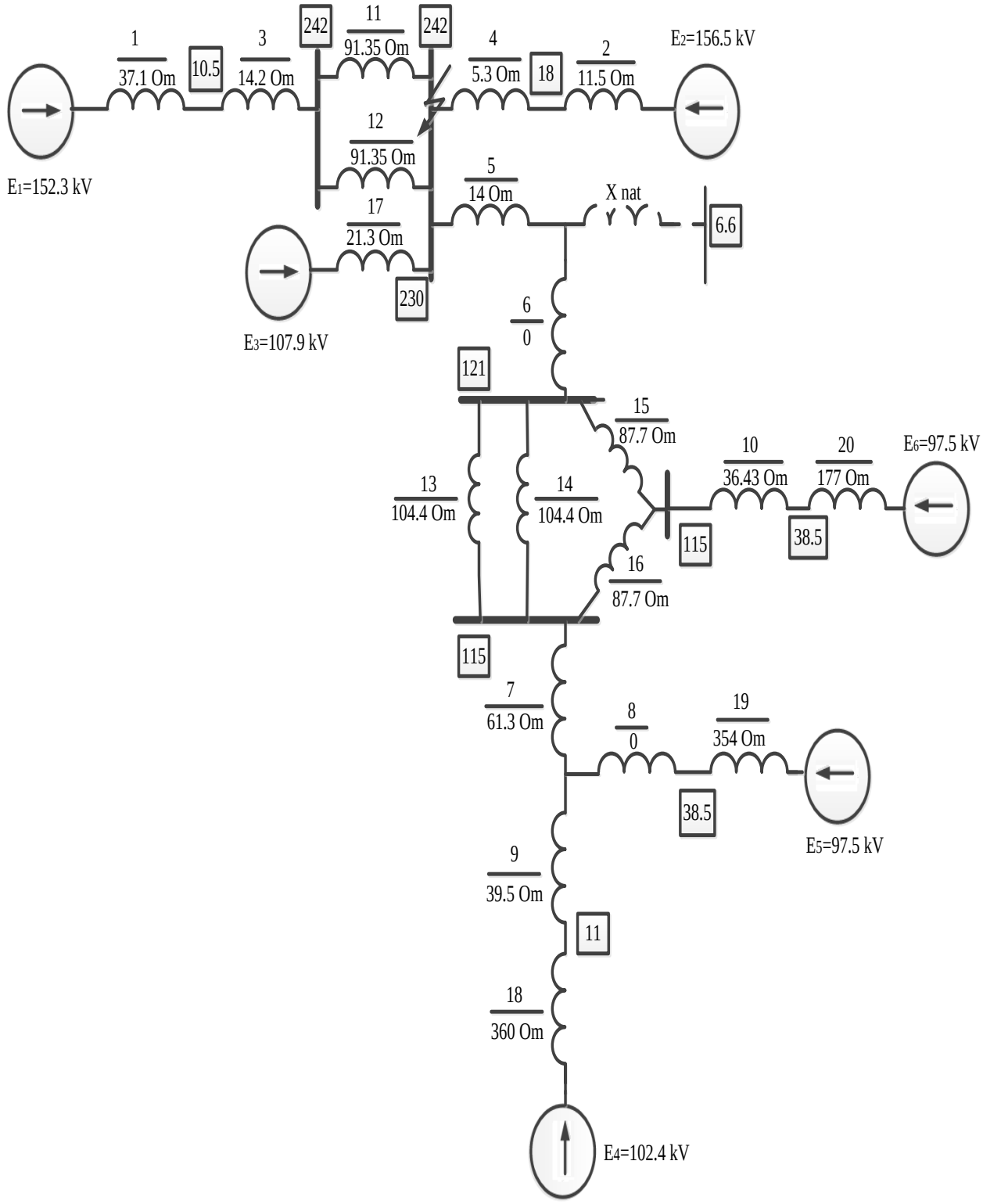
7-jadval.

4.Yuklamalarning aktiv quvvati va quvvat koeffitsiyentlari.

	Yuklamalar parametrlari	Y-1	Y-2	Y-3	Y-4
1.	Aktiv quvvati, MVt	700	35	35	70
2.	Cosφ	0,88	0,83	0,9	0,9
3.	Tuliq quvvati, MVA	795,5	42,2	38,9	77,8

I. Transformatorlarning haqiqiy transformatsiya koeffitsiyentlarini hisobga olib uch fazali qisqa tutashuvni analitik usulda nomlangan birliklarda hisoblash uchun:

1) Hisoblash ishlarni bajarish uchun hisobiy sxema orqali almashtirish sxemani tuzamiz (2-rasm).



2-rasm. Rejimi hisoblanayotgan elektr tarmog‘ining prinsipial sxemasiga mos keluvchi hisobiy almashtirish sxemasi

Eslatma: To‘rtburchak ichidagi sonlar transformatorlarning transformatsiya koeffitsiyentini anglatadi

2) Generatorlar va yuklamalar EYUKsini aniqlaymiz

$$G-1\begin{cases} E_{1*}=\sqrt{\cos^2\varphi+(\sin\varphi+x_d^{''})^2}=\sqrt{0{,}9^2+(0{,}435+0{,}19)^2}=1{,}19* \\ E_{1(кВ)}=E_{1*}\cdot\dfrac{U_{G-1}}{\sqrt{3}}\cdot K_T=1{,}19\cdot\dfrac{10.5}{\sqrt{3}}\cdot\dfrac{242}{10.5}=152{,}3кВ \end{cases}$$

$$G-2\begin{cases} E_{2*}=\sqrt{\cos^2\varphi+(\sin\varphi+x_d^{''})^2}=\sqrt{0{,}8^2+(0{,}6+0{,}185)^2}=1{,}12* \\ E_{2(кВ)}=E_{2*}\cdot\dfrac{U_{G-2}}{\sqrt{3}}\cdot K_T=1{,}12\cdot\dfrac{18}{\sqrt{3}}\cdot\dfrac{242}{18}=156{,}5кВ \end{cases}$$

$$Y-1\quad E_3=E_{*наг}\cdot\frac{U_н}{\sqrt{3}}K_T=0{,}85\cdot\frac{220}{\sqrt{3}}\cdot 1=107{,}9kV$$

$$Y-2\quad E_4=E_{*наг}\cdot\frac{U_н}{\sqrt{3}}K_T=0{,}85\cdot\frac{10{,}5}{\sqrt{3}}\cdot\frac{230}{121}\cdot\frac{115}{11}=102{,}4\ kV$$

$$Y-3\quad E_5=E_{*наг}\cdot\frac{U_н}{\sqrt{3}}K_T=0{,}85\cdot\frac{35}{\sqrt{3}}\cdot\frac{230}{121}\cdot\frac{115}{38{,}5}=97{,}5\ kV$$

$$Y-4\quad E_6=E_{*наг}\cdot\frac{U_н}{\sqrt{3}}K_T=0{,}85\cdot\frac{35}{\sqrt{3}}\cdot\frac{230}{121}\cdot\frac{115}{38{,}5}=97{,}5\ kV$$

3) Sinxron generatorlarning qarshiligini aniqlaymiz:

$$\text{G}-1\quad x_1=\frac{1}{3}\cdot x_d^{''}\cdot\frac{U_н^2}{S_н}\cdot k_T^2=\frac{1}{3}\cdot 0{,}19\cdot\frac{10{,}5^2}{100}\cdot\left(\frac{242}{10{,}5}\right)^2=37{,}1\quad Om$$

$$\text{G}-2\quad x_2=\frac{1}{4}\cdot x_d^{''}\cdot\frac{U_н^2}{S_н}\cdot k_T^2=\frac{1}{4}\cdot 0{,}185\cdot\frac{18^2}{235{,}3}\cdot\left(\frac{242}{18}\right)^2=11{,}5\ Ом$$

4) Kuch transformatorlarining qarshiligini aniqlaymiz

T – 1 transformator qarshiligini aniqlaymiz

$$x_3=\frac{1}{3}\cdot\frac{U_к\%}{100}\cdot\frac{U_н^2}{S_н}\cdot k_T^2=\frac{1}{3}\cdot\frac{11\%}{100}\cdot\frac{220^2}{125}\cdot 1=14{,}2\ Om$$

T – 2 transformator qarshiligini aniqlaymiz

$$x_4=\frac{1}{4}\cdot\frac{U_к\%}{100}\cdot\frac{U_н^2}{S_н}\cdot k_T^2=\frac{1}{4}\cdot\frac{11\%}{100}\cdot\frac{220^2}{250}\cdot 1=5{,}3\ Om$$

AT – 1 avtotransformatorning qisqa tutashuv kuchlanishini 3 ta chulg‘am uchun aniqlaymiz

$$U_{кв}=0{,}5\cdot(U_{кв-с}+U_{кв-н}-U_{кс-н})=0{,}5\cdot(11+32-20)=11{,}5\ \%$$

$$U_{кс} = 0{,}5 \cdot (U_{кв-с} + U_{кс-н} - U_{кв-н}) = 0{,}5 \cdot (11 + 20 - 32) \equiv 0$$

$$U_{кн} = 0{,}5 \cdot (U_{кв-н} + U_{кс-н} - U_{кв-с}) = 0{,}5 \cdot (32 + 20 - 11) = 20{,}5\ \%$$

AT – 1 avtotransformator qarshiliklarini aniqlaymiz

$$x_5 = \frac{1}{2} \cdot \frac{U_{кв}\%}{100} \cdot \frac{U_н^2}{S_н} \cdot k_T^2 = \frac{1}{2} \cdot \frac{11{,}5\%}{100} \cdot \frac{220^2}{200} \cdot 1 = 14\ Om$$

x6=0, Uks=0

$$x_н = \frac{1}{2} \cdot \frac{U_{кн}\%}{100} \cdot \frac{U_н^2}{S_н} \cdot k_T^2 = \frac{1}{2} \cdot \frac{20{,}5\%}{100} \cdot \frac{220^2}{200} \cdot 1 = 24{,}8\ Om$$ - (uch fazali qisqa tutashuv hisoblashda qatnashmaydi)

Transformator T-4 uchun qisqa tutashuv kuchlanishini 3 ta chulg‘am uchun aniqlaymiz

$$U_{кв} = 0{,}5 \cdot (U_{кв-с} + U_{кв-н} - U_{кс-н}) = 0{,}5 \cdot (11 + 18{,}5 - 7) = 11{,}25\ \%$$

$$U_{кс} = 0{,}5 \cdot (U_{кв-с} + U_{кс-н} - U_{кв-н}) = 0{,}5 \cdot (11 + 7 - 18{,}5) \equiv 0$$

$$U_{кн} = 0{,}5 \cdot (U_{кв-н} + U_{кс-н} - U_{кв-с}) = 0{,}5 \cdot (18{,}5 + 7 - 11) = 7{,}25\ \%$$

T – 4 transformator qarshiliklarini aniqlaymiz

$$x_7 = \frac{U_{кв}\%}{100} \cdot \frac{U_н^2}{S_н} \cdot k_T^2 = \frac{11{,}25\%}{100} \cdot \frac{110^2}{80} \cdot \left(\frac{230}{121}\right)^2 = 61{,}3\ Om$$

x8=0, Uks=0

$$x_9 = \frac{U_{кн}\%}{100} \cdot \frac{U_н^2}{S_н} \cdot k_T^2 = \frac{7{,}25\%}{100} \cdot \frac{110^2}{80} \cdot \left(\frac{230}{121}\right)^2 = 39{,}5\ Om$$

T – 3 transformator qarshiligini aniqlaymiz

$$x_{10} = \frac{1}{2} \cdot \frac{U_к\%}{100} \cdot \frac{U_н^2}{S_н} \cdot k_T^2 = \frac{1}{2} \cdot \frac{10{,}5\%}{100} \cdot \frac{110^2}{63} \cdot \left(\frac{230}{121}\right)^2 = 36{,}4\ Om$$

5) Xavo liniyalar qarshiligini aniqlaymiz

L – 1 $x_{11} = x_{12} = x_0 \cdot l \cdot k_T^2 = 0{,}435 \cdot 210 \cdot 1 = 91{,}35\ Om$

L – 2 $x_{13} = x_{14} = x_0 \cdot l \cdot k_T^2 = 0{,}413 \cdot 70 \cdot \left(\frac{230}{121}\right)^2 = 104{,}4\ Om$

L – 3; L – 4 $x_{15} = x_{16} = x_0 \cdot l \cdot k_T^2 = 0{,}405 \cdot 60 \cdot \left(\frac{230}{121}\right)^2 = 87{,}7\ Om$

6) Yuklamalar qarshiligini aniqlaymiz

Y – 1 $x_{17} = x_{*наг} \cdot \frac{U_н^2}{S_н} \cdot k_T^2 = 0{,}35 \cdot \frac{220^2}{795{,}5} \cdot 1 = 21{,}3\ Om$

Y – 2 $x_{18} = x_{*наг} \cdot \frac{U_н^2}{S_н} \cdot k_T^2 = 0{,}35 \cdot \frac{10{,}5^2}{42{,}2} \cdot \left(\frac{230}{121}\right)^2 \cdot \left(\frac{115}{11}\right)^2 = 360\ Om$

Y – 3 $x_{19} = x_{*наг} \cdot \frac{U_н^2}{S_н} \cdot k_T^2 = 0{,}35 \cdot \frac{35^2}{38{,}9} \cdot \left(\frac{230}{121}\right)^2 \cdot \left(\frac{115}{38{,}5}\right)^2 = 354\ Om$

Y – 4 $x_{20} = x_{*наг} \cdot \frac{U_н^2}{S_н} \cdot k_T^2 = 0{,}35 \cdot \frac{35^2}{77{,}8} \cdot \left(\frac{230}{121}\right)^2 \cdot \left(\frac{115}{38{,}5}\right)^2 = 177\ Om$

Almashtirish sxemasini qarshiliklarning ketma ket va parallel ulanishini hisobga olib soddalashtiramiz (3-rasm).

$$x_{21} = x_1 + x_3 + \frac{x_{11} \cdot x_{12}}{x_{11} + x_{12}} = 37{,}1 + 14{,}2 + \frac{91{,}35}{2} = 97\ Om$$

$$x_{22} = x_2 + x_4 = 11{,}5 + 5{,}3 = 16{,}8\ Om$$

$$x_{23} = x_5 + x_6 = 14 + 0 = 14\ Om$$

$$x_{24} = \frac{x_{13} \cdot x_{14}}{x_{13} + x_{14}} = \frac{104{,}4}{2} = 52{,}2\ Om$$

$$x_{25} = x_{10} + x_{20} = 36{,}4 + 177 = 213{,}4\ Om$$

$$x_{26} = x_8 + x_{19} = 354 + 0 = 354\ Om$$

$$x_{27} = x_9 + x_{18} = 39{,}5 + 360 = 399{,}5\ Om$$

$$x_{28} = \frac{x_{26} \cdot x_{27}}{x_{26} + x_{27}} = \frac{354 \cdot 399{,}5}{753{,}5} = 187{,}7\ Om$$

E4 va E5 EYuKlar o‘rnini ekvivalent Ee1 EYuK bilan almashtiramiz

$$E_{э1} = \frac{E_4 \cdot x_{26} + E_5 \cdot x_{27}}{x_{26} + x_{27}} = \frac{102{,}4 \cdot 354 + 97{,}5 \cdot 399{,}5}{354 + 399{,}5} = 100\ kV$$

(x15, x16, x24) qarshiliklarni Δ dan (x29, x30, x31) Y qarshiliklarga o‘tkazamiz

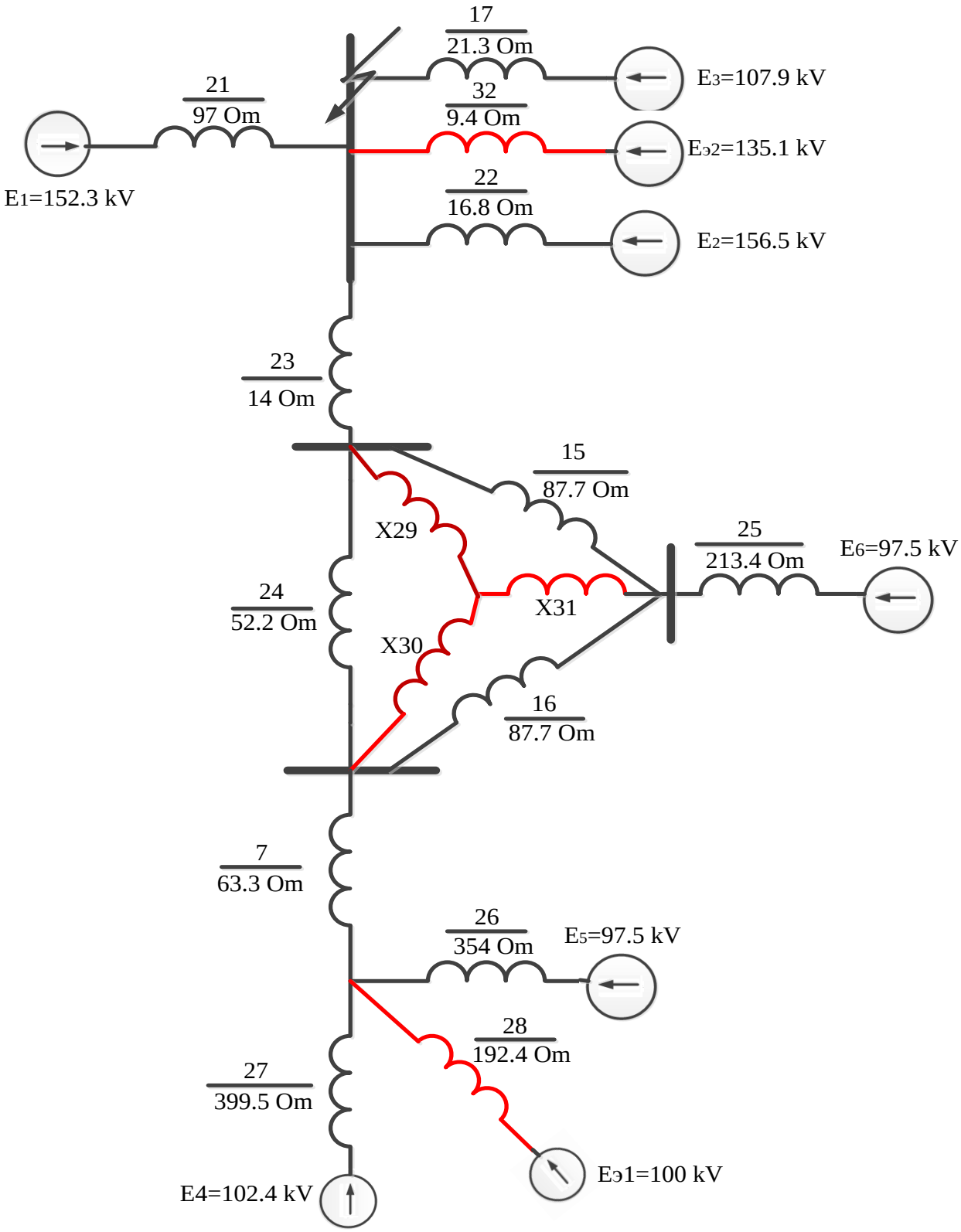
$$x_{29} = x_{30} = \frac{x_{15} \cdot x_{24}}{x_{15} + x_{16} + x_{24}} = \frac{87{,}7 \cdot 52{,}2}{227{,}6} = 20{,}1\ Om$$

$$x_{31} = \frac{x_{15} \cdot x_{16}}{x_{15} + x_{16} + x_{24}} = \frac{87{,}7 \cdot 87{,}7}{227{,}6} = 33{,}8\ Om$$

$$x_{32} = \frac{x_{17} \cdot x_{22}}{x_{17} + x_{22}} = \frac{21{,}3 \cdot 16{,}8}{38{,}1} = 9{,}4\ Om$$

E2 va E3 EYuKlar o‘rnini ekvivalent Ee2 EYuK bilan almashtiramiz

$$E_{э2} = \frac{E_2 \cdot x_{17} + E_3 \cdot x_{22}}{x_{17} + x_{22}} = \frac{156{,}5 \cdot 21{,}3 + 107{,}9 \cdot 16{,}8}{38{,}1} = 135{,}1\ kV$$



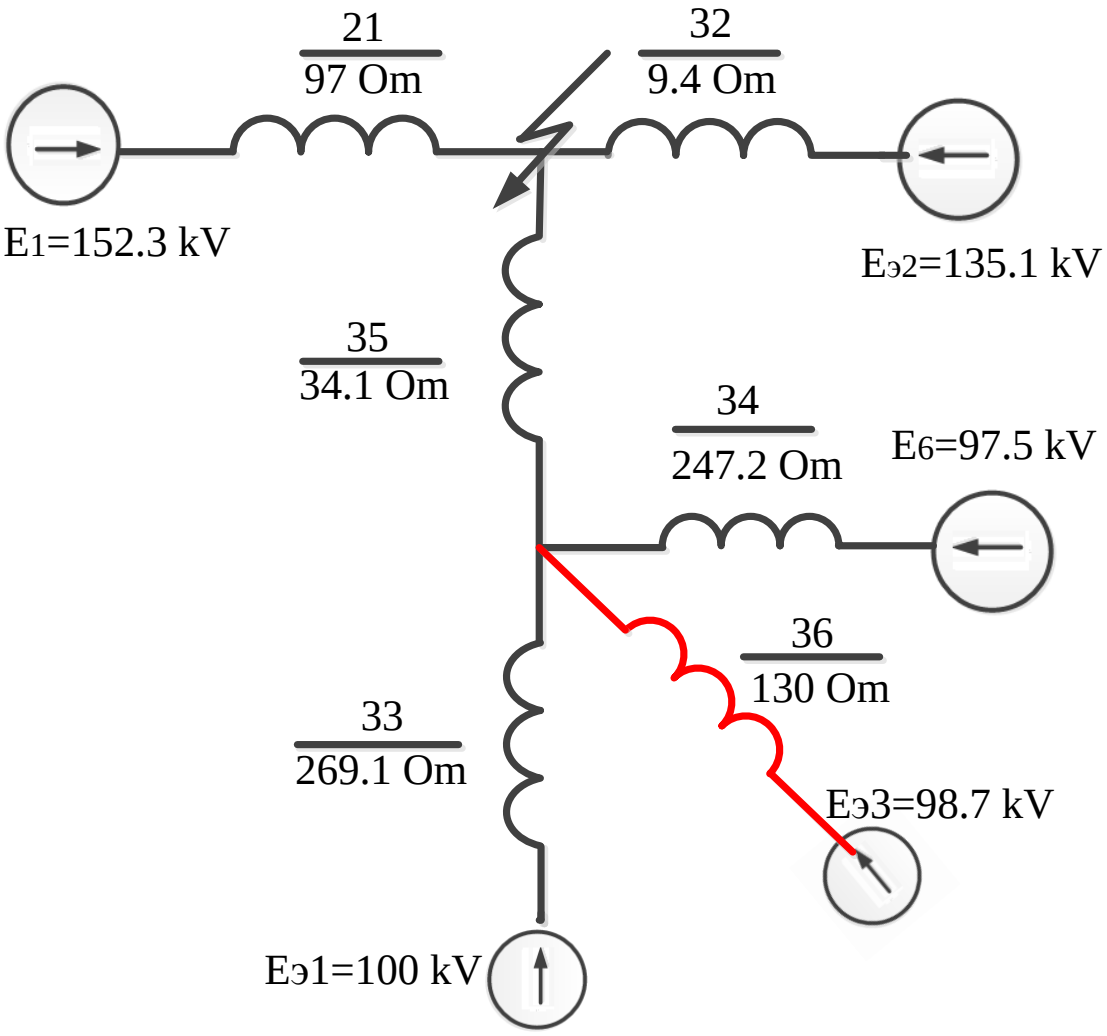
3-rasm. Sistemaning parallel va ketma-ket ulangan shaxobchalaridagi qarshiliklarni ixchamlashtirish natijasida olingan soddalashtirilgan almashtirish sxemasi.

$$x_{33} = x_{28} + x_7 + x_{30} = 187,7 + 61,3 + 20,1 = 269,1 \ Om$$

$$x_{34} = x_{25} + x_{31} = 213,4 + 33,8 = 247,2 \ Om$$

$$x_{35} = x_{29} + x_{23} = 20,1 + 14 = 34,1 \ Om$$

Almashtirish sxemasi quyidagi ko‘rinishga keldi (4-rasm).



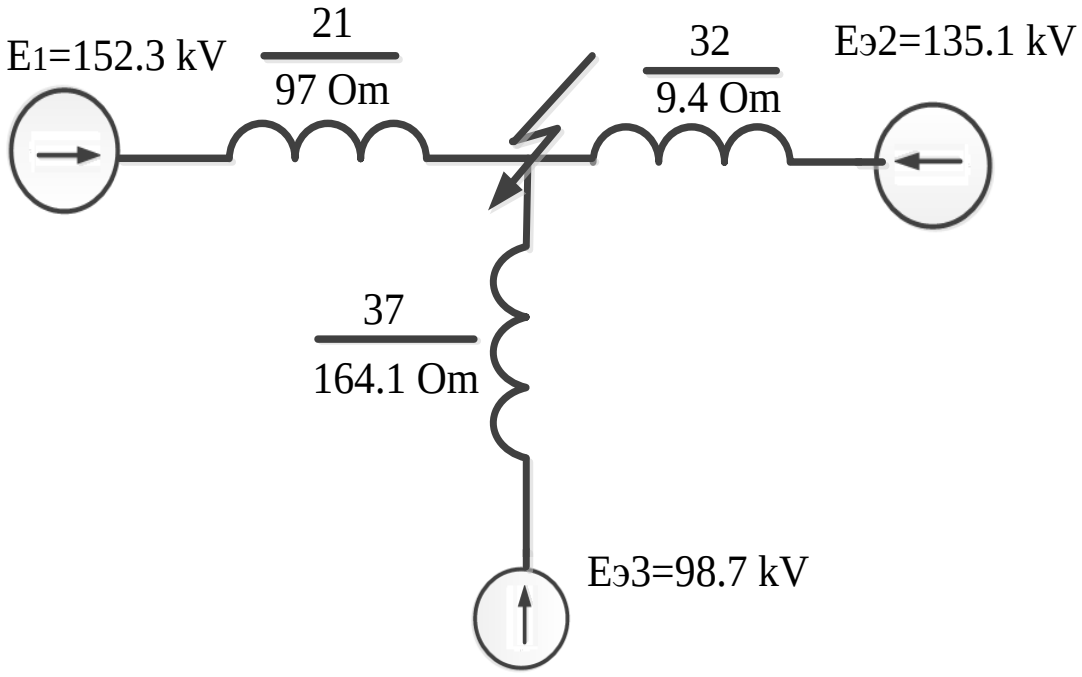
4-rasm. Ee1 va E6 EYuKlar o‘rnini ekvivalent Ee3 EYuK bilan almashtirganimizdagi almashtirish sxemasi.

$$E_{э3} = \frac{E_{э1} \cdot x_{34} + E_6 \cdot x_{33}}{x_{33} + x_{34}} = \frac{100 \cdot 247,2 + 97,5 \cdot 269,1}{516,3} = 98,7 \ kV$$

$$x_{36} = \frac{x_{33} \cdot x_{34}}{x_{33} + x_{34}} = \frac{269,1 \cdot 247,2}{516,3} = 130 \ Om$$

$$x_{37} = x_{36} + x_{35} = 130 + 34,1 = 164,1 \ Om$$

Almashtirish sxemasi avvalgi holatga nisbatan soddalashdi.



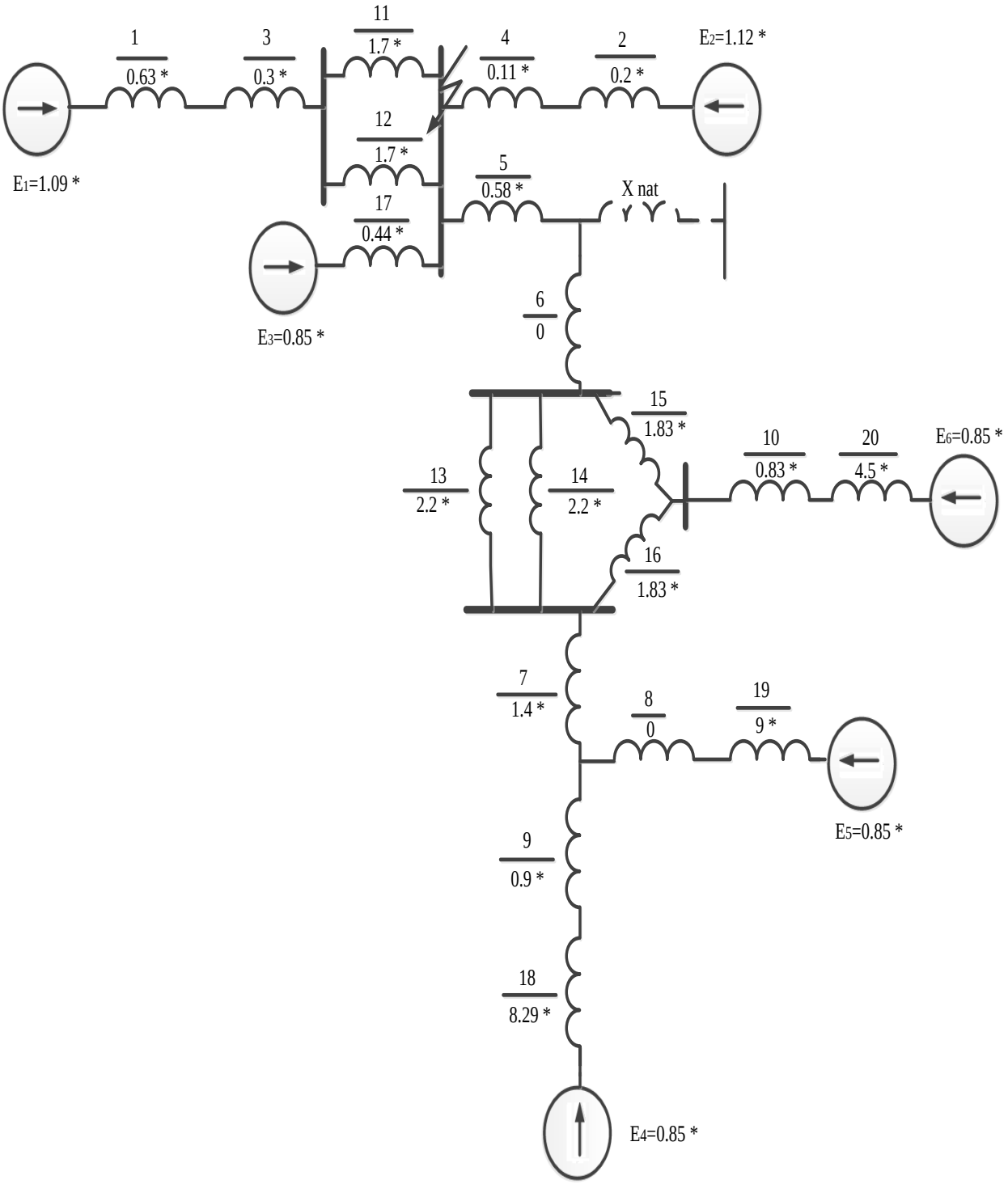
5-rasm. X_{35} va X_{36} larni ekvivalent X_{37} ga almashtirganimizdan keyingi almashtirish sxemasi.

Uch fazali qisqa tutashuv tokini aniqlaymiz

$$I_{к\Sigma}^{(3)} = \frac{E_1}{x_{21}} + \frac{E_{э2}}{x_{32}} + \frac{E_{э3}}{x_{37}} = \frac{152,3}{97} + \frac{135,1}{9,4} + \frac{98,7}{164,1} = 16,53\ kA$$

II. O‘rta kuchlanishlarni hisobga olgan holda nisbiy birliklarda uch fazali qisqa tutashuv toklarini analitik usulni qo‘llab hisoblaymiz:

1) Sistemaning berilgan chiziqli sxema asosida almashtirish sxemasini tuzamiz (6-rasm).



6-rasm. Sistemaning chiziqli sxemasidan olingan almashtirish sxemasi.

Hisoblash ishlarini bajarish uchun tegishli bazis shartlarini tanlaymiz:

Sbaz = 1000 MVA; Ubaz = Uo'r = 230 kV

Bazis tok:

$$I_{баз} = \frac{S_{баз}}{\sqrt{3}U_{б}} = \frac{1000}{\sqrt{3}\cdot 230} = 2{,}51\ \ кА$$

Eslatma: Generatorlar va yuklamalar EYuKlarini avvalgi hisoblardan olamiz

2) Generatorlar qarshiliklarini aniqlaymiz

G – 1 $$x_1 = \frac{1}{3}\cdot x_d^{''}\cdot\frac{S_{б}}{S_{н}} = \frac{1}{3}\cdot 0{,}19\cdot\frac{1000}{100} = 0{,}6_{*}$$

G – 2 $$x_2 = \frac{1}{4}\cdot x_d^{''}\cdot\frac{S_{б}}{S_{н}} = \frac{1}{4}\cdot 0{,}185\cdot\frac{1000}{235{,}3} = 0{,}2_{*}$$

3) Transformatorlar qarshiliklarini aniqlaymiz

T – 1 transformator qarshiligini aniqlaymiz

$$x_3 = \frac{1}{3}\cdot\frac{U_{к}\%}{100}\cdot\frac{S_{б}}{S_{н}} = \frac{1}{3}\cdot\frac{11\%}{100}\cdot\frac{1000}{125} = 0{,}3_{*}$$

T – 4 transformator qarshiligini aniqlaymiz

$$x_4 = \frac{1}{4}\cdot\frac{U_{к}\%}{100} = \frac{1}{4}\cdot\frac{11\%}{100}\cdot\frac{1000}{250} = 0{,}11_{*}$$

AT – 1 avtotransformator qarshiliklarini aniqlaymiz

$$x_5 = \frac{1}{2}\cdot\frac{U_{кв}\%}{100}\cdot\frac{S_{б}}{S_{н}} = \frac{1}{2}\cdot\frac{11{,}5\%}{100}\cdot\frac{1000}{200} = 0{,}58_{*}$$

x6=0, Uks=0

T – 2 transformator qarshiliklarini aniqlaymiz

$$x_7 = \frac{U_{кв}\%}{100}\cdot\frac{S_{б}}{S_{н}} = \frac{11{,}5\%}{100}\cdot\frac{1000}{80} = 1{,}4_{*}$$

x8=0, Uks=0

$$x_9 = \frac{U_{кн}\%}{100}\cdot\frac{S_{б}}{S_{н}} = \frac{7{,}25\%}{100}\cdot\frac{1000}{80} = 0{,}9_{*}$$

T – 3 transformator qarshiligini aniqlaymiz

$$x_{10} = \frac{1}{2}\cdot\frac{U_{к}\%}{100}\cdot\frac{S_{б}}{S_{н}} = \frac{1}{2}\cdot\frac{10{,}5\%}{100}\cdot\frac{1000}{63} = 0{,}83_{*}$$

4) Havo uzatish liniyalar qarshiliklarini aniqlaymiz

L – 1 $$x_{11} = x_{12} = x_0\cdot l\cdot\frac{S_{б}}{U_{ср}^2} = 0{,}435\cdot 210\cdot\frac{1000}{230^2} = 1{,}7_{*}$$

L – 2 $x_{13} = x_{14} = x_0 \cdot l \cdot \frac{S_б}{U_{ср}^2} = 0{,}413 \cdot 70 \cdot \frac{1000}{115^2} = 2{,}2_*$

L – 3; L – 4 $x_{15} = x_{16} = x_0 \cdot l \cdot \frac{S_б}{U_{ср}^2} = 0{,}405 \cdot 60 \cdot \frac{1000}{115^2} = 1{,}83_*$

5) Yuklamalar qarshiliklarini aniqlaymiz

Y – 1 $x_{17} = x_{*наг} \cdot \frac{S_б}{S_н} = 0{,}35 \cdot \frac{1000}{795{,}5} \cdot 1 = 0{,}44_*$

Y – 2 $x_{18} = x_{*наг} \cdot \frac{S_б}{S_н} = 0{,}35 \cdot \frac{1000}{42{,}2} = 8{,}29_*$

Y – 3 $x_{19} = x_{*наг} \cdot \frac{S_б}{S_н} = 0{,}35 \cdot \frac{1000}{38{,}9} = 9_*$

Y – 4 $x_{20} = x_{*наг} \cdot \frac{S_б}{S_н} = 0{,}35 \cdot \frac{1000}{77{,}8} = 4{,}5_*$

6) Almashtirish sxemasini soddalashtiramiz (7-rasm)

$x_{21} = x_1 + x_3 + \frac{x_{11} \cdot x_{12}}{x_{11} + x_{12}} = 0{,}6 + 0{,}3 + \frac{1{,}7}{2} = 1{,}7*$

$x_{22} = x_2 + x_4 = 0{,}2 + 0{,}11 = 0{,}31*$

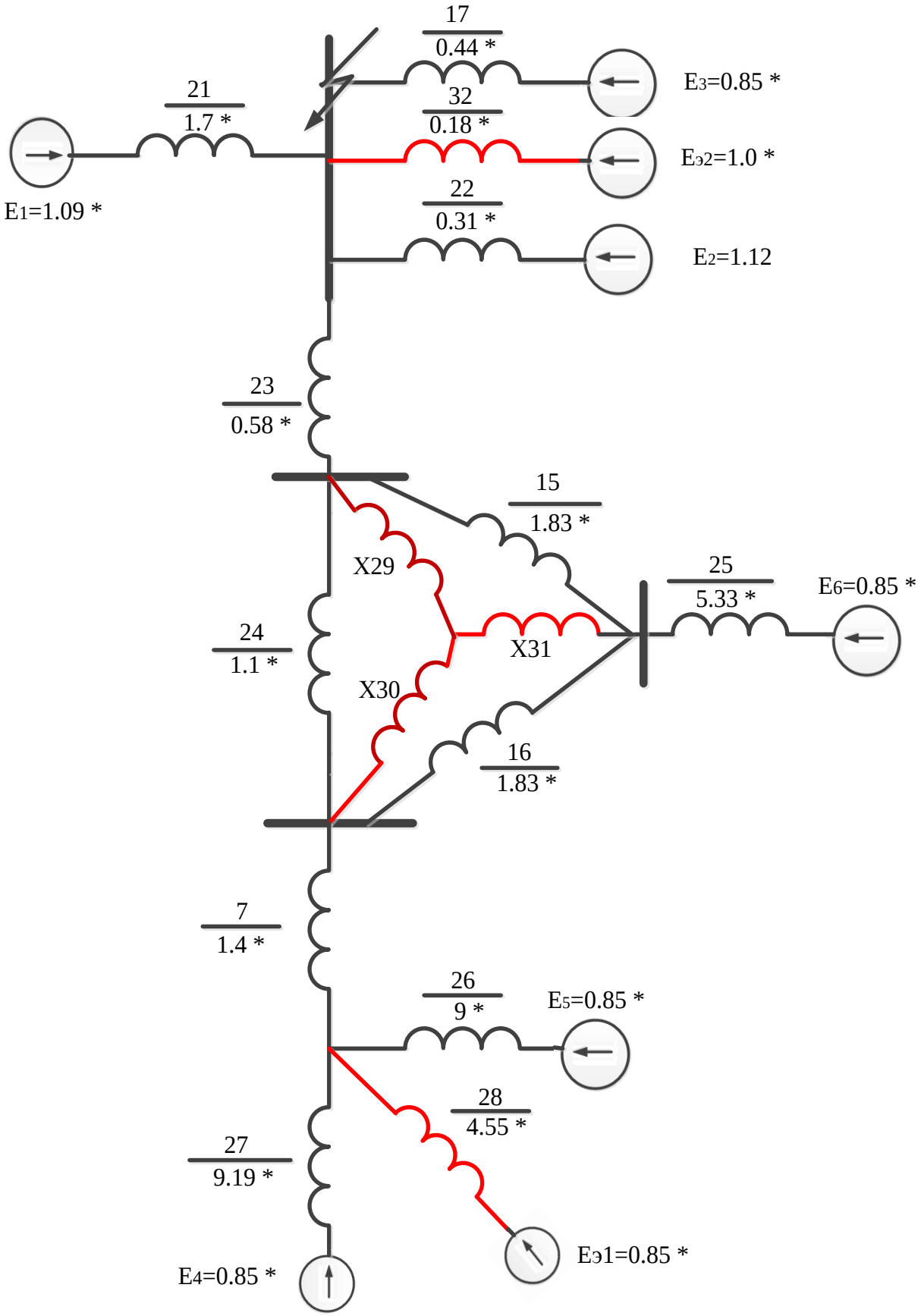
$x_{23} = x_5 + x_6 = 0{,}58 + 0 = 0{,}58*$

$x_{24} = \frac{x_{13} \cdot x_{14}}{x_{13} + x_{14}} = \frac{2{,}2}{2} = 1{,}1*$

$x_{25} = x_{10} + x_{20} = 0{,}83 + 4{,}5 = 5{,}33_*$

$x_{26} = x_8 + x_{19} = 0 + 9 = 9_*$

$x_{27} = x_9 + x_{18} = 0{,}9 + 8{,}29 = 9{,}19_*$



7-rasm. Sistemaning soddalashtirilgan almashtirish sxemasi

$$x_{28} = \frac{x_{26} \cdot x_{27}}{x_{26} + x_{27}} = \frac{9 \cdot 9{,}19}{18{,}19} = 4{,}55_*$$

E4 va E5 EYuKlar o‘rniga ekvivalent Ee1 EYUK bilan almashtiramiz

$$E_{э1} = \frac{E_4 \cdot x_{26} + E_5 \cdot x_{27}}{x_{26} + x_{27}} = \frac{0{,}85(9 + 9{,}19)}{18{,}19} = 0{,}85_*$$

(x15, x16, x24) qarshiliklarni Δ dan (x29, x30, x31) Y ga o‘tkazamiz

$$x_{29} = x_{30} = \frac{x_{15} \cdot x_{24}}{x_{15} + x_{16} + x_{24}} = \frac{1{,}83 \cdot 1{,}1}{4{,}76} = 0{,}42_*$$

$$x_{31} = \frac{x_{15} \cdot x_{16}}{x_{15} + x_{16} + x_{24}} = \frac{1{,}83 \cdot 1{,}83}{4{,}76} = 0{,}7_*$$

$$x_{32} = \frac{x_{17} \cdot x_{22}}{x_{17} + x_{22}} = \frac{0{,}44 \cdot 0{,}31}{0{,}75} = 0{,}18_*$$

$$x_{33} = x_{28} + x_7 + x_{30} = 4{,}55 + 1{,}4 + 0{,}42 = 6{,}37_*$$

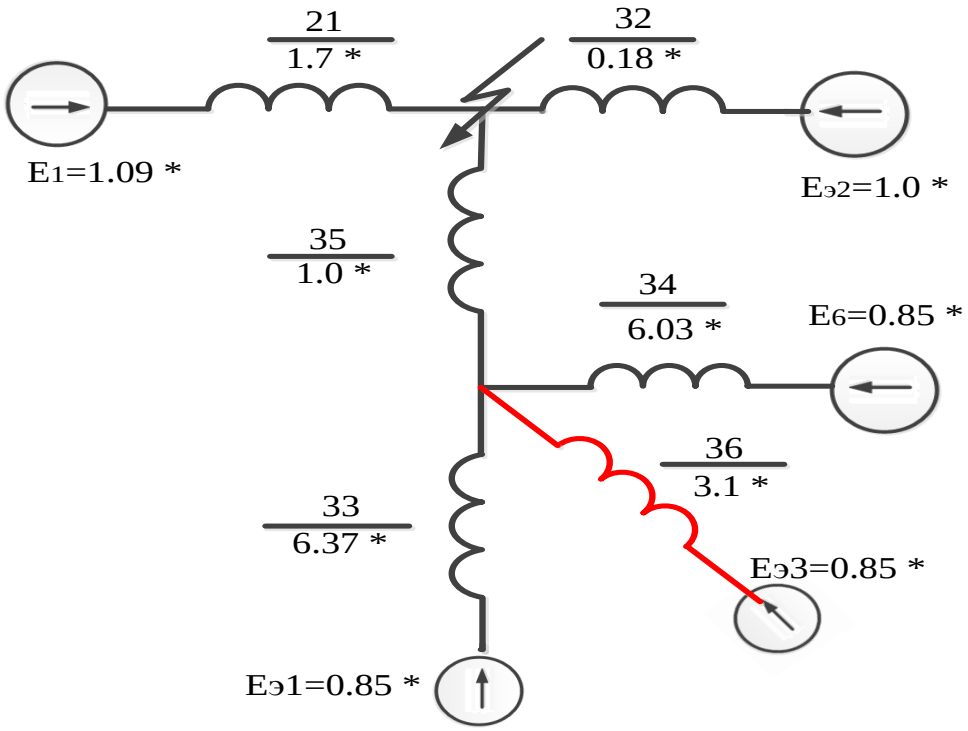
$$x_{34} = x_{25} + x_{31} = 5{,}33 + 0{,}7 = 6{,}03_*$$

$$x_{35} = x_{29} + x_{23} = 0{,}58 + 0{,}42 = 1{,}0_*$$

E2 va E3 EYuKlar o‘rnini ekvivalent Ee2 EYUK bilan almashtiramiz

$$E_{э2} = \frac{E_2 \cdot x_{17} + E_3 \cdot x_{22}}{x_{17} + x_{22}} = \frac{1{,}12 \cdot 0{,}44 + 0{,}85 \cdot 0{,}31}{0{,}75} = 1{,}0_*$$

Almashtirish sxemasi avvalgi holatga nisbatan soddalashdi (8-rasm)



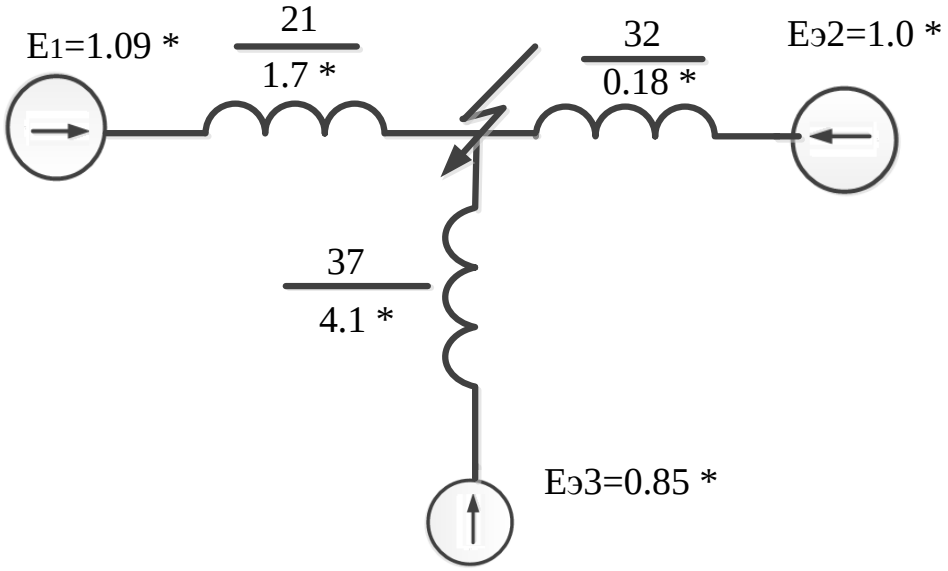
8-rasm. Soddalashtirilgan almashtirish sxemasi

Ee1 va E6 EYuKlar o‘rnini ekvivalent Ee3 EYuK bilan almashtiramiz

$$E_{э3} = \frac{E_{э1} \cdot x_{34} + E_6 \cdot x_{33}}{x_{33} + x_{34}} = \frac{0,85(6,37 + 6,03)}{12,4} = 0,85_*$$

$$x_{36} = \frac{x_{33} \cdot x_{34}}{x_{33} + x_{34}} = \frac{6,37 \cdot 6,03}{12,4} = 3,1_*$$

$$x_{37} = x_{36} + x_{35} = 3,1 + 1,0 = 4,1_*$$



9-rasm. X35 va X36 larni ekvivalent X37 ga almashtirganimizdan keyingi almashtirish sxemasi.

Natijada uch fazali qisqa tutashuv tokini aniqlaymiz

$$I_{к\sum}^{(3)} = \left(\frac{E_1}{x_{21}} + \frac{E_{э2}}{x_{32}} + \frac{E_{э3}}{x_{37}} \right) \cdot I_{б(230)} = \left(\frac{1{,}19}{1{,}7} + \frac{1{,}0}{0{,}18} + \frac{0{,}85}{4{,}1} \right) \cdot 2{,}51 = 16{,}05 \quad kA$$

Ikkita usuli orqali aniqlangan uch fazali qisqa tutashuv toklarining farqi:

$$\delta = \frac{16{,}54 - 16{,}05}{16{,}54} \cdot 100\% = 3\%$$

Uch fazali qisqa tutashuvning zarbaviy toki:

$$i_y^{(3)} = 2{,}55 \cdot I_{к\sum}^{(3)} = 2{,}55 \cdot 16{,}54 = 42{,}17 \quad kA$$

III. $K_3^{(1)}$ nuqtadagi bir fazali nosimmetrik qisqa tutashuvni aniqlash

Eslatma:

1) Hisob – kitob ishlarini o‘rta kuchlanishlarga nisbatan nomli birliklarda amalga oshiramiz;

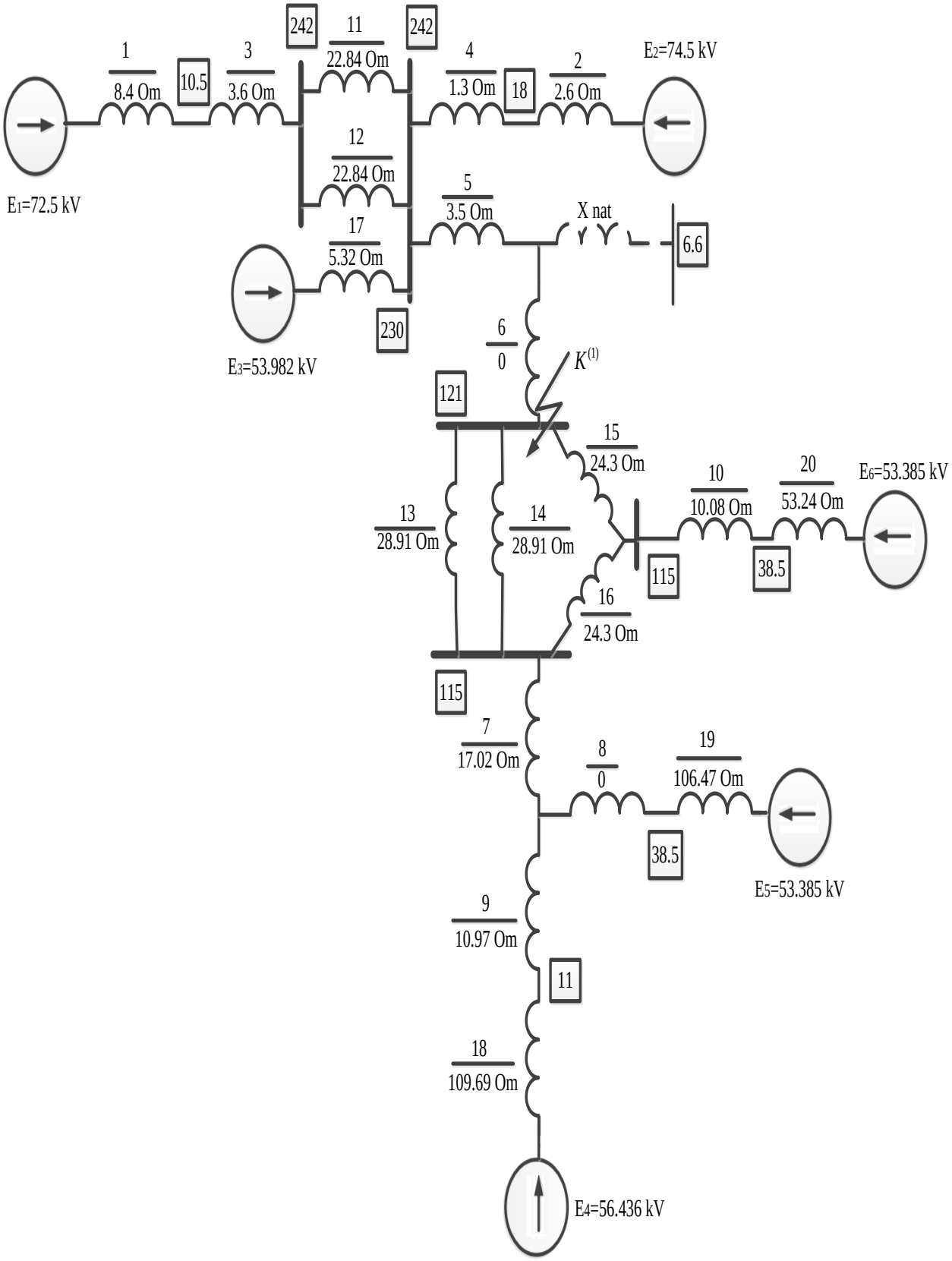
2) Havo uzatish liniyalarida chaqmoqqa qarshi himoya troslari mos koeffitsiyentlar orqali hisobga olinadi;

3) $U_{o'r}$ –tizim elementlar ulangan pog‘onaning o‘rtacha kuchlanishi;

$U_{o'r\ as}$ – nosimmetrik qisqa tutashuv sodir bo‘lgan pog‘onaning o‘rtacha kuchlanishi;

4) L-1 havo uzatish liniyasi chaqmoqqa qarshi himoya trosiga ega, qolgan havo uzatish liniyalarda himoya troslari mavjud emas.

1) Berilgan hisobiy sxema asosida to‘g‘ri ketma-ketlik uchun almashtirish sxemasi tuziladi (10-rasm).



10-rasm. Sistemadagi tokning to‘g‘ri ketma – ketligi uchun almashtirish sxemasi.

1) Generatorlar EYuKlarini aniqlaymiz

$$G-1 \quad E_1 = E_{1*} \cdot \frac{U_{нг}}{\sqrt{3}} \cdot \frac{U_{o'r.as}}{U_{o'r}} = 1{,}19 \cdot \frac{10{,}5}{\sqrt{3}} \cdot \frac{115}{10{,}5} = 72{,}5\ kV$$

$$G-2 \quad E_2 = E_{2*} \cdot \frac{U_{нг}}{\sqrt{3}} \cdot \frac{U_{o'r.as}}{U_{o'r}} = 1{,}12 \cdot \frac{18}{\sqrt{3}} \cdot \frac{115}{18} = 74{,}5\ kV$$

2) Sinxron generatorlar qarshiliklarini aniqlaymiz

$$\text{G}-1 \quad x_1 = \frac{1}{3} \cdot x_d^{''} \cdot \frac{U_н^2}{S_н} \cdot \left(\frac{U_{o'ras}}{U_{o'r}}\right)^2 = \frac{1}{3} \cdot 0{,}19 \cdot \frac{10{,}5^2}{100} \cdot \left(\frac{115}{10{,}5}\right)^2 = 8{,}4\ Om$$

$$\text{G}-2 \quad x_2 = \frac{1}{4} \cdot x_d^{''} \cdot \frac{U_н^2}{S_н} \cdot \left(\frac{U_{o'ras}}{U_{o'r}}\right)^2 = \frac{1}{4} \cdot 0{,}185 \cdot \frac{18^2}{235{,}5} \cdot \left(\frac{115}{18}\right)^2 = 2{,}6\ Om$$

3) Kuch transformatorlari qarshiliklarini aniqlaymiz

$$\text{T}-1 \quad x_3 = \frac{1}{3} \cdot \frac{U_k\%}{100} \cdot \frac{U_n^2}{S_n} \cdot \left(\frac{U_{o'ras}}{U_{o'r}}\right)^2 = \frac{1}{3} \cdot \frac{11\%}{100} \cdot \frac{220^2}{125} \cdot \left(\frac{115}{230}\right)^2 = 3{,}6\ Om$$

$$\text{T}-2 \quad x_4 = \frac{1}{4} \cdot \frac{U_k\%}{100} \cdot \frac{U_n^2}{S_n} \cdot \left(\frac{U_{o'ras}}{U_{o'r}}\right)^2 = \frac{1}{4} \cdot \frac{11\%}{100} \cdot \frac{220^2}{250} \cdot \left(\frac{115}{230}\right)^2 = 1{,}3\ Om$$

$$\text{AT}-1 \quad x_5 = \frac{1}{2} \cdot \frac{U_{кн}\%}{100} \cdot \frac{U_n^2}{S_n} \cdot \left(\frac{U_{o'ras}}{U_{o'r}}\right)^2 = \frac{1}{4} \cdot \frac{11{,}5\%}{100} \cdot \frac{220^2}{200} \cdot \left(\frac{115}{230}\right)^2 = 3{,}5\ Om$$

X6 = 0, Uks = 0

$$x_н = \frac{1}{2} \cdot \frac{U_{km}\%}{100} \cdot \frac{U_n^2}{S_n} \cdot \left(\frac{U_{o'ras}}{U_{o'r}}\right)^2 = \frac{1}{2} \cdot \frac{20{,}5\%}{100} \cdot \frac{220^2}{200} \cdot \left(\frac{115}{230}\right)^2 = 6{,}24\ Om$$ - (uch fazali qisqa tutashuv hisobida qatnashmaydi)

Transformator T-4 uchun qisqa tutashuv kuchlanishini 3 ta chulg‘am uchun aniqlaymiz

$$U_{кв} = 0{,}5 \cdot (U_{кв-с} + U_{кв-н} - U_{кс-н}) = 0{,}5 \cdot (11 + 18{,}5 - 7) = 11{,}25\ \%$$

$$U_{кс} = 0{,}5 \cdot (U_{кв-с} + U_{кс-н} - U_{кв-н}) = 0{,}5 \cdot (11 + 7 - 18{,}5) \equiv 0$$

$$U_{кн} = 0{,}5 \cdot (U_{кв-н} + U_{кс-н} - U_{кв-с}) = 0{,}5 \cdot (18{,}5 + 7 - 11) = 7{,}25\ \%$$

T – 4 transformator qarshiliklarini aniqlaymiz

$$x_7 = \frac{U_{кв}\%}{100} \cdot \frac{U_н^2}{S_н} \cdot \left(\frac{U_{o'ras}}{U_{o'r}}\right)^2 = \frac{11{,}25\%}{100} \cdot \frac{110^2}{80} \cdot 1 = 17{,}02\ Om$$

X8 = 0, Uks = 0

$$x_9 = \frac{U_{кн}\%}{100} \cdot \frac{U_н^2}{S_н} \cdot k_T^2 = \frac{7{,}25\%}{100} \cdot \frac{110^2}{80} \cdot 1 = 10{,}97\ Om$$

T – 3 transformator qarshiligini aniqlaymiz

$$x_{10} = \frac{1}{2} \cdot \frac{U_к\%}{100} \cdot \frac{U_н^2}{S_н} \cdot k_T^2 = \frac{1}{2} \cdot \frac{10{,}5\%}{100} \cdot \frac{110^2}{63} \cdot 1 = 10{,}08\ Om$$

4) Xavo liniyalar qarshiligini aniqlaymiz

L – 1 $x_{11} = x_{12} = x_0 \cdot l \cdot \left(\frac{U_{o'r\,as}}{U_{o'r}}\right)^2 = 0{,}435 \cdot 210 \cdot \left(\frac{115}{230}\right)^2 = 22{,}84\ Om$

L – 2 $x_{13} = x_{14} = x_0 \cdot l \cdot \left(\frac{U_{o'r\,as}}{U_{o'r}}\right)^2 = 0{,}413 \cdot 70 \cdot 1 = 28{,}91\ Om$

L – 3; L – 4 $x_{15} = x_{16} = x_0 \cdot l \cdot \left(\frac{U_{o'r\,as}}{U_{o'r}}\right)^2 = 0{,}405 \cdot 60 \cdot 1^2 = 24{,}3\ Om$

5) Yuklamalar qarshiligini aniqlaymiz

Y – 1 $x_{17} = x_{*наг} \cdot \frac{U_н^2}{S_н} \cdot \left(\frac{U_{o'r\,as}}{U_{o'r}}\right)^2 = 0{,}35 \cdot \frac{220^2}{795{,}5} \cdot \left(\frac{115}{230}\right)^2 = 5{,}32\ Om$

Y – 2 $x_{18} = x_{*наг} \cdot \frac{U_н^2}{S_н} \cdot \left(\frac{U_{o'r\,as}}{U_{o'r}}\right)^2 = 0{,}35 \cdot \frac{10{,}5^2}{42{,}2} \cdot \left(\frac{115}{10{,}5}\right)^2 = 109{,}69\ Om$

Y – 3 $x_{19} = x_{*наг} \cdot \frac{U_н^2}{S_н} \cdot \left(\frac{U_{ср\,ос}}{U_{ср}}\right)^2 = 0{,}35 \cdot \frac{35^2}{38{,}9} \cdot \left(\frac{115}{37}\right)^2 = 106{,}47\ Om$

Y – 4 $x_{20} = x_{*наг} \cdot \frac{U_н^2}{S_н} \cdot \left(\frac{U_{o'r\,as}}{U_{o'r}}\right)^2 = 0{,}35 \cdot \frac{35^2}{77{,}8} \cdot \left(\frac{115}{37}\right)^2 = 53{,}24\ Om$

6) Almashtirish sxemasini soddalashtiramiz (11-rasm).

$$x_{21} = x_1 + x_3 + \frac{x_{11} \cdot x_{12}}{x_{11} + x_{12}} = 8{,}4 + 3{,}6 + \frac{22{,}84}{2} = 23{,}42\ Om$$

$$x_{22} = x_2 + x_4 + = 2{,}6 + 1{,}3 = 3{,}9\ Om$$

$$x_{23} = x_5 + x_6 + = 3{,}5 + 0 = 3{,}5\ Om$$

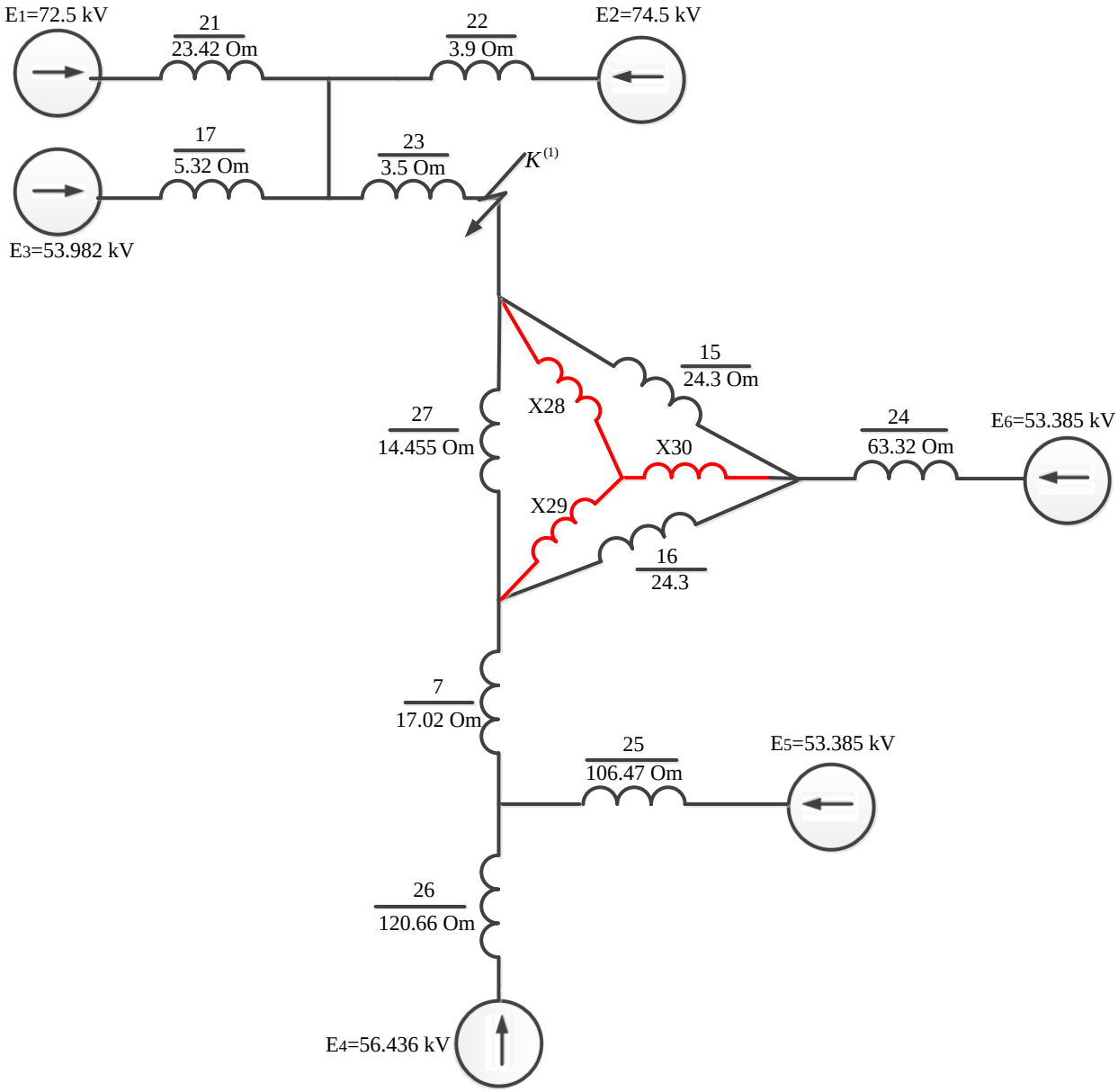
$$x_{24} = x_{10} + x_{20} + = 10{,}08 + 53{,}24 = 63{,}32\ Om$$

$x_{24} = x_{10} + x_{20}$ =10,08+53,24= 63,32 Om

$x_{25} = x_8 + x_{19} = 0 + 106{,}47$ = 106,47 Om

$x_{26} = x_9 + x_{18} = 10{,}97 + 109{,}69$ = 120,66 Om

$$x_{21} = \frac{x_{13} \cdot x_{14}}{x_{13} + x_{14}} = \frac{28{,}91}{2} = 14{,}455\ Om$$



11-rasm. Δ (X_{15}, $X_{16,}$ X_{27}) qarshiliklardan Y (X_{28}, X_{29}, X_{30}) ga o‘tkazganimizdagi almashtirish sxemasi.

Almashtirish sxemasini soddalashtiramiz

Δ (X_{15}, $X_{16,}$ X_{27}) qarshiliklardan Y (X_{28}, X_{29}, X_{30}) ga o‘tkazamiz

$$x_{28} = \frac{x_{15} \cdot x_{27}}{x_{15} + x_{16} + x_{27}} = \frac{24{,}3 \cdot 14{,}455}{24{,}3 + 24{,}3 + 14{,}455} = 5{,}57\ Om$$

$$x_{29} = \frac{x_{16} \cdot x_{27}}{x_{15} + x_{16} + x_{27}} = \frac{24{,}3 \cdot 14{,}455}{24{,}3 + 24{,}3 + 14{,}455} = 5{,}57\ Om$$

$$x_{30} = \frac{x_{15} \cdot x_{16}}{x_{15} + x_{16} + x_{27}} = \frac{24{,}3 \cdot 24{,}3}{24{,}3 + 24{,}3 + 14{,}455} = 9{,}36\ Om$$

$$x_{31} = \frac{x_{21} \cdot x_{22}}{x_{21} + x_{22}} = \frac{23{,}42 \cdot 3{,}9}{23{,}42 + 3{,}9} = 3{,}34\ Om$$

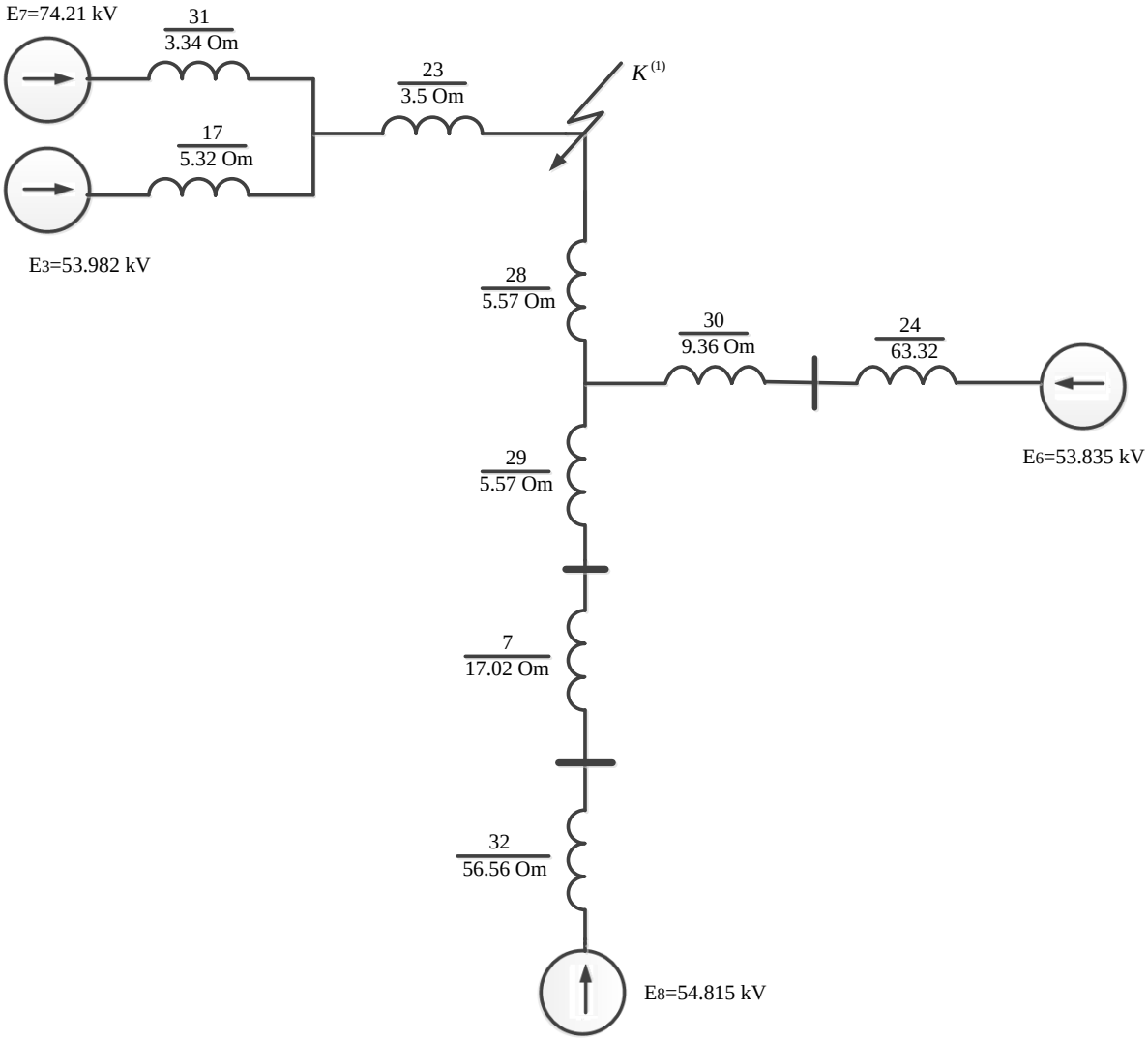
E1 va E2 EYuKlar o‘rnini ekvivalent E_7 EYuK bilan almashtiramiz

$$E_7 = \frac{E_1 \cdot x_{22} + E_2 x_{21}}{x_{21} + x_{22}} = \frac{72{,}5 \cdot 3{,}9 + 74{,}5 \cdot 23{,}42}{3{,}9 + 23{,}42} = 74{,}21\ kV$$

E4 va E5 EYUKlar o‘rnini ekvivalent E_8 EYUK bilan almashtiramiz (12-rasm)

$$E_8 = \frac{E_4 \cdot x_{25} + E_5 x_{26}}{x_{25} + x_{26}} = \frac{56{,}436 \cdot 106{,}47 + 53{,}385 \cdot 120{,}66}{106{,}47 + 120{,}66} = 54{,}815\ kV$$

$$x_{32} = \frac{x_{25} \cdot x_{26}}{x_{25} + x_{26}} = \frac{106{,}47 \cdot 120{,}66}{106{,}47 + 120{,}66} = 56{,}56\ Om$$



12-rasm. E4 va E5 EYUKlar o‘rnini ekvivalent E_8 EYUK bilan almashtirish natijasidan hosil bo‘lgan almashtirish sxemasi.

Almashtirish sxemasini soddalashtiramiz

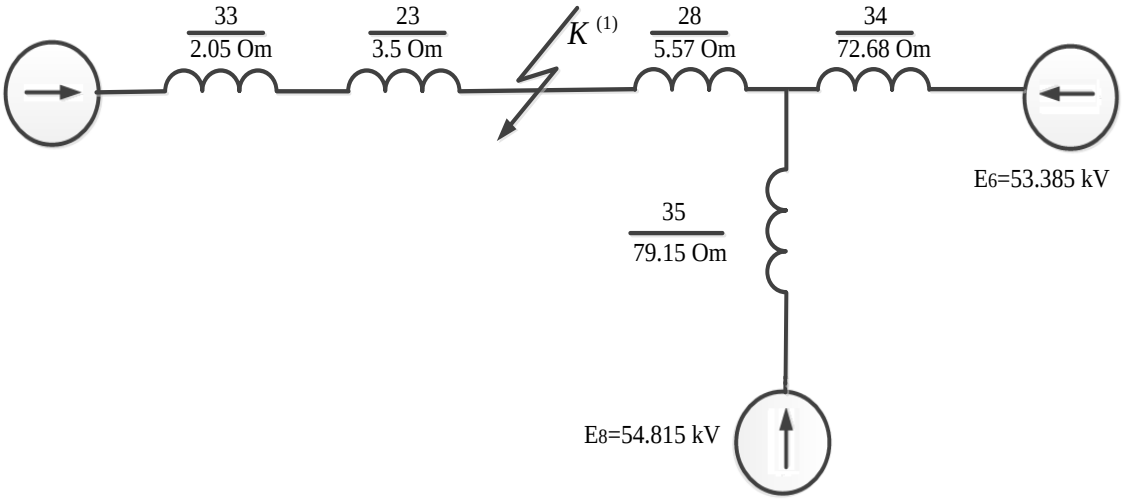
$$x_{33} = \frac{x_{17} \cdot x_{31}}{x_{17} + x_{31}} = \frac{5{,}32 \cdot 3{,}34}{5{,}32 + 3{,}34} = 2{,}05\ Om$$

$$x_{34} = x_{24} + x_{30} = 63{,}32 + 9{,}36 = 72{,}68\ Om$$

$$x_{35} = x_{7} + x_{29} + x_{32} = 17{,}02 + 5{,}57 + 56{,}56 = 79{,}15\ Om$$

E3 va E7 EYUKlar o‘rnini ekvivalent E_9 EYUK bilan almashtiramiz

$$E_9 = \frac{E_3 \cdot x_{31} + E_7 x_{17}}{x_{17} + x_{31}} = \frac{53{,}982 \cdot 3{,}34 + 74{,}21 \cdot 5{,}32}{3{,}34 + 5{,}32} = 66{,}408\ kV$$



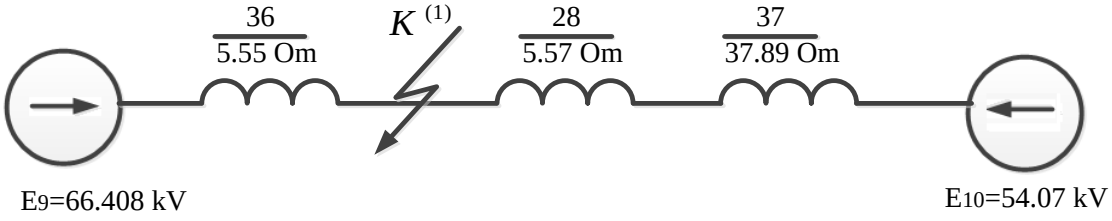
13-rasm. E3 va E7 EYUKlarni ekvivalent E_9 EYuK bilan almashtirish natijasidagi sxema.

$$x_{36} = x_{23} + x_{33} = 3{,}5 + 2{,}05 = 5{,}55\ Om$$

$$x_{37} = \frac{x_{34} \cdot x_{35}}{x_{34} + x_{35}} = \frac{72{,}68 \cdot 79{,}15}{72{,}68 + 79{,}15} = 37{,}89\ Om$$

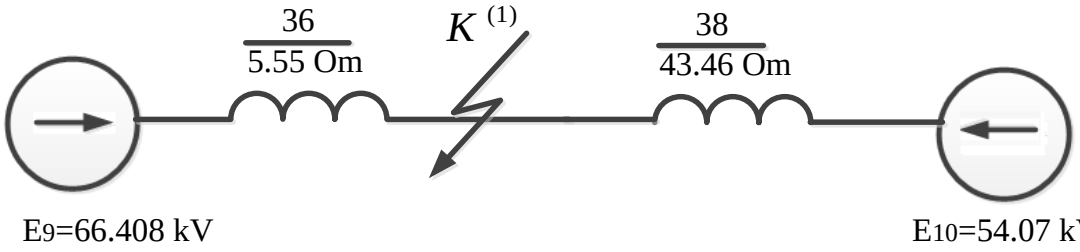
E_6 va E_8 EYUKlar o‘rnini ekvivalent E_{10} EYuK bilan almashtiramiz

$$E_{10} = \frac{E_6 \cdot x_{35} + E_8 x_{34}}{x_{34} + x_{35}} = \frac{53{,}385 \cdot 79{,}15 + 54{,}815 \cdot 72{,}68}{79{,}15 + 72{,}68} = 54{,}07\ kV$$



14-rasm. E_6 va E_8 EYUKlar o‘rnini ekvivalent E_{10} EYuK bilan almashtirish natijasida hosil bo‘lgan sxema.

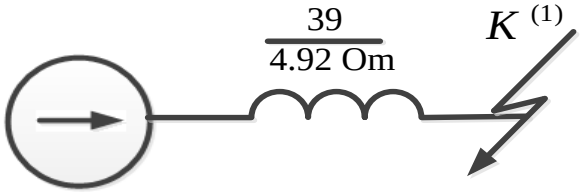
$$x_{38} = x_{28} + x_{37} = 5{,}57 + 37{,}89 = 43{,}46\ Om$$



15-rasm. X28 va X37 qarshiliklarni ekvivalent X38 qarshilikka aylantirishdagi sxema.

$$x_{39} = \frac{x_{36} \cdot x_{38}}{x_{36} + x_{38}} = \frac{5{,}55 \cdot 43{,}46}{5{,}55 + 43{,}46} = 4{,}92\ Om$$

$$E_{11} = \frac{E_9 \cdot x_{38} + E_{10} x_{36}}{x_{36} + x_{38}} = \frac{66{,}408 \cdot 43{,}46 + 54{,}07 \cdot 5{,}55}{43{,}46 + 5{,}55} = 65{,}01\ kV$$



16-rasm. Elektr tizimning qisqa tutashuv nuqtasiga nisbatan yig‘ilgan natijaviy qarshilik va EYuK dan iborat almashtirish sxemasi.

$$x_{1\Sigma} = 4{,}92\ Om;\ E_{1\Sigma} = 65{,}01\ kV$$

2) Berilgan hisobiy sxema asosida teskari ketma - ketlik uchun almashtirish sxemasi tuziladi (17-rasm).

Teskari ketma-ketlik sxemasi

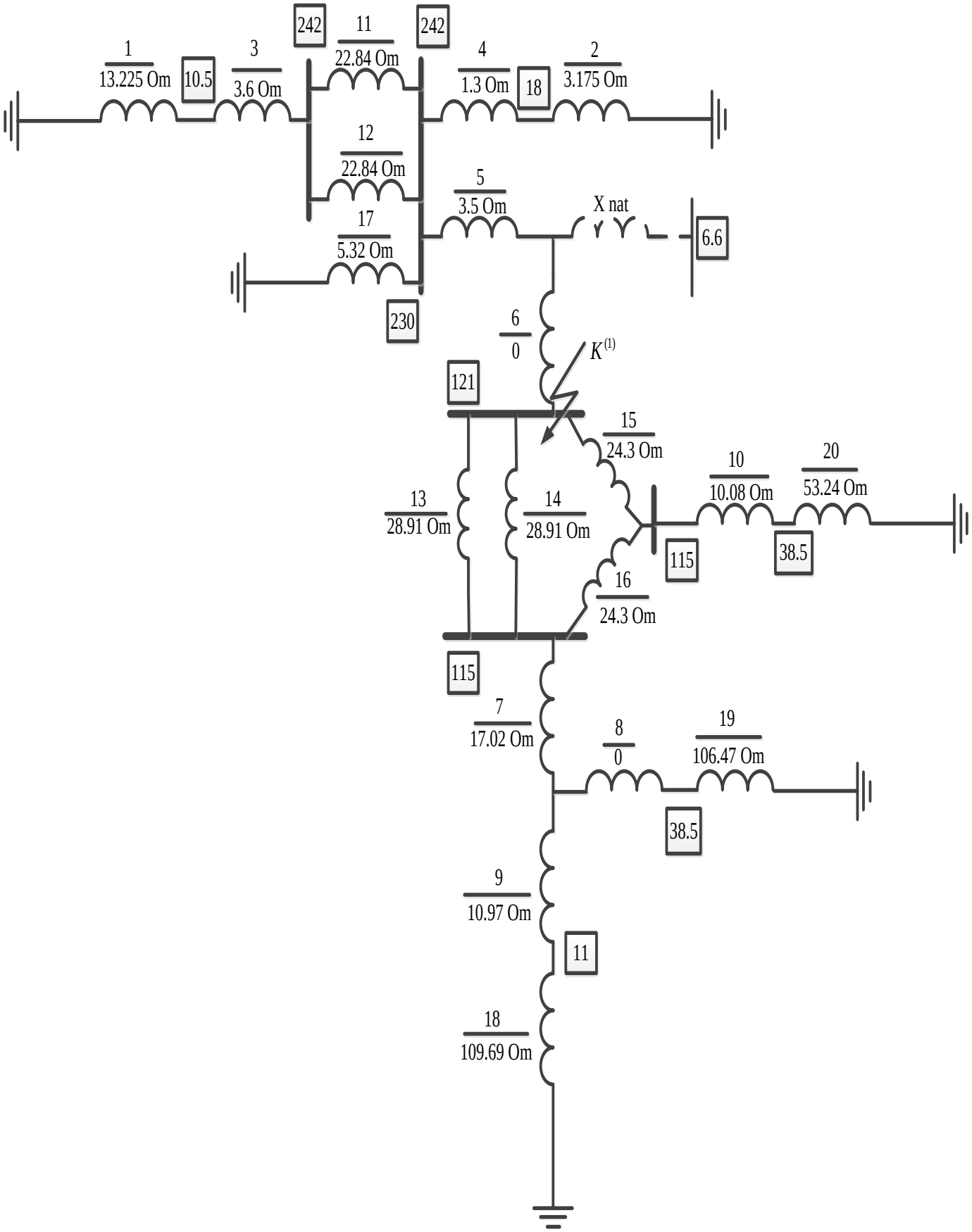
Teskari ketma-ketlik (K-K2) sxemasi ko‘rinishi jihatidan to’g’ri ketma-ketlik (K-K1) sxemasiga o‘xshaydi. Ularning farqi shundan iboratki, K-K2 sxemasida generatsiya elementlarining EYUK lari nolga teng deb olinadi. Bundan tashqari, barcha elementlarning K-K2 reaktiv qarshiligi o‘zgarmas va ularning nosimmetriya sodir bo‘lish shartlari va turi hamda o‘tkinchi jarayonning davomiyligiga bog‘liq emas deb hisoblanadi.

Agarda generator, motor va umumlashgan yuklamalar uchun K-K2 qarshiliklarining aniq qiymatlari ma’lum bo‘lmasa, ular quyidagicha qabul qilinadi:

- dempfer chulg‘amisiz mashinalar uchun $X_2 \approx 1.45 \cdot X_d^{'}$;
- dempfer chulg‘amli mashina va turbogeneratorlar uchun $X_2 \approx 1.22 \cdot X_d^{'}$;
- umumlashgan yuklamalar uchun X_2= 0.35. Bu qiymat shu yuklama ulangan pog‘onaning o‘rtacha nominal kuchlanishi va yuklamaning to‘la ishchi quvvatiga keltirilgan qiymatdir.

K-K2 sxemasidagi qolgan barcha elementlar parametrlarining qiymatlari (tokni chegaralovchi reaktorlar, transformatorlar, avtotransformatorlar, havo va kabel uzatish liniyalari) K-K1 dagi qiymatlariga teng bo‘ladi. Zeroki, ularning magnit maydon orqali bog‘langan qismlari bir-biriga nisbatan harakatsiz bo‘ladi.

K-K2 sxemasining boshi va oxiri xuddi K-K1 sxemasidek aniqlanadi.



17-rasm. Sistemaning tokning teskari ketma – ketligi (K-K2) uchun almashtirish sxemasi tuziladi

1) Sinxron generatorlar qarshiliklarini aniqlaymiz

G-1 $x_1 = \frac{1}{3} \cdot x_2 \cdot \frac{U_н^2}{S_н} \cdot \left(\frac{U_{o'ras}}{U_{o'r}}\right)^2 = \frac{1}{3} \cdot 0{,}3 \cdot \frac{10{,}5^2}{100} \cdot \left(\frac{115}{10{,}5}\right)^2 = 13{,}225\ Om$

G-2 $x_2 = \frac{1}{4} \cdot x_2 \cdot \frac{U_н^2}{S_н} \cdot \left(\frac{U_{o'ras}}{U_{o'r}}\right)^2 = \frac{1}{4} \cdot 0{,}226 \cdot \frac{18^2}{235{,}5} \cdot \left(\frac{115}{18}\right)^2 = 3{,}175\ Om$

2) Kuch transformatorlari qarshiliklarini aniqlaymiz

T – 1 $x_3 = \frac{1}{3} \cdot \frac{U_k\%}{1} \cdot \frac{U_n^2}{S_n} \cdot \left(\frac{U_{o'ras}}{U_{o'r}}\right)^2 = \frac{1}{3} \cdot \frac{11\%}{100} \cdot \frac{220^2}{125} \cdot \left(\frac{115}{230}\right)^2 = 3{,}6\ Om$

T – 2 $x_4 = \frac{1}{4} \cdot \frac{U_k\%}{100} \cdot \frac{U_n^2}{S_n} \cdot \left(\frac{U_{o'ras}}{U_{o'r}}\right)^2 = \frac{1}{4} \cdot \frac{11\%}{100} \cdot \frac{220^2}{250} \cdot \left(\frac{115}{230}\right)^2 = 1{,}3\ Om$

AT – 1 $x_5 = \frac{1}{2} \cdot \frac{U_{kн}\%}{100} \cdot \frac{U_n^2}{S_n} \cdot \left(\frac{U_{o'ras}}{U_{o'r}}\right)^2 = \frac{1}{4} \cdot \frac{11{,}5\%}{100} \cdot \frac{220^2}{200} \cdot \left(\frac{115}{230}\right)^2 = 3{,}5\ Om$

X6 = 0, Uks = 0

$x_н = \frac{1}{2} \cdot \frac{U_{km}\%}{100} \cdot \frac{U_n^2}{S_n} \cdot \left(\frac{U_{o'ras}}{U_{o'r}}\right)^2 = \frac{1}{2} \cdot \frac{20{,}5\%}{100} \cdot \frac{220^2}{200} \cdot \left(\frac{115}{230}\right)^2 = 6{,}24\ Om$ - (uch fazali qisqa tutashuv hisobida qatnashmaydi)

Transformator T-4 uchun qisqa tutashuv kuchlanishini 3 ta chulg‘am uchun aniqlaymiz

$U_{кв} = 0{,}5 \cdot (U_{кв-с} + U_{кв-н} - U_{кс-н}) = 0{,}5 \cdot (11 + 18{,}5 - 7) = 11{,}25\ \%$

$U_{кс} = 0{,}5 \cdot (U_{кв-с} + U_{кс-н} - U_{кв-н}) = 0{,}5 \cdot (11 + 7 - 18{,}5) \equiv 0$

$U_{кн} = 0{,}5 \cdot (U_{кв-н} + U_{кс-н} - U_{кв-с}) = 0{,}5 \cdot (18{,}5 + 7 - 11) = 7{,}25\ \%$

T – 4 transformator qarshiliklarini aniqlaymiz

$x_7 = \frac{U_{кв}\%}{100} \cdot \frac{U_н^2}{S_н} \cdot \left(\frac{U_{o'ras}}{U_{o'r}}\right)^2 = \frac{11{,}25\%}{100} \cdot \frac{110^2}{80} \cdot 1 = 17{,}02\ Om$

X8 = 0, Uks = 0.

$x_9 = \frac{U_{кн}\%}{100} \cdot \frac{U_н^2}{S_н} \cdot k_T^2 = \frac{7{,}25\%}{100} \cdot \frac{110^2}{80} \cdot 1 = 10{,}97\ Om$

T – 3 transformator qarshiligini aniqlaymiz

$x_{10} = \frac{1}{2} \cdot \frac{U_к\%}{100} \cdot \frac{U_н^2}{S_н} \cdot k_T^2 = \frac{1}{2} \cdot \frac{10{,}5\%}{100} \cdot \frac{110^2}{63} \cdot 1 = 10{,}08\ Om$

3) Xavo liniyalar qarshiligini aniqlaymiz

L – 1 $x_{11} = x_{12} = x_0 \cdot l \cdot \left(\frac{U_{o'r\,as}}{U_{o'r}}\right)^2 = 0{,}435 \cdot 210 \cdot \left(\frac{115}{230}\right)^2 = 22{,}84\ Om$

L – 2 $x_{13} = x_{14} = x_0 \cdot l \cdot \left(\frac{U_{o'r\,as}}{U_{o'r}}\right)^2 = 0{,}413 \cdot 70 \cdot 1 = 28{,}91\ Om$

L – 3; L – 4 $x_{15} = x_{16} = x_0 \cdot l \cdot \left(\frac{U_{o'r\,as}}{U_{o'r}}\right)^2 = 0{,}405 \cdot 60 \cdot 1^2 = 24{,}3\ Om$

4) Yuklamalar qarshiligini aniqlaymiz

Y – 1 $x_{17} = x_{*наг} \cdot \frac{U_н^2}{S_н} \cdot \left(\frac{U_{o'r\,as}}{U_{o'r}}\right)^2 = 0{,}35 \cdot \frac{220^2}{795{,}5} \cdot \left(\frac{115}{230}\right)^2 = 5{,}32\ Om$

Y – 2 $x_{18} = x_{*наг} \cdot \frac{U_н^2}{S_н} \cdot \left(\frac{U_{o'r\,as}}{U_{o'r}}\right)^2 = 0{,}35 \cdot \frac{10{,}5^2}{42{,}2} \cdot \left(\frac{115}{10{,}5}\right)^2 = 109{,}69\ Om$

Y – 3 $x_{19} = x_{*наг} \cdot \frac{U_н^2}{S_н} \cdot \left(\frac{U_{ср\,ос}}{U_{ср}}\right)^2 = 0{,}35 \cdot \frac{35^2}{38{,}9} \cdot \left(\frac{115}{37}\right)^2 = 106{,}47\ Om$

Y – 4 $x_{20} = x_{*наг} \cdot \frac{U_н^2}{S_н} \cdot \left(\frac{U_{o'r\,as}}{U_{o'r}}\right)^2 = 0{,}35 \cdot \frac{35^2}{77{,}8} \cdot \left(\frac{115}{37}\right)^2 = 53{,}24\ Om$

5) Almashtirish sxemasini soddalashtiramiz (18-rasm).

$x_{21} = x_1 + x_3 + \frac{x_{11} \cdot x_{12}}{x_{11} + x_{12}} = 13{,}225 + 3{,}6 + \frac{22{,}84}{2} = 28{,}245\ Om$

$x_{22} = x_2 + x_4 = 3{,}175 + 1{,}3 = 4{,}475\ Om$

$x_{22} = x_2 + x_4 = 3{,}175 + 1.3 = 4{,}475$ Om

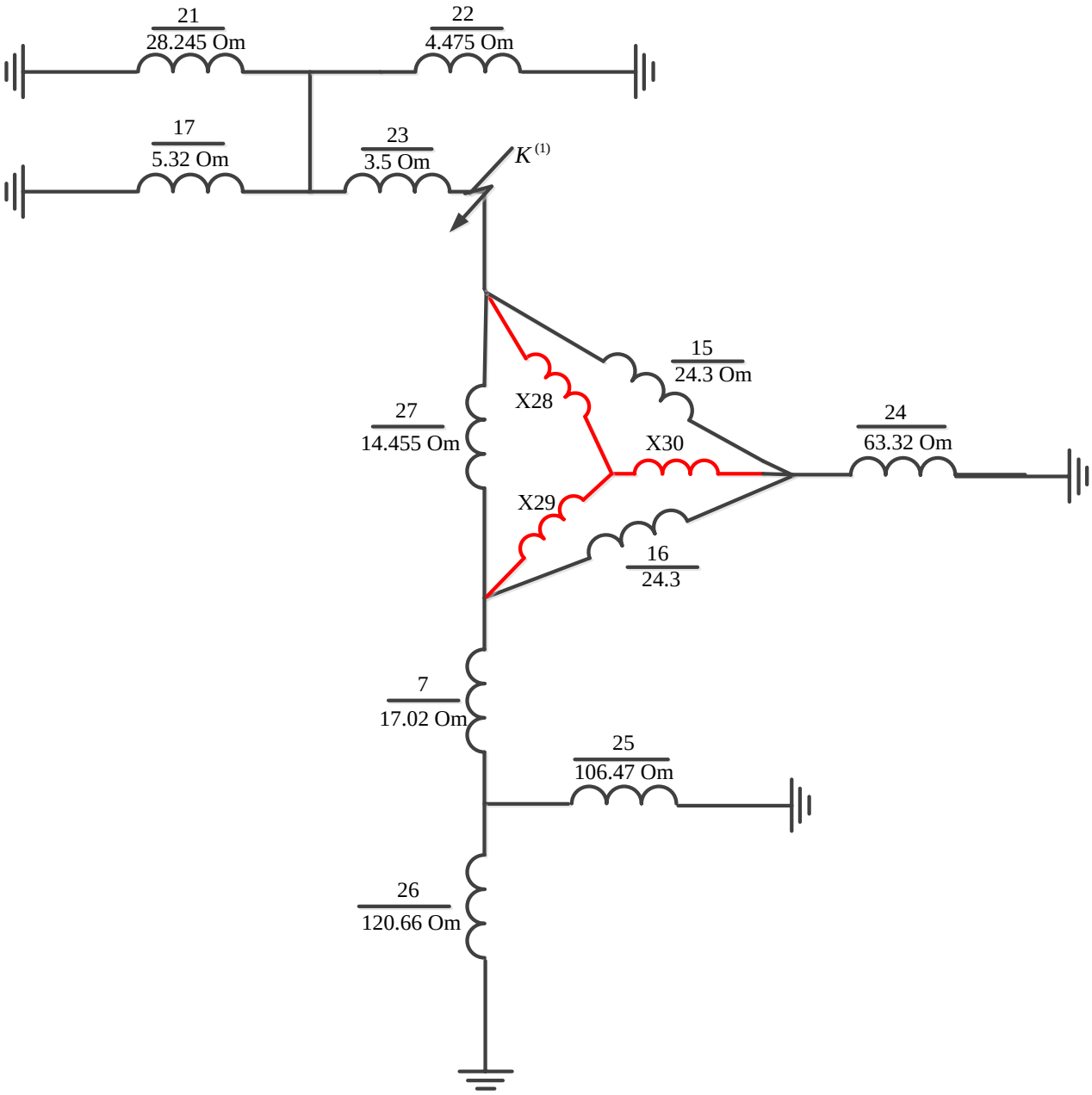
$x_{23} = x_5 + x_6 = 3{,}5 + 0 = 3{,}5$ Om

$x_{24} = x_{10} + x_{20}$ =10,08+53,24= 63,32 Om

$x_{25} = x_8 + x_{19} = 0 + 106{,}47$ = 106,47 Om

$x_{26} = x_9 + x_{18} = 10{,}97 + 109{,}69$ = 120,66 Om

$x_{27} = \frac{x_{13} \cdot x_{14}}{x_{13} + x_{14}} = \frac{28{,}91}{2} = 14{,}455\ Om$



18-rasm. Sistemaning tokning teskari ketma – ketligi uchun tuzilgan almashtirish sxemasini soddalashtiramiz.

Δ (X_{15}, $X_{16,}$ X_{27}) qarshiliklardan Y (X_{28}, X_{29}, X_{30}) ga o‘tkazamiz

$$x_{28} = \frac{x_{15} \cdot x_{27}}{x_{15} + x_{16} + x_{27}} = \frac{24{,}3 \cdot 14{,}455}{24{,}3 + 24{,}3 + 14{,}455} = 5{,}57\ Om$$

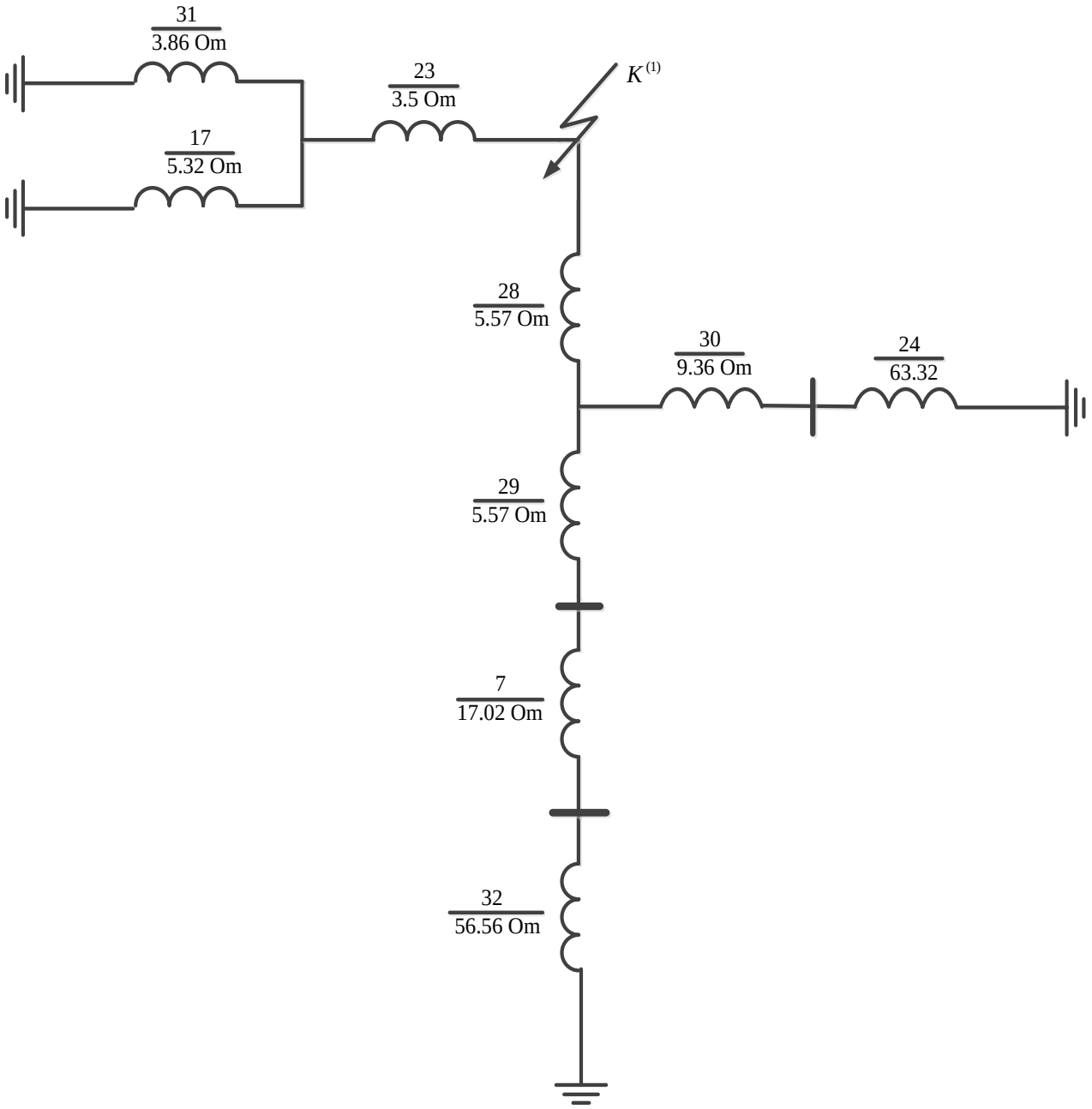
$$x_{29} = \frac{x_{16} \cdot x_{27}}{x_{15} + x_{16} + x_{27}} = \frac{24{,}3 \cdot 14{,}455}{24{,}3 + 24{,}3 + 14{,}455} = 5{,}57\ Om$$

$$x_{29} = \frac{x_{16} \cdot x_{27}}{x_{15} + x_{16} + x_{27}} = \frac{24,3 \cdot 14,455}{24,3 + 24,3 + 14,455} = 5,57\ Om$$

$$x_{30} = \frac{x_{15} \cdot x_{16}}{x_{15} + x_{16} + x_{27}} = \frac{24,3 \cdot 24,3}{24,3 + 24,3 + 14,455} = 9,36\ Om$$

$$x_{31} = \frac{x_{21} \cdot x_{22}}{x_{21} + x_{22}} = \frac{28,245 \cdot 4,475}{28,245 + 4,475} = 3,86\ Om$$

$$x_{32} = \frac{x_{25} \cdot x_{26}}{x_{25} + x_{26}} = \frac{106,47 \cdot 120,66}{106,47 + 120,66} = 56,56\ Om$$



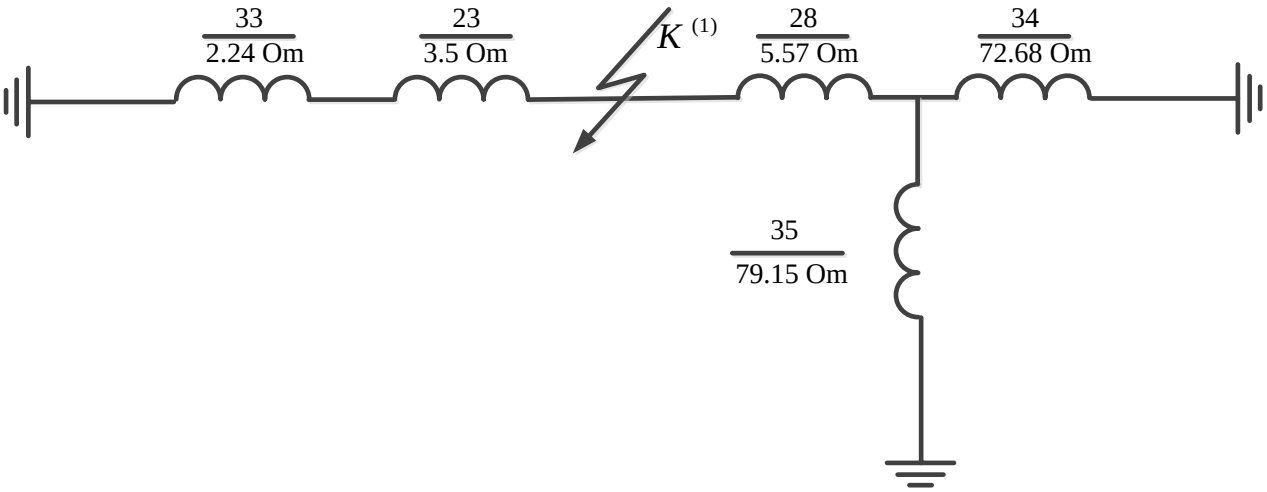
19-rasm. Soddalashtirilgan almashtirish sxemasi.

Almashtirish sxemasini soddalashtiramiz

$$x_{33} = \frac{x_{17} \cdot x_{31}}{x_{17} + x_{31}} = \frac{5{,}32 \cdot 3{,}86}{5{,}32 + 3{,}86} = 2{,}24\ Om$$

$$x_{34} = x_{24} + x_{30} = 63{,}32 + 9{,}36 = 72{,}68\ Om$$

$$x_{35} = x_{7} + x_{29} + x_{32} = 17{,}02 + 5{,}57 + 56{,}56 = 79{,}15\ Om$$

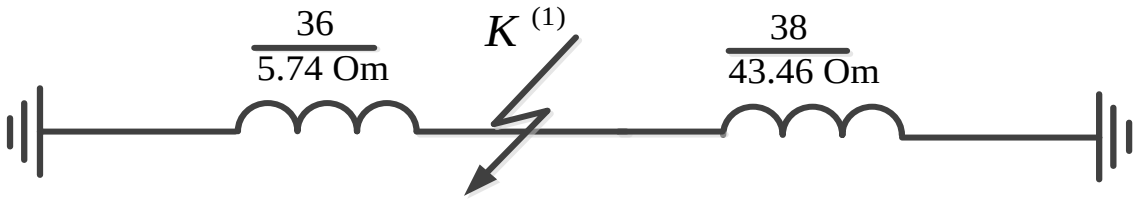


20-rasm. Hisoblashlar natijasida hosil bo‘lgan almashtirish sxemasi.

$$x_{36} = x_{23} + x_{33} = 3{,}5 + 2{,}24 = 5{,}74\ Om$$

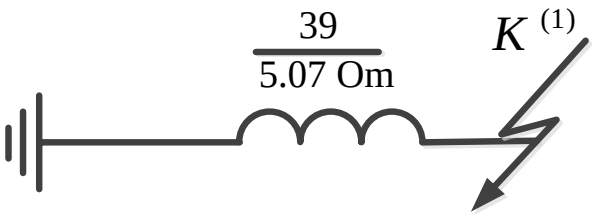
$$x_{37} = \frac{x_{34} \cdot x_{35}}{x_{34} + x_{35}} = \frac{72{,}68 \cdot 79{,}15}{72{,}68 + 79{,}15} = 37{,}89\ Om$$

$$x_{38} = x_{28} + x_{37} = 5{,}57 + 37{,}89 = 43{,}46\ Om$$



21-rasm. X_{23} va X_{33} qarshiliklarni ekvivalent X_{36} qarshilikkka hamda X_{28} va X_{37} qarshiliklarni ekvivalent X_{38} qarshilik bilan almashtirganimizdagi sxema.

$$x_{39} = \frac{x_{36} \cdot x_{38}}{x_{36} + x_{38}} = \frac{5{,}74 \cdot 43{,}46}{5{,}74 + 43{,}46} = 5{,}07\ Om$$



$$x_{2\Sigma} = 5{,}07\ \text{Ом}$$

22-rasm. Elektr tizimning qisqa tutashuv nuqtasiga nisbatan yig‘ilgan natijaviy teskari ketma-ketlik qarshiligi.

3) Berilgan hisobiy sxema asosida nol ketma - ketlik usuli uchun almashtirish sxemasi tuziladi (23-rasm).

Nolinchi ketma-ketlik sxemasi

Nol ketma-ketlik (K-K0) sxemasining tuzilishi asosan unga kiruvchi transformator va avtotransformatorlar chulg‘amlarining ulanish sxemasiga bog‘liqdir.

Bu sxemaning tuzilishini odatda nosimmetriya sodir bo‘lgan nuqtadan boshlash kerak. Bunda nosimmetriya sodir bo‘lgan nuqtada barcha fazalar bir-biri bilan qisqa tutashtirilgan va bu nuqtaga K-K0 ning kuchlanishi biriktirilgan deb hisoblash kerak.

Bu kuchlanish nosimmetriya turiga bog‘liq ravishda yerga nisbatan (ko‘ndalang nosimmetriya uchun), yoki fazalarning uzilish joyiga ketma-ket qo‘yiladi (bo‘ylama nosimmetriya uchun).

Berilgan nosimmetriyaga mos keluvchi K-K0 kuchlanishining ulash usulidan kelib chiqib, K-K0 toklarining har bir elektr bog‘langan zanjir chegaralaridagi mumkin bo‘lgan yo‘llarini aniqlash kerak.

K-K0ning kuchlanishi (U_0) yerga nisbatan ulanganda K-K0 toklarining oqishi uchun sig‘im o‘tkazuvchanligi bo‘lmagan holda shu kuchlanish qo‘yilgan bevosita (elektr) bog‘langan zanjirda kamida bitta yerga ulangan neytral nuqtasi bo‘lishi shart.

Bo‘ylama nosimmetriyada o‘sha elektr bog‘langan zanjirning aylanib o‘tish yo‘llari orqali yopiq kontur mavjud bo‘lsa, K-K0 toklari hatto erga ulangan neytrallar yo‘q bo‘lgan taqdirda ham oqishi mumkin.

Shunga muvofiq almashtirish sxemasida K-K0 toklari oqib o‘tuvchi elementlarga kiritiladi.

Elementlarning K-K0 sxemasidagi qarshiliklari umumiy holda ularning K-K1 va K-K2lar toklari bo‘lgan qarshiliklardan anchagina farq qiladi.

A) Sinxron mashinalar (SM) sistemasiga chulg‘amlarning ulash sxemasi Δ/Y bo‘lgan transformatorlar orqali ulanadi, generatorlarning o‘zi esa izolyatsiya yoki kompensatsiyalangan neytral bilan ishlaydi. Bu holda SM K-K0 sxemasiga kiritilmaydi.

B) *UMUMLASHGAN YUKLAMALAR* uchun X_0 qarshiligi ularning tarkibidagi elementlarni pasaytiruvchi transformatorlarning ta’minlovchi chulg‘amlarining qarshiliklari va ulanish sxemalari orqali aniqlanadi. Odatda pasaytiruvchi transformatorlarning ta’minlovchi chulg‘amlari uchburchak usulida ulanadi, bu esa yuklamada K-K0 toklari hosil bo‘lishiga to‘sqinlik qiladi. Ammo, bu hol 110 kV va undan katta kuchlanishli tarmoqlarga keltirilgan umumlashgan yuklamalar uchun taalluqli emas. Ular uchun X_0 masalaning boshlang‘ich shartlarida beriladi yoki aloxida aniqlanadi.

V) *TRANSFORMATORlarning* X_0 kattaligi ularning konstruktiv tuzilishi va chulg‘amlarining ulanish usuli bilan aniqlanadi.

Uchburchak yoki yulduzcha sxemasiga ulangan chulg‘am tomonidan neytrali izolyasiya qilingan boshqa chulg‘amlar qanday ulanganidan qat’iy nazar, K-K0 toklari hosil bo‘la olmaydi, chunki ular uchun er orqali qaytish yo‘li yoki boshqa yopiq zanjir yo‘q. Bu holda transformatorlar uchun $X_0=\infty$.

K-K0 toklari oqishi uchun yo‘l faqat shikastlanishi yerga tutashgan tomonidan neytrali yerga bevosita ulangan transformatorlardagina mavjuddir. Bu holda transformatorning qarshiligi K-K0 almashtirish sxemasida hisobga olinishi kerak.

Chulg‘amlarining ulanish sxemasi Y/Δ bo‘lgan ikki chulg‘amli barcha transformatorlar uchun K-K0 reaktansi induktiv qarshiligi quyidagicha bo‘ladi:

$$X_0 = X_I + X_{II} = X_1$$

ya’ni K - K1 reaktansiga tengdir.

Bularga o‘xshash transformatorlarning ikkilamchi chulg‘amlarida K-K0ning EYuKi hosil bo‘ladi. Chulg‘am fazalari uchburchak usulida ulangani tufayli ularda K-K0 toklari yuzaga keladi, lekin bu toklar uchburchakdan tashqariga chiqa olmaydi. Shunday qilib ikkilamchi chulg‘amdagi hosil bo‘lgan K-K0 EYUKi ikkilamchi chulg‘am qarshiligi X_{II}dan K-K0 tokini o‘tkazishga sarflanadi. Uchburchak usulida ulangan chulg‘amning tashqi zanjirini uzib qo‘yib, X_{II} qarshilikli shaxobchaning oxiri yerga ulab qo‘yiladi.

Sxemada transformator tuzilishiga bog‘liq ravishda K-K0 magnitlanish reaktansi $X_{\mu o}$ hisobga olinishi mumkin.

Uchta bir fazali transformatorlar guruhi hamda zirxli transformatorlar uchun K-K0 magnitlanish toki juda ham kichikdir, chunki bu holda Φ_0 magnit oqimi uchun sharoitlar K-K1 (Φ_1) sharoitlari bilan bir xildir. Shuning uchun ham $X_{\mu O}=\infty$ deb hisoblash mumkin.

Uch fazali uch o‘zakli transformatorlarda sharoitlar boshqachadir. Ularda K-K0 magnit oqimlari nomagnit muhit va transformatorning g‘ilofi orqali berkitiladi. Magnit qarshiligi katta bo‘lgan yo‘l orqali magnit oqimini o‘tkazish uchun shunga mos katta magnitlash toki kerak bo‘ladi. Shuning uchun ham bunday tipdagi transformatorlarda $X_{\mu O}$ reaktansi $X_{\mu d}$ga qaraganda ancha kichik bo‘lib, u $X_{\mu O}$=(0.3-1.0) oralig‘ida yotadi. X_{II}ning kattaligi $X_{\mu O}$ dan anchagina kichikligini nazarda tutgan holda chulg‘amlari Y/Δ usulida ulangan uch o‘zakli transformator uchun ham amalda $X_{\mu O}=\infty$ deb hisoblash mumkin.

Uchburchak usulida ulangan chulg‘am ham almashtirish sxemasiga shunga o‘xshash kiritiladi. Transformatorning almashtirish sxemasidagi neytral izolyatsiyalangan yulduz usulida ulangan chulg‘am kiritilmaydi, chunki unda K-K0 toklari hosil bo‘lmaydi. Neytrali yerga yulduzcha usulida ulangan chulg‘am almashtirish sxemasiga quyidagi shart bajarilganda kiritiladi: bu chulg‘am tomonidan K-K0 toki o‘tishi uchun yo‘l ta’minlangan bo‘lishi kerak, ya’ni uning zanjirida kamida yana bitta yerga ulangan neytral bo‘lishi shart.

Avtotransformatorlarda K-K0 toklari yuqori kuchlanish chulg‘ami tomonidan o‘rta kuchlanish chulg‘ami tomoniga va teskari yo‘nalishda o‘tishi mumkin, chunki yuqori kuchlanish chulg‘amlari avtotransformatorlar uchun umumiy neytralga ega. SHuning uchun almashtirish sxemasida avtotransformatorning barcha chulg‘amlari ishtirok etadi.

G) *HAVO UZATISH LINIYAlari* to‘g‘ri (teskari) ketma-ketlik qarshiligidan ancha katta bo‘lgan X_0 qarshiligiga ega. Buning sababi quyidagicha: To‘g‘ri (yoki teskari) ketma-ketlik toki oqqanda boshqa fazalar bilan o‘zaro induksiya fazalarning umumiy oqimini kamaytirsa, K-K0 toki oqqanda esa u fazalar umumiy oqimini oshiradi. SHunga muvofiq ravishda bir zanjirli uch fazali uzatish liniyasi uchun K-K0 qarshiligi quyidagicha bo‘ladi:

$$x_0 = x_L + 2x_M ,$$

To‘g‘ri ketma-ketlik qarshiligiga esa:

$$x_1 = x_L - x_M$$

Bu yerda x_L va x_M K-K0 tokining yer orqali qaytishini hisobga olib aniqlangan faza induktivligi (reaktansi) va fazalararo induksiya qarshiligi.

Ikki zanjirli uzatish liniyasi har bir zanjirining K-K0 qarshiligiga parallel zanjirlar simlari orasidagi o‘zaro induksiya hisobiga qo‘shimcha yanada ortadi. Parallel zanjirlar bir xil bo‘lganda $x_{I0} = x_{II0} = x_0$ ularning har birining K-K0 qarshiligi

$$x_0^{'} = x_0 + x_{I-II0}$$

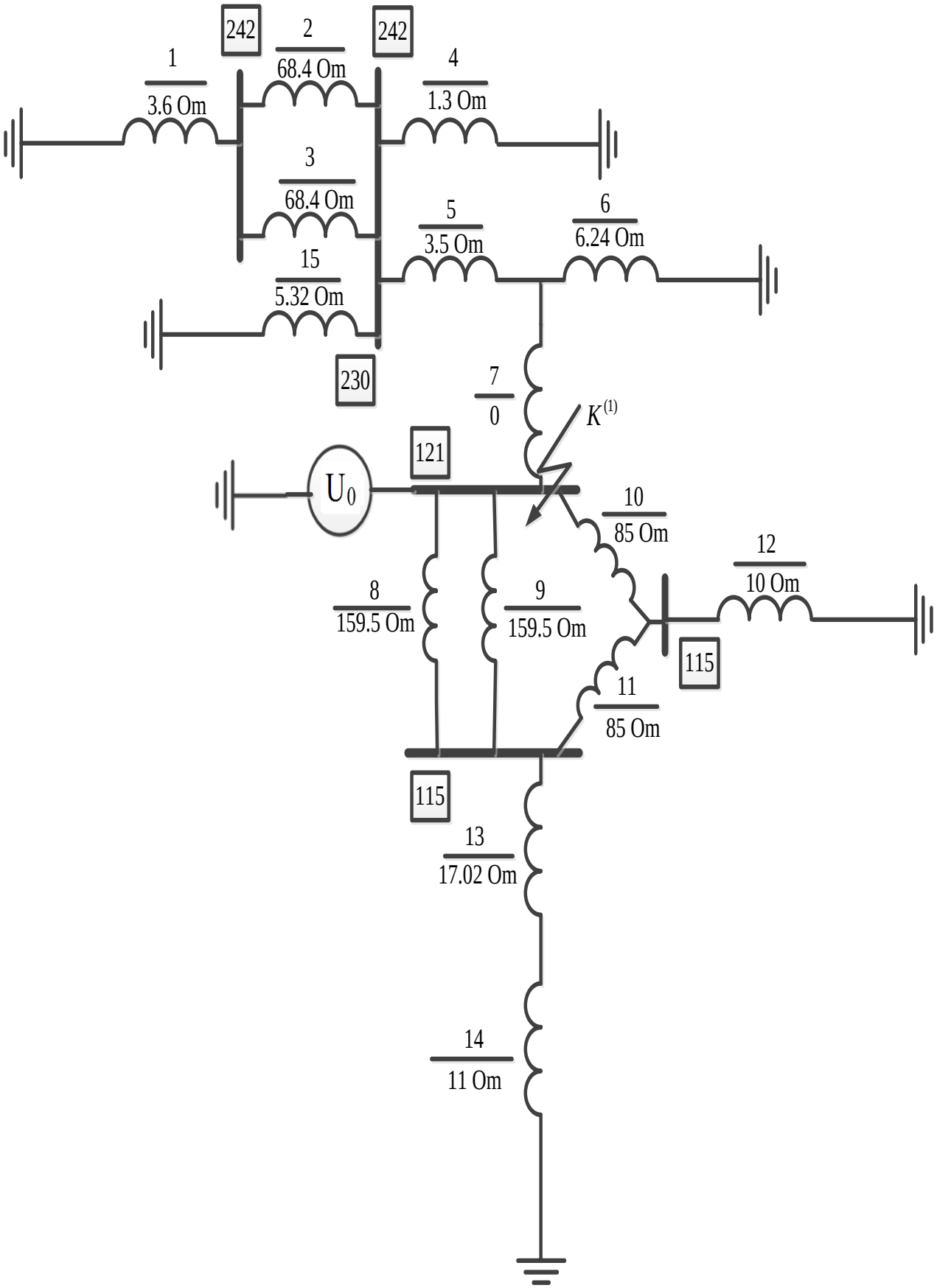
va ularning natijaviy qarshiligi (ya’ni ikki zanjirli uzatish liniyasining umumiy qarshiligi):

$$x_0^{''} = 0.5x_0^{'} = 0.5(x_0 + x_{I-II0}).$$

Agar uzatish liniyasining yerga ulangan yashindan himoyalovchi troslari bo‘lsa, uning K-K0 induktiv qarshiligi trosda paydo bo‘lgan toklar reaksiyasi hisobiga pasayadi.

Amaliy hisoblarda quyidagi qiymatlar qabul qilinadi:

- bir zanjirli trosi yo‘q liniya uchun: $X_0=3,5X_1$,
- yerga ulangan troslar bilan: $X_0=2,0X_1$,
- ikki zanjirlitrosi yo‘q liniya uchun: $X_0=5,5X_1$,
- yerga ulangan troslar bilan: $X_0=3,0X_1$.



23-rasm. Sistemaning tokning nolinchi ketma-ketligiga (K-K0) bo‘lgan almashtirish sxemasi

1) Kuch transformatorlari qarshiliklarini aniqlaymiz

T – 1 $x_1 = \frac{1}{3} \cdot \frac{U_k\%}{100} \cdot \frac{U_n^2}{S_n} \cdot \left(\frac{U_{o'ras}}{U_{o'r}}\right)^2 = \frac{1}{3} \cdot \frac{11\%}{100} \cdot \frac{220^2}{125} \cdot \left(\frac{115}{230}\right)^2 = 3{,}6\ Om$

T – 2 $x_4 = \frac{1}{4} \cdot \frac{U_k\%}{100} \cdot \frac{U_n^2}{S_n} \cdot \left(\frac{U_{o'ras}}{U_{o'r}}\right)^2 = \frac{1}{4} \cdot \frac{11\%}{100} \cdot \frac{220^2}{250} \cdot \left(\frac{115}{230}\right)^2 = 1{,}3\ Om$

AT - 1 $x_5 = \frac{1}{2} \cdot \frac{U_{kн}\%}{100} \cdot \frac{U_n^2}{S_n} \cdot \left(\frac{U_{o'ras}}{U_{o'r}}\right)^2 = \frac{1}{4} \cdot \frac{11{,}5\%}{100} \cdot \frac{220^2}{200} \cdot \left(\frac{115}{230}\right)^2 = 3{,}5\ Om$

$x_6 = \frac{1}{2} \cdot \frac{U_{km}\%}{100} \cdot \frac{U_n^2}{S_n} \cdot \left(\frac{U_{o'ras}}{U_{o'r}}\right)^2 = \frac{1}{2} \cdot \frac{20{,}5\%}{100} \cdot \frac{220^2}{200} \cdot \left(\frac{115}{230}\right)^2 = 6{,}24\ Om$

X7 = 0, Uks = 0

T – 3 $x_{12} = \frac{1}{2} \cdot \frac{U_к\%}{100} \cdot \frac{U_н^2}{S_н} \cdot k_T^2 = \frac{1}{2} \cdot \frac{10{,}5\%}{100} \cdot \frac{110^2}{63} \cdot 1 = 10{,}08\ Om$

T – 4 $x_{13} = \frac{U_{кв}\%}{100} \cdot \frac{U_н^2}{S_н} \cdot \left(\frac{U_{o'ras}}{U_{o'r}}\right)^2 = \frac{11{,}25\%}{100} \cdot \frac{110^2}{80} \cdot 1 = 17{,}02\ Om$

$x_{14} = \frac{U_{кн}\%}{100} \cdot \frac{U_н^2}{S_н} \cdot \left(\frac{U_{o'r.as}}{U_{o'r}}\right)^2 = \frac{7{,}25\%}{100} \cdot \frac{110^2}{80} \cdot 1 = 10{,}97\ Om$

N – 1 $x_{15} = x_{*наг} \cdot \frac{U_н^2}{S_н} \cdot \left(\frac{U_{o'r\ as}}{U_{o'r}}\right)^2 = 0{,}35 \cdot \frac{220^2}{795{,}5} \cdot \left(\frac{115}{230}\right)^2 = 5{,}32\ Om$

2) Xavo uzatish liniyalari qarshiliklarini aniqlaymiz

To‘g‘ri ketma-ketlik qarshiligi

L – 1 $x_{2(1)} = x_{3(1)} = x_0 \cdot l \cdot \left(\frac{U_{o'r\ as}}{U_{o'r}}\right)^2 = 0{,}435 \cdot 210 \cdot \left(\frac{115}{230}\right)^2 = 22{,}84\ Om$

Nol ketma - ketlik qarshiligi

L – 1 $x_{2(0)} = x_{3(0)} = x_{2(1)} \cdot K = 22{,}84 \cdot 3 = 68{,}4\ Om$

To‘g‘ri ketma - ketlik qarshiligi

L – 2 $x_{8(1)} = x_{9(1)} = x_0 \cdot l \cdot \left(\frac{U_{o'r\ as}}{U_{o'r}}\right)^2 = 0{,}413 \cdot 70 \cdot \left(\frac{115}{115}\right)^2 = 29\ Om$

Nol ketma - ketlik qarshiligi

L – 2 $x_{8(0)} = x_{9(0)} = x_{8(1)} \cdot K = 29 \cdot 5{,}5 = 159{,}5\ Om$

To‘g‘ri ketma - ketlik qarshiligi

L – 3; L – 4

$$x_{10(1)} = x_{11(1)} = x_0 \cdot l \cdot \left(\frac{U_{o'r\,as}}{U_{o'r}}\right)^2 = 0{,}405 \cdot 60 \cdot \left(\frac{115}{115}\right)^2 = 24{,}3\ Om$$

Nol ketma - ketlik qarshiligi

L – 3; L – 4

$$x_{10(0)} = x_{11(0)} = x_{10(1)} \cdot K = 24 \cdot 3{,}5 = 85\ Om$$

3) Almashtirish sxemasini soddalashtiramiz

$$x_{16} = x_1 + \frac{x_2 \cdot x_3}{x_2 + x_3} = 3{,}55 + \frac{68{,}4}{2} = 37{,}75\ Om$$

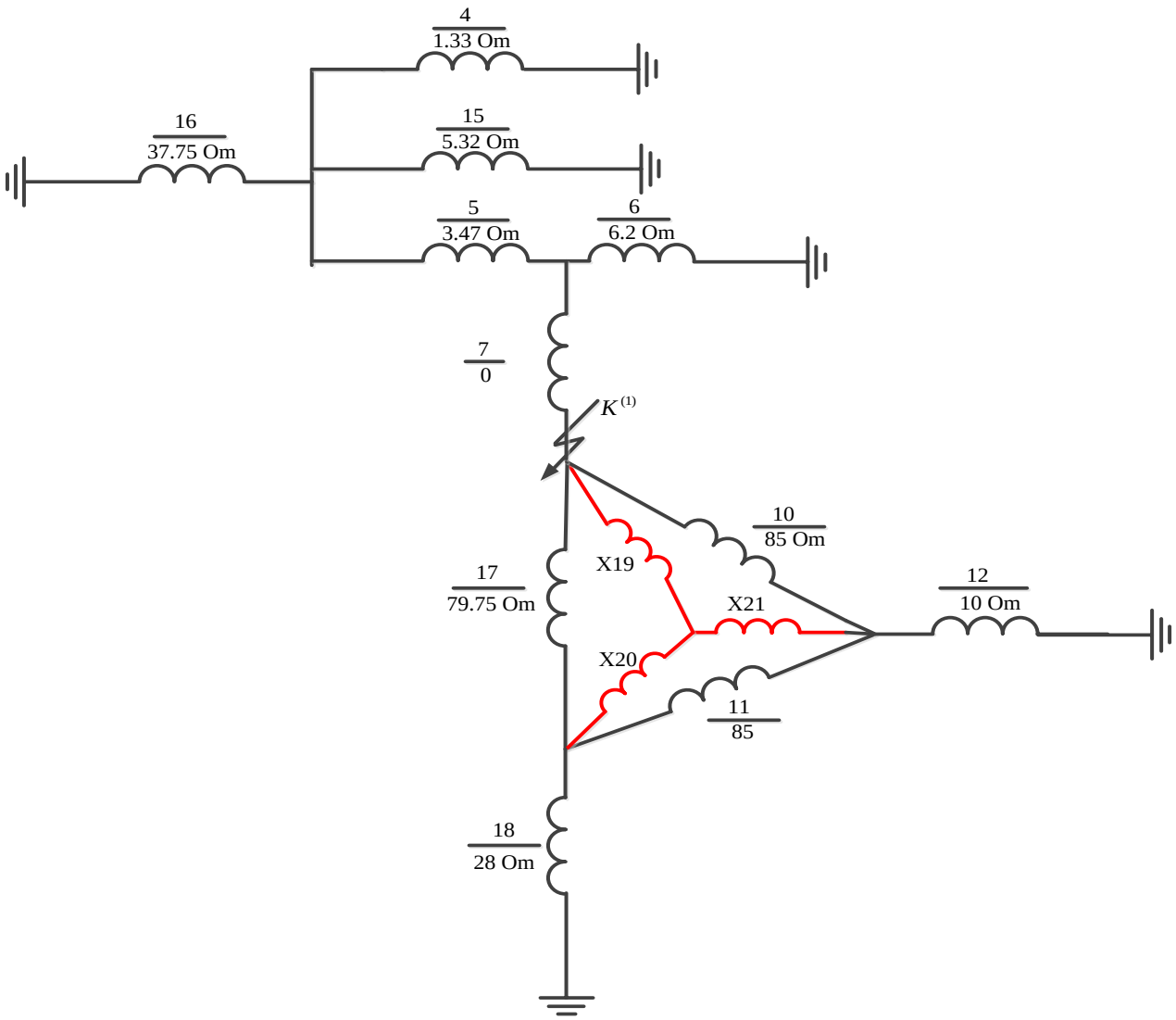
$$x_{17} = \frac{x_8 \cdot x_9}{x_8 + x_9} = \frac{159{,}5}{2} = 79{,}95\ Om$$

$$x_{18} = x_{13} + x_{14} = 17 + 11 = 28\ Om$$

Δ (X_{10}, $X_{11,\ X17}$) qarshiliklardan Y (X_{19}, X_{20}, X_{21}) ga o‘tkazamiz (rasm 24).

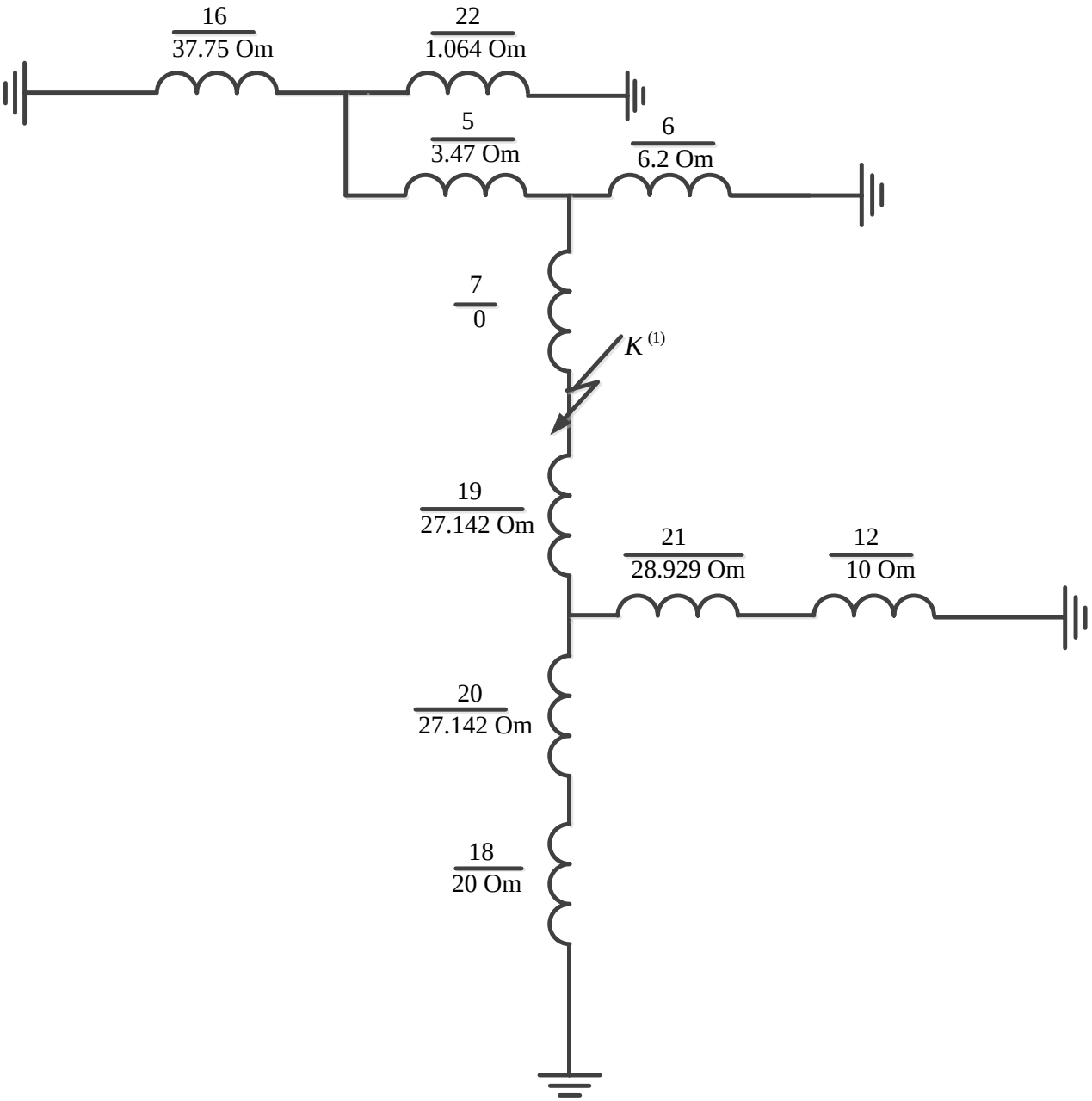
$$x_{19} = x_{20} = \frac{x_{10} \cdot x_{17}}{x_{10} + x_{11} + x_{17}} = \frac{85 \cdot 79{,}75}{85 + 85 + 79{,}75} = 27{,}142\ Om$$

$$x_{21} = \frac{x_{10} \cdot x_{11}}{x_{10} + x_{11} + x_{17}} = \frac{85 \cdot 85}{85 + 85 + 79{,}75} = 28{,}929\ Om$$



24-rasm. Δ (X_{10}, $X_{11,\ X17}$) qarshiliklardan Y (X_{19}, X_{20}, X_{21}) ga o‘tkazganimizdagi almashtirish sxemasi.

$$x_{22} = \frac{x_4 \cdot x_{15}}{x_4 + x_{15}} = \frac{1{,}33 \cdot 5{,}32}{1{,}33 + 5{,}32} = 1{,}064\ Om$$

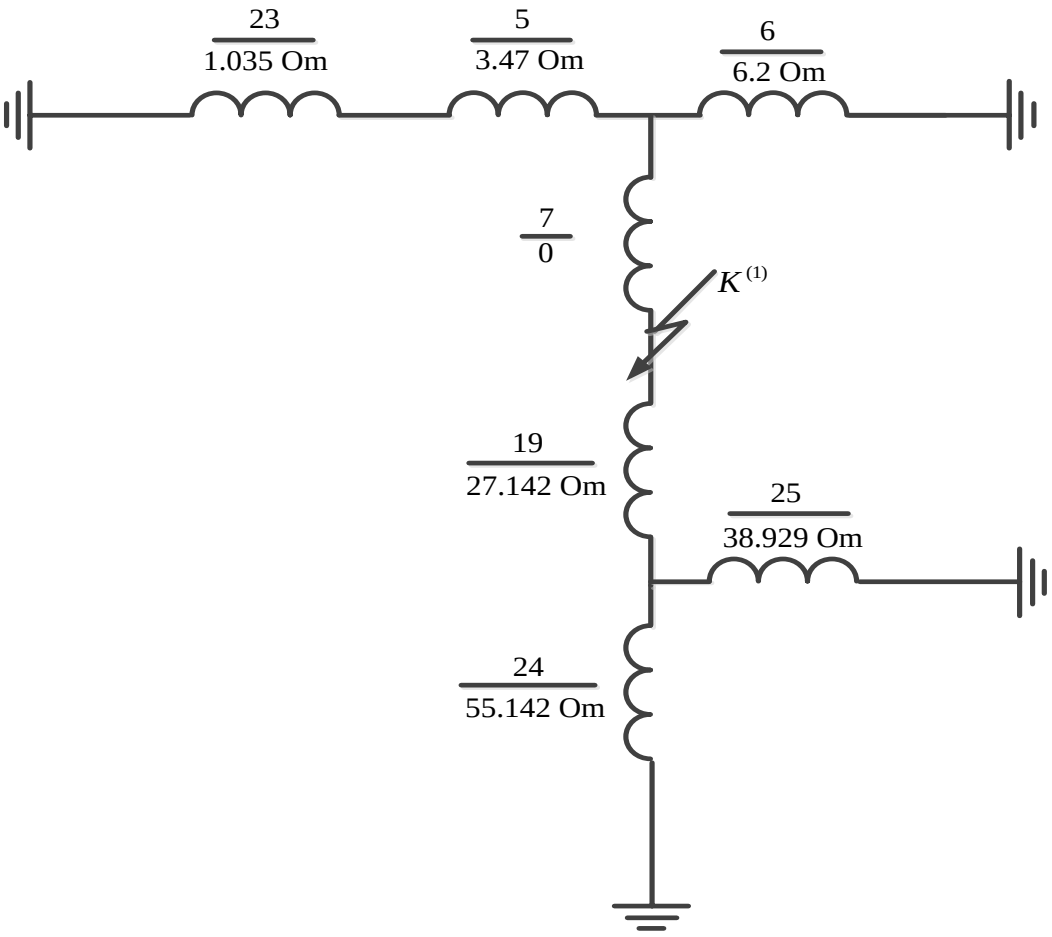


25-rasm. X_4 va X_{15} qarshiliklarni ekvivalent X_{22} qarshilikka almashtirganimizdagi almashtirish sxemasi.

$$x_{23} = \frac{x_{16} \cdot x_{22}}{x_{16} + x_{22}} = \frac{37,75 \cdot 1,064}{37,75 + 1,064} = 1,035\ Om$$

$$x_{24} = x_{18} + x_{20} = 28 + 27,142 = 55,142\ Om$$

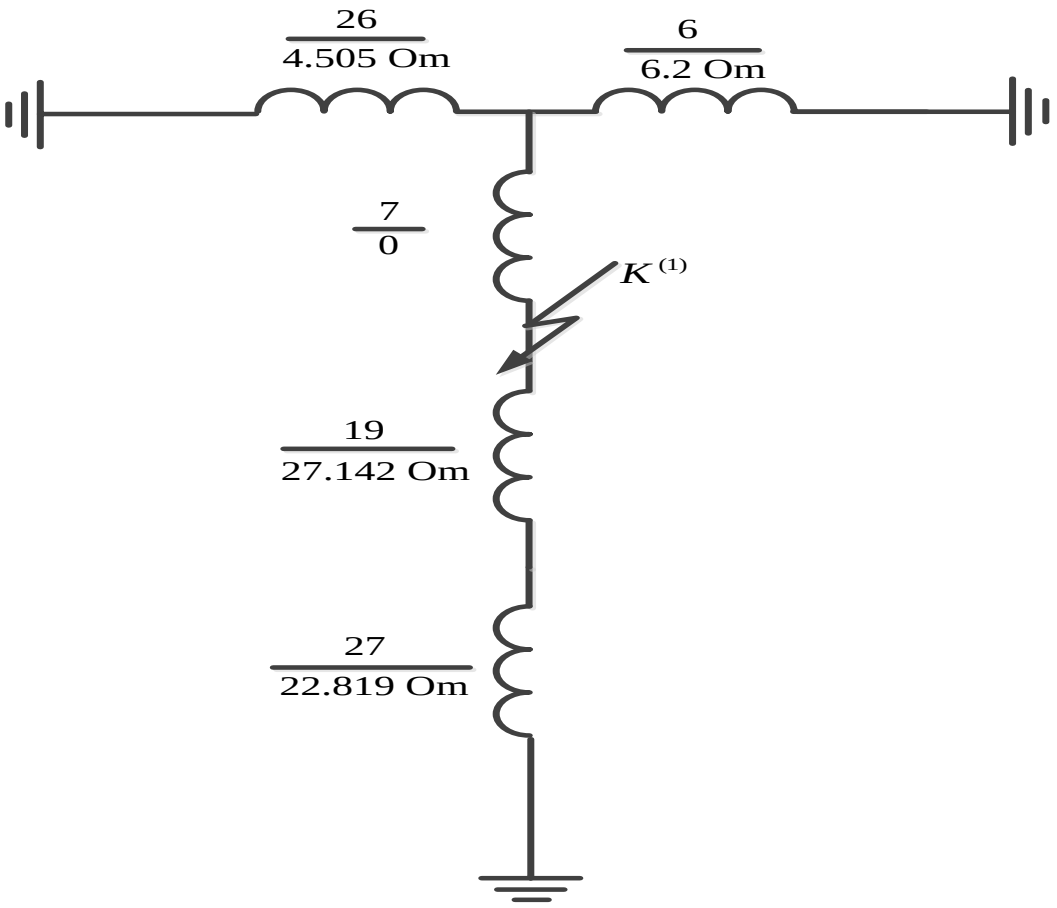
$$x_{25} = x_{12} + x_{21} = 10 + 28,929 = 38,929\ Om$$



26-rasm. X_{23}, X_{24} va X_{25} qarshiliklar hosil bo‘lgandagi almashtirish sxemasi.

$$x_{26} = x_5 + x_{23} = 3.47 + 1{,}035 = 4{,}505\ Om$$

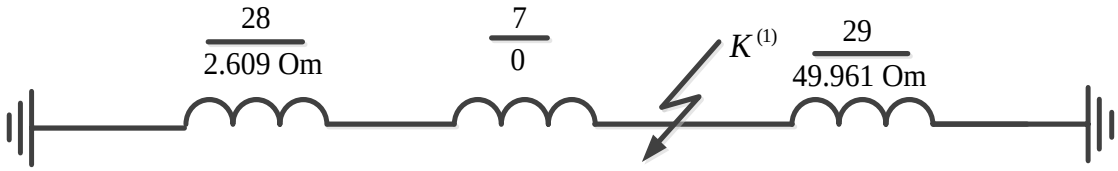
$$x_{27} = \frac{x_{24} \cdot x_{25}}{x_{24} + x_{25}} = \frac{55{,}142 \cdot 38{,}929}{55{,}142 + 38{,}929} = 22{,}819\ Om$$



27-rasm. *X26* va *X27* qarshiliklar hosil bo‘lgandagi almashtirish sxemasi.

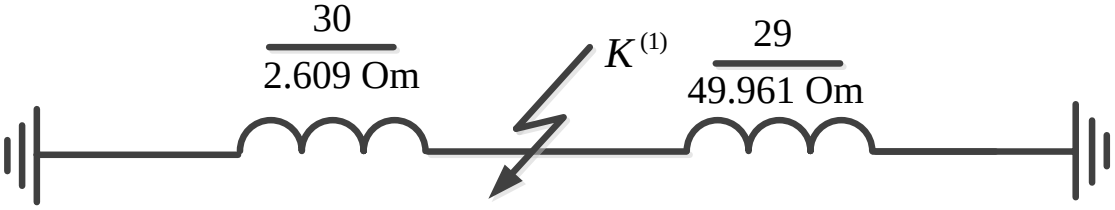
$$x_{28} = \frac{x_6 \cdot x_{26}}{x_6 + x_{26}} = \frac{6{,}2 \cdot 4{,}505}{6{,}2 + 4{,}505} = 2{,}609\ Om$$

$$x_{29} = x_{19} + x_{27} = 27{,}142 + 22{,}819 = 49{,}961\ Om$$



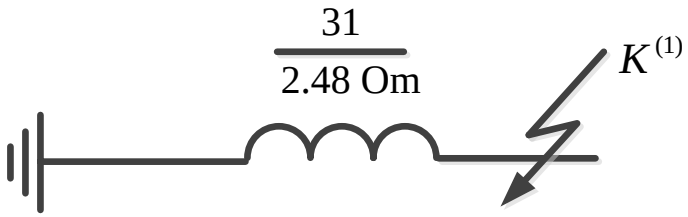
28-rasm. *X28* va *X29* qarshiliklar hosil bo‘lgandagi almashtirish sxemasi.

$$x_{30} = x_{28} + x_7 = 2.609 + 0 = 2{,}609\ Om$$



29-rasm. *X30* qarshilik hosil bo‘lgandagi almashtirish sxemasi.

$$x_{31} = \frac{x_{29} \cdot x_{30}}{x_{29} + x_{30}} = \frac{49{,}961 \cdot 2{,}609}{49{,}961 + 2{,}609} = 2{,}48\ Om$$



30-rasm. Elektr tizimning qisqa tutashuv nuqtasiga nisbatan yig‘ilgan natijaviy nol ketma-ketlik qarshiligi.

4) Bir fazali qisqa tutashuvning to‘g‘ri ketma-ketlik tokini aniqlaymiz

$$I_{A1}^{(1)} = \frac{E_{1\Sigma}}{j(x_{1\Sigma} + x_{\Delta}^{(1)})} = \frac{74.2}{j(6{,}9 + 9{,}5)} = 4{,}5\ kA$$

Qo‘shimcha qarshilik $x_{\Delta}^{(1)} = x_{2\Sigma} + x_{0\Sigma} = 6.9 + 2.6 = 9{,}5\ Om$

5) Bir fazali qisqa tutashuvning to‘liq tokini aniqlaymiz.

$I_{k}^{(1)} = m^{(1)} \cdot I_{kA1}^{(1)} = 3 \cdot 4{,}5 = 13{,}5\ kA$

6) To‘g‘ri, teskari va nol ketma-ketlik kuchlanishlarini aniqlaymiz

$U_{kA1}^{(1)} = jI_{kA1} \cdot x_{\Delta}^{(1)} = j4{,}5 \cdot 9{,}5 = 42{,}8\ kV$

$U_{kA2}^{(1)} = -jI_{kA1} \cdot x_{2\Sigma} = -j4{,}5 \cdot 6{,}9 = 31{,}1\ kV$

$U_{kA0}^{(1)} = -jI_{kA1} \cdot x_{0\Sigma} = -j4{,}5 \cdot 2{,}6 = 11{,}7\ kV$

$\sum (U_{kA1} + U_{kA2} + U_{kA0}) = 0$

Shikastlanmagan «B» va «C» fazalaridagi kuchlanishlar

$$U_{\kappa B}^{(1)} = 0{,}87 \cdot I_{kA1}^{(1)} \cdot (2x_{2\sum} + x_{0\sum}) - j0{,}87 \cdot I_{kA1}^{(1)} \cdot x_{0\sum} =$$

$$= 0{,}87 \cdot 4{,}5 \cdot (2 \cdot 6{,}9 + 2{,}6) - j0{,}87 \cdot 4{,}5 \cdot 2{,}6 = 64{,}2 - j10{,}2 = \left|65\right| e^{-j12^{0}03'}$$

$$U_{\kappa C}^{(1)} = -0{,}87 \cdot I_{kA1}^{(1)} \cdot (2x_{2\sum} + x_{0\sum}) - j0{,}87 \cdot I_{kA1}^{(1)} \cdot x_{0\sum} =$$

$$= -0{,}87 \cdot 4{,}5 \cdot (2 \cdot 6{,}9 + 2{,}6) - j0{,}87 \cdot 4{,}5 \cdot 2{,}6 = -64{,}2 - j10{,}2 = \left|65\right| e^{-j191^{0}03'}$$

Ikki fazali qisqa tutashuv yerga

$$x_{\Delta}^{(1,1)} = \frac{x_{2\Sigma} \cdot x_{0\Sigma}}{x_{2\Sigma} + x_{0\Sigma}} = \frac{6{,}9 \cdot 2{,}6}{6{,}9 + 2{,}6} = 1{,}88\ Om$$

$$I_{A1}^{(1,1)} = \frac{E_{1\Sigma}}{j(x_{1\Sigma} + x_{\Delta}^{(1,1)})} = \frac{74.2}{j(6{,}9 + 1{,}88)} = 8{,}45\ kA$$

$$I_{A2}^{(1,1)} = -\frac{x_{\Delta}^{(1,1)}}{x_{2\Sigma}^{(1,1)}} \cdot I_{A1}^{(1,1)} = -2{,}3\ kA$$

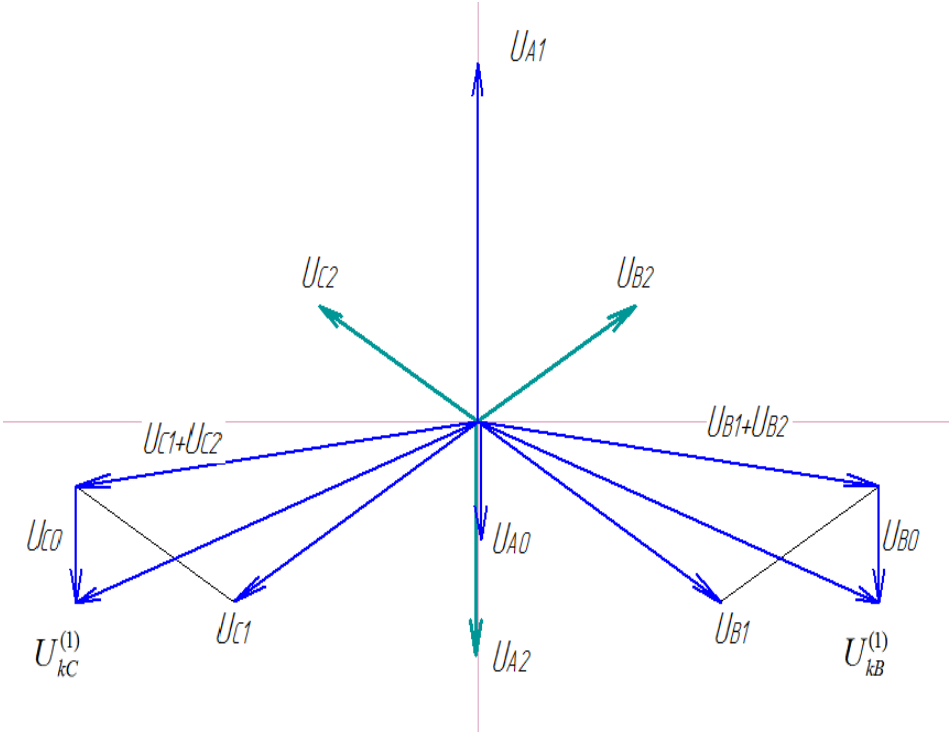
$$I_{A0}^{(1,1)} = -\frac{x_{\Delta}^{(1,1)}}{x_{0\Sigma}^{(1,1)}} \cdot I_{A1}^{(1,1)} = -6{,}11\ kA$$

$$U_{A1}^{(1,1)} = U_{A2}^{(1,1)} = U_{A0}^{(1,1)} = x_{\Delta}^{(1,1)} \cdot I_{A1}^{(1,1)} = 15{,}88\ kV$$

Bir fazali qisqa tutashuv kuchlanishlarining vektor diagrammasi (31-rasm)

$U_{kA1}^{(1)} = 42{,}8\,kV$ $U_{kA2}^{(1)} = 31{,}1\,kV$ $U_{kA0}^{(1)} = 11{,}7\,kV$

Masshtab 1sm = 10 kV

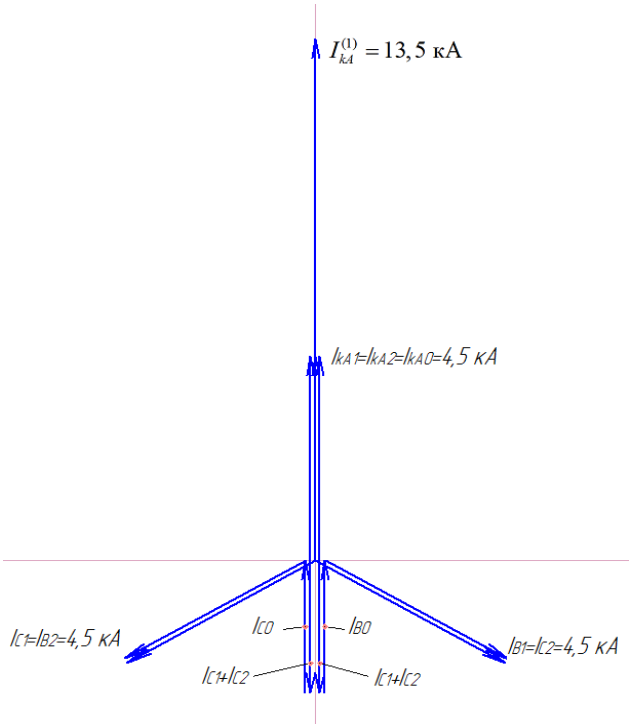


31-rasm. Bir fazali qisqa tutashuv kuchlanishlarining vektor diagrammasi

Bir fazali qisqa tutashuv toklarining vektor diagrammasi (32-rasm)

$I_{A1}^{(1)} = I_{A2}^{(1)} = I_{A0}^{(1)} = 4{,}5$ кА

Masshtab 1sm = 1 kA



32-rasm. Bir fazali qisqa tutashuv toklarining vektor diagrammasi

Kurs ishining ikkinchi qismini bajarish bo‘yicha vazifa

2.1. Elektromexanik o‘tkinchi o‘tish jarayonlarini tahlil qilish:

2. 1.1. Oddiy sistemaning statik turg‘unligini tahlil qilish

2.1.2 Kurs ishining birinchi qismida 1-rasmda berilgan sxemani soddalashtirish natijasida sxemani oddiy elektr sistemasi ko‘rinishiga keltiramiz (33-rasm). Sistema elementlarining parametrlarini sistema kuchlanishiga keltirib nisbiy birliklarda ifodalaymiz. Tanlangan bazis shartlari bo‘yicha rejim parametrlarini nisbiy birlikka keltiramiz.

2.1.3. Elektr sistema rejim parametrlarining skalyar qiymatini aniqlash uchun sistemaning vektor diagrammasini qurib va undan foydalanib sistemaning rejim parametrlari aniqlanilib oddiy elektr sistemaning statik turg‘unligi tahlil qilinsin:

Uzatuvchi stansiya generatorlarida proporsional va kuchli ta’sirli qo‘zg‘atishni avtomatik rostlash (QAR) qurilmasi o‘rnatilgan deb qabul qilib xususiy hollar uchun tarmoq kuchlanishlarining vektor diagrammasi qurilsin. Uzatuvchi stansiyasi generatorlarida berilgan turdagi QAR qurilmasi ishlayotganda elektr sistemaning sun’iy turg‘unlik sohasi aniqlansin. Har bir holat uchun elektr sistemaning $P=f(\delta)$ burchak xarakteristikasi qurilsin va statik turg‘unlik koeffitsiyentlari Kst – hisoblab topilsin. Havo elektr uzatish yo‘lining (HEUY)-ning aktiv qarshiligi yoki yuklama shinalarida kuchlanishning pasayishini hisobga olgan holda sistemaning statik turg‘unlik koeffitsiyenti aniqlansin. Yuklama shinasidagi kuchlanishning pasayishining aktiv quvvat uzatilish chegarasiga ta’sirini hisobga olib aktiv quvvatning haqiqiy uzatilish chegarasini aniqlang.

2.2. Oddiy sistemaning dinamik turg‘unligini tahlil qilish

2.2.1. Normal holat uchun elektr tarmog‘ining almashtirish sxemasi tuzilib, uning quvvat xarakteristikasi (boshlang‘ich ma’lumotlar statik turg‘unlik bo‘limidagi hisoblash natijalaridan olinsin). Bunda uzatuvchi stansiya generatorlarida proporsional ta’sirli quzg‘atishni avtomatik rostlagich (p. t. QAR) o‘rnatilgan deb qabul qilingan. Unda ekvivalent generator sistemaning almashtirish sxemasida o‘zining o‘tkinchi qarshiligi X’d hamda o‘zining o‘zgarmas o‘tkinchi EYuK E’ – orqali ifodalab olinsin. Havo elektr uzatish yo‘lining (HEUY) normal ishlash jarayoni uchun quvvatning $P_I = f(\delta')$ burchak xarakteristikasi qurilsin. Shikastlanish holati uchun elektr sistemaning almashtirish sxemasi

tuzilsin. Uch fazali va indivudial variantda ko‘rsatilgan nosimmetrik qisqa tutashuvlar uchun q.t. tugunida hosil bo‘lgan ekvivalent shunt qarshiligi (X_{SH}) hisoblab topilsin. Hamda ushbu shikastlanish holatlari uchun quvvatning $P_{III}=f(\delta')$ qurilsin.

Elektr uzatish uskunasining shikastlangan qismi rele himoyasi yordamida o‘chirilgan sharoit (ya’ni shikastlanishdan keyingi holat) uchun sistemaning almashtirish sxemasi tuzililib, shunt qarshiligining qiymatini hisobga olgan holda umumiy ekvivalent qarshilik ($X_{\Sigma II}$) aniqlansin va quvvatning burchak xarakteristikasi $P_{II}=f(\delta')$ qurilsin. Sistemaning dinamik turg‘unligini tekshirishda tekisliklar (energetik) qoidasidan foydalanilsin. Sinxron generator rotorining nisbiy harakat teglamasini ketma- ket intervallar usuli yordamida sonli integrallash orqali uch fazali va berilgan turdagi qisqa tutashuvlar tahlil qilinib, tegishli holatlar uchun qisqa tutashuvning o‘chirilish burchagining chegaraviy qiymati (δ_{cheg}) hamda kritik burchak (δ_{KR}) aniqlansin. Qisqa tutashuvning berilgan vaqt davomiyligi ($t_{Q.T}$) uchun elektromexanik o‘tish jarayoni hisoblanib yuklanish burchagining tegishli qiymatlari topilsin. Tezlashish va tormozlanish hamda tormozlanish mumkin bo‘lgan maydonlar qurilsin. Elektr uzatish qurilmasi burchagining vaqt davomida o‘zgarishi grafigi $\delta`=f(t)$ -olinsin.

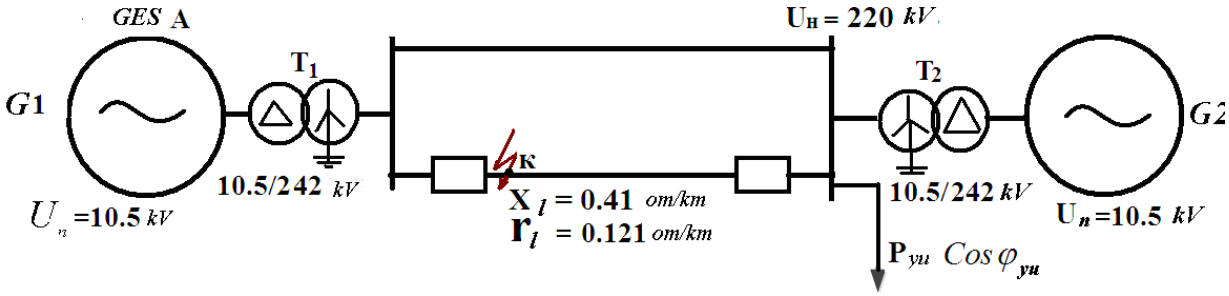
2.2.2. Sistemaning dinamik turg‘unligiga QARning, HEUY-ning o‘chirilgan zanjirini yoki fazasini avtomatik qayta ulash (AQU) qurilmasini qo‘llashning, bug‘ turbinasi quvvatini avariya holatida impulsli yuksizlantirishning ta’siri tahlil qilinsin.

2.3. Kurs ishining ikkinchi qismini bajarishga doir qisqacha nazariy ma’lumot

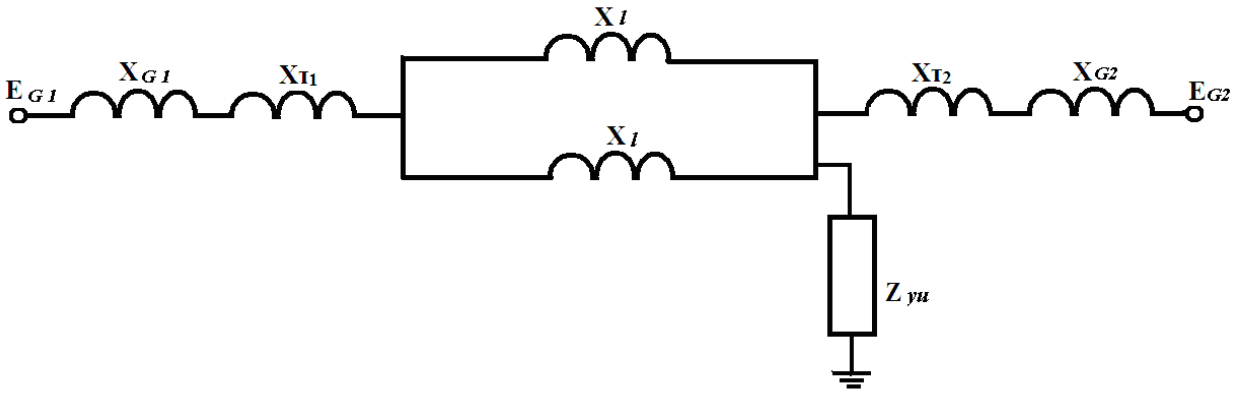
O‘qituvchi tomonidan berilgan elektr sistemasining chizmasi soddalashtirilib, oddiy elektr sistemasining 33 b-rasmdagi ko‘rinishga keltirib olinib quyidagi talablar bajariladi.

O‘qituvchi ko‘rsatmasi bo‘yicha quyidagi holatlar uchun qabul qiluvchi sistema (yuklama) shinalarida kuchlanishni o‘zgarmas bo‘lgan (U_c=const) hol uchun elektr sistema elementlarining parametrlari ixtiyoriy tanlangan bazis shartlari bo‘yicha hisoblab nisbiy birliklarda ifodalansin.

a)



b)



33-rasm. Oddiy elektr sistemasining prinsipial (a) ва almashtirish (b) sxemasi

1) Oddiy elektr sistemaning statik turg‘unligi koeffitsiyentining zaxirasi, hamda uzatilayotgan aktiv quvvatining chegaraviy qiymatlari aniqlansin:

- Sistema elementlarining parametrlari tanlangan bazis shartlari bo‘yicha nisbiy birliklarda ifodalansin;

- uzatuvchi gidravlik elektr stansiya generatorida qo‘zg‘atishni avtomatik rostlagich (QAR) o‘rnatilmagan holat uchun (Eq=const) ;

- issiqlik elektr stansiyasi (IES) generatorlarida proporsional ta’sirli (p.t. QAR) o‘rnatilgan ($E' = const$).

- issiqlik elektr stansiyasi (IES) generatorlarida kuchli ta’sirli (k.t. QAR) o‘rnatilgan (U_G=const).

2) O‘qituvchininig ko‘rsatmasi bo‘yicha elektr uzatish qurilmasida aktiv qarshilikning o‘zgarish yoki yuklama shinalarida kuchlanish o‘zgarishining elektr sistemasining statik turg‘unligi ta’siri baholansin.

3) K -nuqtasida o‘qituvchi tomonidan ko‘rsatilgan qisqa tutashuv (q. t.) bo‘lgan hol uchun q.t o‘chirilishi vaqtining va burchagining chegaraviy qiymati aniqlansin.

4) Yuqorida keltirilgan qisqa tutashuvlar uchun sistemaning dinamik turg‘unligi hisoblansin va unga ba’zi tadbirlarning ta’siri baholansin:

a) Sistema dinamik turg‘unligiga q.t. turi va vaqtining;

b) Sistema dinamik turg‘unligiga QARning;

c) Sistema turg‘unligiga elektr uzatish uskunasi zanjirlarida avtomatik qayta ulagich (AQU) qurilmasini qo‘llash;

d) Bug‘ turbinasi quvvatini avariya holatida boshqarish (BTAXB);

5) Sistemaning berilgan sxemasi uchun yuklamaning (asinxron motorning) parametrlari aniqlanib statik va dinamik xarakteristikalari qurilsin. Asinxron motorning rostlash effekti va statik turg‘unlik mezoni aniqlanib sistema turg‘unligi baholansin.

IZOH: elektreneregetika sistema elementlari (generatorlar, transformatorlar, havo elektr uzatish yo‘li, kompensatsiyalovchi qurilmalar va yuklamalarning) parametrlari va sistema holatining boshlangich qiymatlari (shartlari) har bir talaba uchun alohida variantlarda ko‘rsatilgan tartibda o‘qituvchi tomonidan berilgan.

2. 4. Kurs ishining ikkinchi qismini bajarish tartibi

O‘tkinchi jarayonlar fanidan kurs ishining ikkinchi qismini bajarish uchun boshlang‘ich qiymatlar:

Γ_1: $P_{G1} = 270 MVt$; $\cos\varphi_H = 0.9$; $T_J = 7.6c$; $U_H = 10.5 kV$;

$X_d = 0.75 n.b.$; $X_2 = 0.3 n.b.$; $X_q = 0.46 n.b.$; $X'_d = 0.27 n.b$

Γ_2: $P_{\Gamma 2} = 800 MVt$; $\cos\varphi_H = 0.8$; $X_{d2} = 1.896 n.b.$

T_1: $S_{T1} = 3x125$ MVa; $U_{K\%} = 11$; $U_{HTP} = 242 kV$

T_2: $S_{T2} = 3x353 MVa$; $U_{K\%} = 11$; $U_{HTP} = 242 kV$

Yuklama: $P_{IO} = 840 MVt$; $Cos\varphi_H = 0.89$

Elektr uzatish yo‘li:

$l = 210$ km; $P_0 = 265$ MVt; $Cos\varphi_0 = 0.97$

Qisqa tutashuv shartlari:

$t_{KT} = 0.3c$; $t_{AKY} = 0.25c$; $\Delta t = 0.05c$

2.4.1. Sistemaning rejim va almashtirish sxemasining parametrlarini nisbiy birliklarda ifodalash.

Sistema elementlarining almashtirish sxemasi parametrlarini va sistemaning rejim parametrlarini tanlangan bazis shartlari bo‘yicha nisbiy birliklarga keltiramiz. Hisoblash ishlarini bajarishda aktiv quvvat uchun bazis shartini normal rejimda sistemaga uzatilayotgan aktiv quvvatni va kuchlanish bo‘yicha bazis sharti sifatida qabul qiluvchi sistema qisqichidagi kuchlanishni olamiz.

$$P_b = P_0 = 265 \text{ MVt}; \; U_b = U_0 = 220 kV$$

U holda sistemaga uzatilayotgan aktiv va sistema kuchlanishini nisbiy birlikda ifodalaymiz:

$$\mathrm{P}_0=\frac{\mathrm{P}_0\mathrm{MB_T}}{\mathrm{P}_b\,\mathrm{MB_T}}=\frac{265\,\mathrm{MB_T}}{265\,\mathrm{MB_T}}=1$$

$$U_0=\frac{U_0\,kV}{U_b\,kV}==\frac{220\,kV}{220\,kV}=1$$

Sistemaga P_0 aktiv quvvatni uzatib berish uchun kerak bo‘ladigan reaktiv quvvatni, sistema kuchlanishi bilan sistemaga kelayotgan tok orasidagi faza siljishini sistemaning quvvat koeffitsiyentidan aniqlaymiz:

$$Cos\varphi_0=0.97$$

$$\varphi_0=\arccos 0.97=14.07^0$$

Quvvatlar uchburchagidan reaktiv quvvatni aniqlaymiz

$$\frac{Q_0}{\mathrm{P}_0}=tg\varphi_0\rightarrow Q_0=\mathrm{P}_0 tg\varphi_0=1\cdot tg14.07^0=0.251$$

Sistema almashtirish sxemasi parametrlari

G_1: Sinxron generatorning d o‘qi bo‘yicha sinxron induktiv qarshiligi

$$\mathrm{X}d_1=\frac{\mathrm{X}d\cdot\mathrm{P}_B\cdot U_n^2}{n_\Gamma\cdot S_{ng}U_B^2}\cdot\mathrm{K}_\mathrm{T}^2=\frac{\mathrm{X}d\cdot\mathrm{P}_b\cdot U_n^2}{n_\Gamma\cdot S_bU_b^2}\cdot\frac{U_{ntr}^2}{U_{ng}^2}=\frac{0.75\cdot265\cdot10.5^2}{3\cdot90\cdot220^2}\frac{242^2\cdot0.9}{10.5^2}=0.802$$

Sinxron generatorning q o‘qi bo‘yicha sinxron induktiv qarshiligi

$$\mathrm{X}q_1=\frac{\mathrm{X}q\cdot\mathrm{P}_b\cdot U_n^2}{n_g\cdot S_{ng}U_b^2}\cdot\mathrm{K}_\mathrm{T}^2=\frac{\mathrm{X}q\cdot\mathrm{P}_b\cdot U_n^2}{n_g\cdot S_{ng}U_b^2}\cdot\frac{U_{ntr}^2}{U_{ng}^2}=\frac{0.46\cdot265\cdot10.5^2}{3\cdot90\cdot220^2}\frac{242^2\cdot0.9}{10.5^2}=0.492$$

Sinxron generatorning d o‘qi bo‘yicha o‘tkinchi induktiv qarshiligi

$$\mathrm{X}'d_1=\frac{\mathrm{X}'d\cdot\mathrm{P}_b\cdot U_n^2}{n_g\cdot S_{ng}U_b^2}\cdot\mathrm{K}_\mathrm{T}^2=\frac{\mathrm{X}'d\cdot\mathrm{P}_b\cdot U_n^2}{n_g\cdot S_{ng}U_b^2}\cdot\frac{U_{ntr}^2}{U_{ng}^2}=\frac{0.27\cdot265\cdot10.5^2}{3\cdot90\cdot220^2}\frac{242^2\cdot0.9}{10.5^2}=0.289$$

Sinxron generator stator chulg‘amining qisqa tutashuv tokining teskari tashkil etuvchisiga bo‘lgan induktiv qarshiligi

$$\mathrm{X}_{2G1}=\frac{\mathrm{X}_{2g1}\cdot\mathrm{P}_B\cdot U_n^2}{n_g\cdot S_{ng}U_b^2}\cdot\mathrm{K}_\mathrm{T}^2=\frac{\mathrm{X}_{2g1}\cdot\mathrm{P}_b\cdot U_n^2}{n_g\cdot S_{ng}U_b^2}\cdot\frac{U_{ntr}^2}{U_{ng}^2}=\frac{0.23\cdot265\cdot10.5^2}{3\cdot90\cdot220^2}\frac{242^2\cdot0.9}{10.5^2}=0.245$$

T1: transformatorning induktiv qarshiligi

$$\mathrm{X}_{\mathrm{T}1}=\frac{U_{\mathrm{K}\%.}\cdot\mathrm{P}_b\cdot U_{ntr1}^2}{100\cdot n\cdot S_{ntr1}\cdot U_b^2}=\frac{11\cdot265\cdot242^2}{100\cdot3\cdot125\cdot220^2}=0.094$$

Ikkita parallel elektr uzatish yo‘lining reaktiv qarshiligi:

$$\mathrm{X}_l=\frac{\mathrm{X}_0l}{2}\frac{\mathrm{P}_b}{U_b^2}=\frac{0.435\cdot210\cdot265}{2\cdot220^2}=\frac{0.50}{2}=0.25$$

Ikkita parallel elektr uzatish yo‘lining aktiv qarshiligi:

$$r_l=\frac{r_0l}{2}\frac{\mathrm{P}_b}{U_b^2}=\frac{0.121\cdot210\cdot270}{2\cdot220^2}=0.07$$

Qabul qiluvchi sistema generatorining bo‘ylama (d) o‘qi bo‘yicha induktiv qarshiligi

$$\mathrm{X}d_2 = \frac{\mathrm{X}d_2 \cdot \mathrm{P}_b \cdot U_n^2}{n_\Gamma \cdot S_{ng2} \cdot U_b^2} \cdot \mathrm{K}_\mathrm{T}^2 = \frac{\mathrm{X}d_2 \cdot \mathrm{P}_b \cdot U_n^2}{n_\Gamma \cdot S_{ng2} \cdot U_b^2} \cdot \frac{U_{ntr}^2}{U_{ng}^2} = \frac{1.896 \cdot 265 \cdot 13.8^2}{4 \cdot 200 \cdot 220^2} \frac{242^2 \cdot 0.85}{13.8^2} = 0.646$$

T2: transformatorning induktiv qarshiligi

$$\mathrm{X}_{t2} = \frac{U_{\mathrm{K}\%.} \cdot \mathrm{P}_b \cdot U_{ntr1}^2}{100 \cdot n \cdot S_{ntr1} \cdot U_b^2} = \frac{11 \cdot 265 \cdot 242^2}{100 \cdot 4 \cdot 250 \cdot 220^2} = 0.035$$

Yuklamaning aktiv va reaktiv qarshiliklarini quyidagi formuladan foydalanib aniqlaymiz:

$$\bar{Z}_{yu} = R_{yu} + j\mathrm{X}_{yu}; \qquad Z_{yu} = \sqrt{R_{yu}^2 + \mathrm{X}_{yu}^2}$$

$$\bar{Z}_{yu} = Z_{yu} e^{j\varphi_{yu}}$$

$$Z_{yu} = \frac{U_{yu}^2}{S_{yu}} (\cos\varphi_{yu} + jSin\varphi) \frac{\mathrm{P}_b}{U_b^2} = \frac{220^2}{\frac{840}{0.89}} (0.89 + j0.456) \frac{265}{220^2} =$$

$$= \frac{0.89 \cdot 265}{840} (0.89 + j0.456) = 0.25 + j0.128$$

$$Z_{yu} = \sqrt{0.25^2 + 0.128^2} = \sqrt{0.0625 + 0.0164} = 0.281 e^{j\,27.11^0}$$

$$\varphi_{yu} = arctg \frac{0.128}{0.25} = 27.11^0$$

2.4.2 Sistemaning statik turg‘unligini tekshiramiz

Sistemaning rejim parametrlarining skalyar qiymatini aniqlash uchun vektor diagrammasini quramiz.

Uzatuvchi stansiya cheksiz quvvatli sistema bilan parallel ishlayotgan bo‘lsa oddiy elektr sistemaning ishlash rejimini tahlil qilishimizda uning ikkita xususiy holatiga mos keluvchi, ya’ni normal davrtezlikdagi ($\omega_0=\omega_g$) va normal davrtezlikdan farq qiluvchi ($\omega_0\neq\omega_g$) vektor diagrammani qurishimiz mumkin.

Oddiy elektr sistemaning vektor diagrammalarini uzatayotgan stansiya ayon (GES) va noayon (IES) qutbli generatorlar bilan jihozlangan holatlar uchun quriladi. Vektor diagrammani qurish uchun elektr sistemaning normal ishlashida har xil QARli xususiy hollariga mos keluvchi almashtirish sxemasini tuzamiz. Oddiy elektr sistemaning holat parametrlari orasidagi bog‘lanishni topish uchun uning vektor diagrammasidan foydalanamiz. Bu diagrammadan ekvivalent generatorda qaysi turdagi QAR borligini e’tiborga olib tegishli elektr yurituvchi

kuchlar $E_q, E_q^{'}, U_\Gamma, E_Q$- larni topamiz. Agar sistema rostlanmaydigan va uning generatorlarining magnit sistemasi to‘yinmagan bo‘lsa, bu diagrammadagi generatorning salt ishlash rejimidagi EYUK $E_q$uning qo‘zg‘atish tokiga proporsional bo‘ladi. Rostlanmaydigan sistemaning ish rejimi sekin o‘zgarganida bu EYUK o‘zgarmasdan qoladi va sistema holati keskin o‘zgarganida esa bu EYUK rotor tokining o‘zgarishini tokrorlaydi deb olinadi. Hisobiy bog‘lanishlarni aniqlash amallari nisbiy birliklar sistemasidan foydalanilgan holda olib boriladi.

Ekvivalent generatordan undagi qo‘llanilgan avtomatik rostlagichlarning turiga qarab sistemaning rejim parametrlari va ular orasidagi bog‘lanishni olish uchun vektor diagrammani qurishda quyidagi amallar ketma-ketligi bajariladi:

1. Sistema kuchlanishi U_0 son jihatdan aniq va o‘zgarmas bo‘lganligidan uni nisbiy birlikda sanoq boshi ko‘rinishida qabul qilib, uni tanlangan masshtabda ixtiyoriy yo‘nalishda qo‘yib olamiz;

2.Sistemaning quvvat koeffitsiyenti $Cos\varphi_0$-ga mos keluvchi va kuchlanish vektoridan φ_0 -burchakga orqada qoluvchi sistemaga oqib kelayotgan tok I vektorini qo‘yib olamiz;

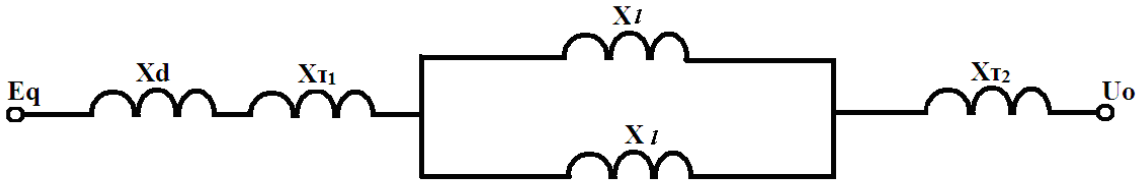
3. Sistemaga kirayotgan tokni uning aktiv I_a va reaktiv I_P tashkil etuvchilarga ajratamiz. Tokning aktiv tashkil etuvchisini ushbu ifodadan foydalanib topamiz

$$P_0 = \sqrt{3}U_0 I\cos\varphi_0 \rightarrow I_a = \frac{P_0}{\sqrt{3}U_0} = \frac{1}{\sqrt{3}} = 0.577$$

Topilgan tokning aktiv tashkil etuvchisining yo‘nalishi sistema kuchlanishi vektorining yo‘nalishi bilan ustma-ust tushadi;

4. Tok Ia vektorining oxiridan tushirilgan perpendikulyarni tok I vektor bilan kesishishigacha davom ettiramiz. Bu bizga tok vektorining Ip tashkil etuvchisini beradi;.

a) Sinxron generatorda QAR o‘rnatilmagan va ayon qutblilik hisobga olinmaydi (34-rasm):



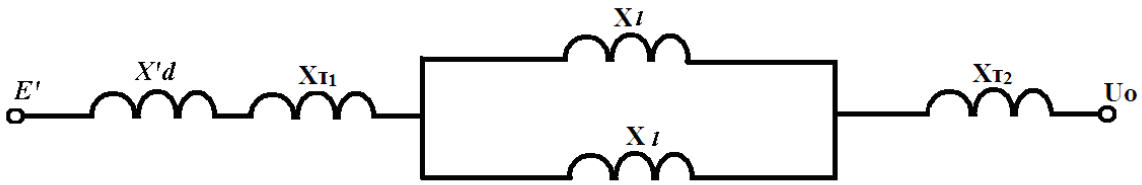
34-rasm. Oddiy elektr sistemaning generatorida QAR o‘rnatilmagan holat uchun almashtirish sxemasi.

Sistemaning to‘la induktiv qarshiligini topamiz;

$$X_{d\Sigma} = X_d + X_{T1} + \frac{X_l}{2}$$

$$E_q = U_0 + X_{d\Sigma} I = U_0 + X_{d\Sigma}(I_a + jI_P)$$

b) Sinxron generatorda p.t. QAR o‘rnatilgan va ayon qutblilik hisobga olinmaydi (35-rasm):



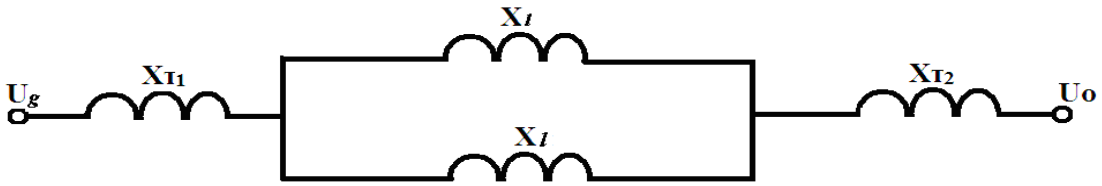
35-rasm. Oddiy elektr sistemaning ekvivalent generatorida p.t. QAR o‘rnatilgan

Sistemaning to‘la induktiv qarshiligini topamiz;

$$X'_{d\Sigma} = X'_d + X_{T1} + \frac{X_l}{2}$$

$$E' = U_0 + X'_{d\Sigma} I = U_0 + X'_{d\Sigma\, d\Sigma}(I_a + jI_P)$$

v) Sinxron generatorda k.t. QAR o‘rnatilgan va ayon qutblilik hisobga olinmaydi (36-rasm):



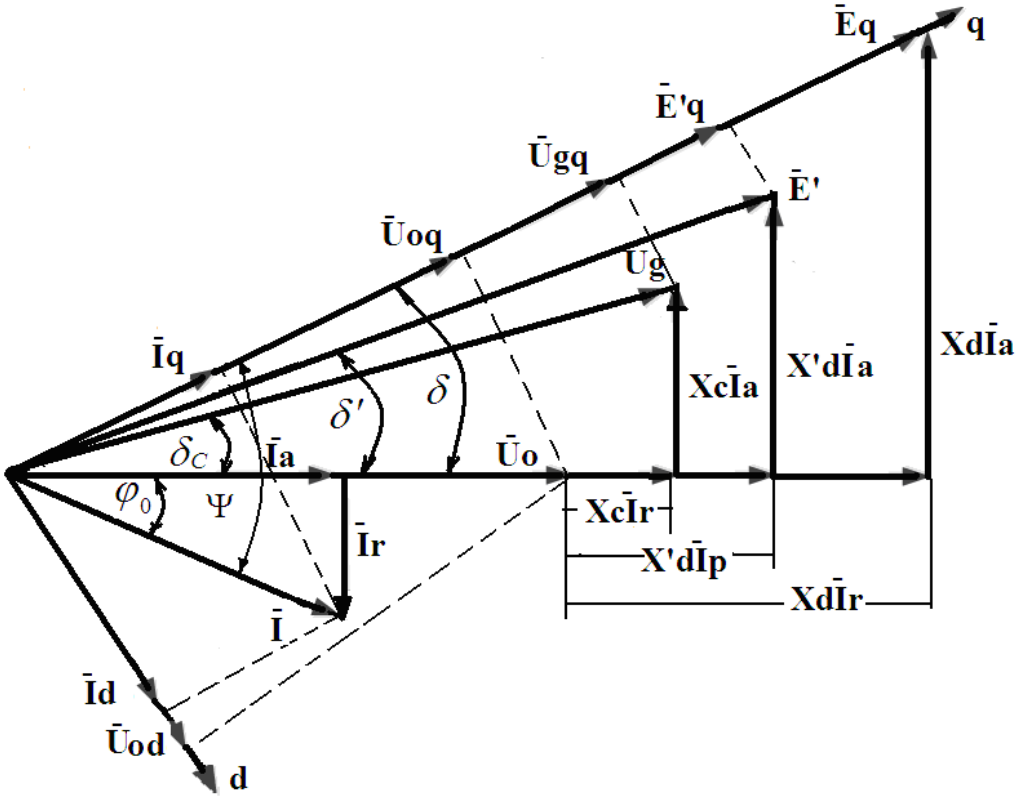
36-rasm. Oddiy elektr sistemaning ekvivalent generatorida k.t. QAR o‘rnatilgan.

Sistemaning to‘la induktiv qarshiligini topamiz;

$$X_C = X_{t1} + \frac{X_l}{2} = 0.094 + 0.25 = 0.344$$

$$U_\Gamma = U_0 + X_C I = U_0 + X_C(I_a + jI_P)$$

2. Om qonunining vektor ko‘rinishidan foydalanib, E_q, E', U_Γ, E_Q larning geometrik o‘rnining topilishi biz qidirayotgan vektor diagrammaning qurilganini bildiradi (37- rasm)



37-rasm. Noayon qutbli sinxron generatorli oddiy elektr sistemaning vektor diagrammasi

Vektor diagrammadan Pifagor teoremasidan foydalanib ekvivalent generatordan sistemaga uzatilayotgan aktiv quvvatning maksimal qiymatini, generatorlarning yuklanish burchagini va statik turg‘unlik koeffitsiyentining zaxirasini unda mavjud bo‘lgan qo‘zg‘atishni avtomatik rostlagichlar turiga mos keluvchi formulalarini keltirib chiqaramiz. Izlanayotgan rejim parametrlarining skalyar qiymatini aniqlaymiz:

a) ekvivalent generatorda kuchli ta’sirli (k.t.) QAR bor bo‘lsin. Ichki uchburchakdan foydalanib generator qisqichlaridagi kuchlanish vektori U_g ni aniqlaymiz:

$$U_g^2 = (U_0 + X_C I_r)^2 + (X_C I_a)$$

(Bizga doimo sistemada oqayotgan tok emas, balki sistemaga uzatilayotgan aktiv quvvat bilan reaktiv quvvat aniq, u holda toklarni quvvatlar orqali ifodalaymiz.) Toklarni aktiv va reaktiv quvvatlar orqali

$$I_a = \frac{P_0}{U_0} \text{ va } I_r = \frac{Q_0}{U_0}$$

ifodalaymiz, chunki sistemada uzatilayotgan aktiv va reaktiv quvvatlar ma’lum. U holda generator shinasidagi kuchlanishni aniqlovchi ifodani olamiz va sonli qiymatini aniqlaymiz.

$$U_g = \sqrt{(U_0 + \frac{X_C Q_0}{U_0})^2 + (\frac{X_C P_0}{U_0})^2} = \sqrt{(1 + \frac{0.251 \cdot 0.344}{1})^2 + (\frac{1 \cdot 0.344}{1})^2} = 1.14$$

Uzatilayotgan aktiv quvvatga mos keluvchi generator kuchlanishi bilan sistema kuchlanishi vektorlari orasidagi burchakni aniqlaymiz:

$$U_g \hat{} U_0 \to \delta_C = arctg \frac{X_C P_0}{U_0^2 + X_C Q_0} = arctg \frac{0.344 \cdot 1}{1^2 + 0.251 \cdot 0.344} = 17.57^0 .$$

Burchak sinusini aniqlash formulasidan foydalanib

$Sin\delta_C = \frac{X_C I_a}{U_\Gamma} \to I_a = \frac{U_g}{X_C} Sin\delta_c$-ni topib, kuchli ta'sirli QARli ekvivalent generatordan sistemaga uzatilayotgan aktiv quvvatni aniqlovchi formulani aniqlaymiz

$$P_{U\Gamma} = U_0 I_a = \frac{U_g U_0}{X_C} Sin\delta_C = \frac{1.14 \cdot 1}{0.344} Sin17.57^0 = 1.$$

Uzatilayotgan aktiv quvvatning maksimumiga $\delta = 90^0$ erishadi

$$P_{max} = \frac{1.14 \cdot 1}{0.344} = 3.314$$

Sistemaning statik turg‘unlik zaxirasini aniqlaymiz

$$K_{CT} = \frac{3.314 - 1}{1} \cdot 100\% = 231.4\%$$

b) ekvivalent generatorda proporsional ta'sirli qo‘zg‘atishni avtomatik rostlagich(p.t. QAR) o‘rnatilgan E′ = const.

Sistemaning almashtirish sxemasidan to‘la induktiv qarshilikni aniqlaymiz:

$$X'_{d\Sigma} = X'_d + X_{T1} + \frac{X_l}{2} = 0.289 + 0.094 + 0.250 = 0.633$$

Ikkinchi uchburchakdan yuqoridagi amallarni bajarish natijasida quyidagi formulalarni keltirib chiqaramiz:

$$E' = \sqrt{(U_0 + \frac{X'_{d\Sigma} Q_0}{U_0})^2 + (\frac{P_0 \cdot X'_{d\Sigma}}{U_0})^2} = \sqrt{(1 + \frac{0.633 \cdot 0.251}{1})^2 + (\frac{1 \cdot 0.633}{1})^2} = 1.32$$

Generator o‘tkinchi EYUK si bilan sistema kuchlanishi vektorlari orasidagi burchakni aniqlaymiz:

$$E' \hat{} U_0 \to \delta' = arctg \frac{X'_{d\Sigma} P_0}{U_0^2 + X^1_{d\Sigma} Q_0} = arctg \frac{1 \cdot 0.633}{1 + 0.633 \cdot 0.251} = 28.64^0$$

$Sin\delta' = \frac{X'_{d\Sigma} I_a}{E'}$ sinδ'-dan tokning aktiv tashkil etuvchisini $I_a = \frac{E'}{X'_{d\Sigma}} Sin\delta'$ topib p.t. QAR-li ekvivalent generatordan sistemaga uzatilayotgan aktiv quvvatni aniqlash formulasini olamiz

$$P_{E'} = U_0 I_a = \frac{E' U_0}{X'_{d\Sigma}} Sin\delta' = \frac{1.32 \cdot 1}{0.633} Sin28.64^0 = 1$$

Uzatilayotgan aktiv quvvatning maksimumiga $\delta = 90^0$-da erishadi

$$P_{max} = \frac{E' \cdot U_0}{X^1_{d\Sigma}} = \frac{1.32 \cdot 1}{0.633} = 2.09$$

Sistemaning statik turg‘unlik zaxirasini aniqlaymiz

$$K_{CT} = \frac{P_{max} - P_0}{P_0} \cdot 100\% = \frac{2.09 - 1}{1} \cdot 100\% = 109\%$$

v) ekvivalent generatorida qo‘zg‘atishning avtomatik rostlagichi yo‘q bo‘lsin Eq = const.

Sistemaning almashtirish sxemasidan to‘la induktiv qarshiligini hisoblaymiz

$$X_{d\Sigma} = X_d + X_{T1} + \frac{X_l}{2} = 0.802 + 0.094 + 0.25 = 1.146$$

Tashqi uchburchakdan foydalanib amallarni bajarish natijasida ichki elektr yurituvchi kuchni Eq va ekvivalent generatordan uzatilayotgan aktiv quvvatni aniqlash formulalarini olamiz.

$$E_q = \sqrt{(U_0 + \frac{X_{d\Sigma} Q_0}{U_0})^2 + (\frac{P_0 X_{d\Sigma}}{U_0})^2} = \sqrt{(1 + \frac{0.251 \cdot 1.146}{1})^2 + (\frac{1 \cdot 1.146}{1})^2} =$$

$$\sqrt{(1.288)^2 + (1.146)^2} = 1.723$$

E_q bilan sistema kuchlanishi U_0 vektorlari orasidagi burchakni aniqlaymiz

$$E_q \hat{} U_0 \rightarrow \delta = arctg \frac{X_{d\Sigma} P_0}{U_0^2 + X_{d\Sigma} Q_0} = arctg \frac{1 \cdot 1.146}{1 + 0.251 \cdot 1.146} = 41.67^0.$$

$Sin\delta = \frac{X_{d\Sigma} \cdot I_a}{E_q}$-dan, $I_a = \frac{E_q}{X_{s\Sigma}} Sin\delta$-topib olgandan keyin

$$P_{Eq} = \frac{E_q U_0}{X_{d\Sigma}} Sin\delta = \frac{1.723 \cdot 1}{1.146} Sin41.67 = 1$$-ni olamiz.

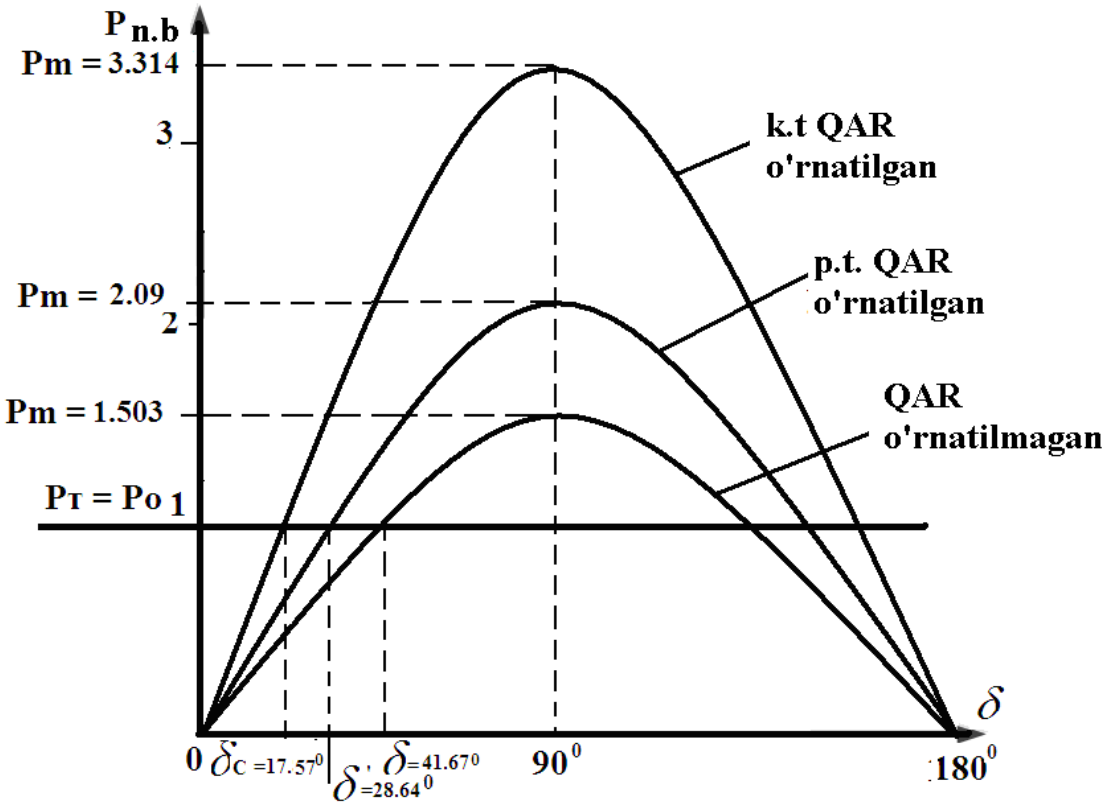
Ekvivalent generatorda QAR o‘rnatilmagan bo‘lsa, sistemaga uzatilayotgan maksimal aktiv quvvat.

$$P_{MAX} = \frac{E_q \cdot U_0}{X_{d\Sigma}} = \frac{1.723 \cdot 1}{1.146} = 1.503$$

Sistema statik turg‘unligi koeffitsiyentining zaxirasini aniqlaymiz:

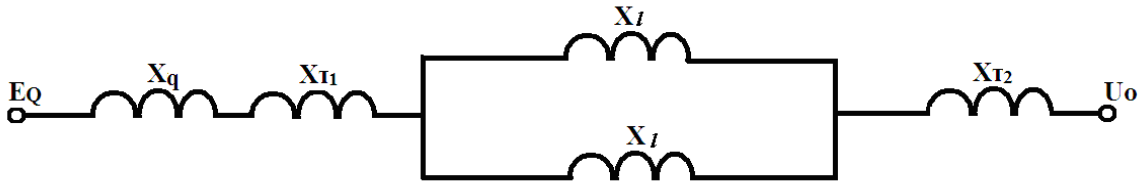
$$K_{CT} = \frac{P_{MAX} - P_0}{P_0} \cdot 100\% = \frac{1.503 - 1}{1} 100\% = 50.3\%$$

Quvvat formulalaridagi burchakka ($\delta = 0 \div 180^0$) qiymat berib quvvat xarakteristikasini quramiz (38-rasm).



38-rasm. Oddiy elektr sistemaning noayon qubli sinxron generatorning quvvat xarakteristikasi.

g) Ekvivalent generator suv elektr stansiyani ekvivalentlashtirayotgan bo‘lib va unda qo‘zg‘atishning avtomatik rostlagich yo‘q deb faraz qilamiz va uning almashtirish sxemasini tuzamiz (39-rasm).



39-rasm. Ayon qutbli sinxron generatori bo‘lgan elektr sistemaning almashtirish sxemasi

Sistemaning almashtirish sxemasidan generatorning q o‘qi bo‘yicha to‘la induktiv qarshilikni aniqlaymiz:

$$X_{q\Sigma} = X_q + X_{T1} + \frac{X_l}{2} = 0.492 + 0.094 + 0.25 = 0.836$$

Ayon qutbli sinxron generatorning fiktiv elektr yurituvchi kuchi

$$E_Q = \sqrt{(U_0 + \frac{Q_0 X_{q\Sigma}}{U_0})^2 + (\frac{P_0 \cdot X_{q\Sigma}}{U_0})^2} = \sqrt{(1 + \frac{0.251 \cdot 0.836}{1})^2 + (\frac{1 \cdot 0.836}{1})^2} = 1.471$$

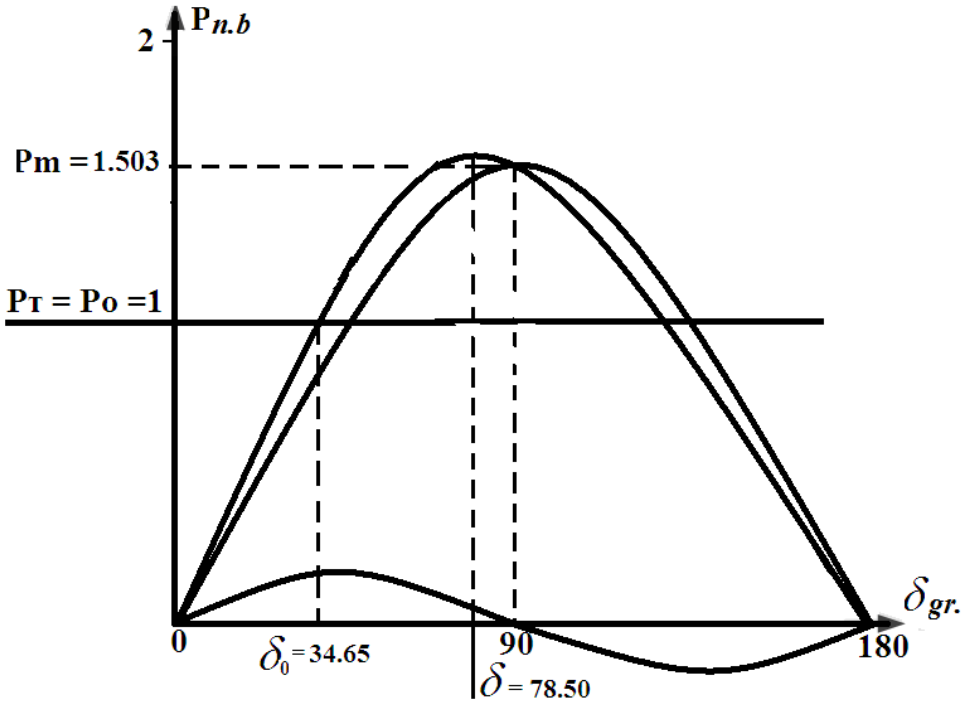
Fiktiv elektr yurituvchi kuch bilan sistema kuchlanishi orasidagi burchakni aniqlaymiz

$$E_Q \hat{} U_0 \rightarrow \delta = arctg \frac{X_{q\Sigma} P_0}{U_0^2 + X_{q\Sigma} Q_0} = arctg \frac{0.836 \cdot 1}{1^2 + 0.251 \cdot 0.836} = 34.645^0$$

$$E_q^{'} = E' Cos(\delta - \delta_0) = 1.32 Cos(34.645 - 28.65) = 1.313$$

Vektor diagrammasidan E_q, E_Q va $E_q^{'}$lar orasidagi bog‘liqlikdan $E_q$ning haqiqiy qiymatini aniqlaymiz.

$$E_q = E_Q \frac{X_d - X_d^{'}}{X_q - X_d^{'}} - E_q^{'} \frac{X_d - X_q}{X_q - X_d^{'}} = 1.471 \frac{0.802 - 0.289}{0.492 - 0.289} - 1.313 \frac{0.802 - 0.492}{0.492 - 0.289} = 1.712$$



40-rasm. Ayon qutbli sinxron generatorli sistemaning QAR yo‘q holatidagi burchak xarakteristikasi

EYUK va burchaklarning topilgan qiymatlarining to‘g‘ri topilganini aniqlash uchun ularni aktiv quvvat formulasiga qo‘yib hisoblaymiz. Aktiv quvvatning $P = U_0 I Cos\varphi_0$ ifodasidan foydalanamiz. Bu holda $E_q \wedge I \rightarrow \Psi$burchakdan $\varphi_0 = \Psi - \delta$ni e’tiborga olib, ayon qutbli generatorning quvvat formulasini olamiz va ayon qutbli sinxron generatorli sistemaning quvvat xarakteristikasini quramiz (41-rasm);

$$P_{EQ} = \frac{E_q U_0}{X_{d\Sigma}} Sin\delta + \frac{U_0^2}{2} \frac{X_d - X_q}{X_{d\Sigma} X_{q\Sigma}} Sin2\delta = \frac{1.712 \cdot 1}{1.146} Sin34.645^0 + \frac{1^2}{2} \frac{0.802 - 0.492}{1.146 \cdot 0.836} Sin69.29 = 1.01 \approx 1$$

Vektor diagrammasiga muvofiq o‘tkinchi EYUKning q o‘qidagi proeksiyasini topamiz:

Hisoblash natijasida olingan aktiv quvvatning qiymati boshlang‘ich holatda berilgan qiymatga taxminan teng, bu esa hisoblash ishlari to‘g‘ri bajarilganini bildiradi. Ayon qutbli sinxron generatordan uzatilayotgan aktiv quvvatning maksimalga erishilgandagi burchakni aniqlash uchun aktiv quvvat formulasidan birinchi tartibli hosila olamiz va maksimal quvvatni $\mathrm{P}_{\mathrm{MAX}} = const$ deb qabul qilamiz

$$\frac{d\mathrm{P}_{\mathrm{MAX}}}{d\delta} = 0$$

$$\frac{d\mathrm{P}}{d\delta} = \frac{\mathrm{E}_q U_0}{\mathrm{X}_{d\Sigma}} Cos\delta + 2(\frac{U_0^2}{2}\frac{\mathrm{X}_d - \mathrm{X}_q}{\mathrm{X}_{d\Sigma}\cdot \mathrm{X}_{q\Sigma}})Cos2\delta = 0$$

$$\frac{d\mathrm{P}}{d\delta} = \frac{1.712\cdot 1}{1.146} Cos\delta + 2(\frac{1^2}{2}\frac{0.802-0.492}{1.146\cdot 0.836})Cos2\delta = 1.494Cos\delta + 2(0.162)Cos2\delta$$

Bu ifodadagi $Cos2\delta$ ni $2Cos^2\delta - 1$ bilan almashtirib quyidagi formulani olamiz:

$$1.494Cos\delta + 4(0.162)Cos^2\delta - 2\cdot(0.162) = 0$$

$$Cos^2\delta + 2.306Cos\delta - 0.5 = 0$$

$$Cos\delta = -1.153 \pm \sqrt{1.329 + 0.5} = 0.199$$

$$\delta = \arccos(0.199) = 78.50^0$$

Ayon qutbli generatorning burchak xarakteristikasidan ko‘rinadiki, u quvvatning maksimumiga burchakning $\delta<90^0$ da erishar ekan. Bunga sabab quvvatning ikkinchi tashkil etuvchisidir. Bu tashkil etuvchiga quvvatning reaksion tashkil etuvchisi deyiladi. U umumiy quvvatning 10% ni tashkil etishi mumkin. Bu quvvat qo‘zg‘atish tokiga bog‘liq bo‘lmay, balki generator statori reaksiyasining d va q o‘qlari bo‘yicha farqiga bog‘liq.

Uzatilayotgan aktiv quvvatning maksimal qiymatini va statik turg‘unlik koeffitsiyentining zaxirasini aniqlaymiz.

$$\mathrm{P}_{\mathrm{MAX}} = 1.153Sin^2 78.50 + 0.162Sin157^0 = 1.107 + 0.063 = 1.17$$

Ayon qutblilik hisobga olingandagi sistemaning statik turg‘unlik koeffitsiyentining zaxirasini aniqlaymiz.

$$\mathrm{K}_{CT} \quad \frac{\mathrm{P}_{\mathrm{MAX}} - \mathrm{P}_0}{\mathrm{P}_0}\cdot 100\% = \frac{1.17-1}{1}\cdot 100\% = 17\%$$

Uzatuvchi stansiya generatorlarida QAR o‘rnatilmagan va elektr uzatish yo‘lining aktiv qarshiligi hisobga olinadi. Sistemaning almashtirish sxemasining to‘la kompleks qarshiligini aniqlaymiz:

$$\dot{Z}_{Л} = r_l + j\mathrm{X}_l + j\mathrm{X}_{\mathrm{T1}} + j\mathrm{X}_d = 0.07 + j1.146$$

$$\mathrm{Z} = \sqrt{r_l^2 + \mathrm{X}_{d\Sigma}^2} = \sqrt{0.07^2 + 1.146^2} = 1.148$$

Tok bilan kuchlanish orasidagi faza siljishni aniqlaymiz

$$\Psi = arctg\frac{\mathrm{X}_{d\Sigma}}{r_{Л}} = arctg\frac{1.148}{0.07} = 86.51^0$$

Tok fazasini 90^0 gacha to‘ldiruvchi burchakni aniqlaymiz:

$$\alpha = 90 - \Psi = 90 - 86.51 = 3.49^0$$

Ekvivalent generatorning ayon qutbliligini hisobga olmasdan uning ichki EYUKsi E_q va yuklanish burchagining taxminiy qiymatini aniqlaymiz

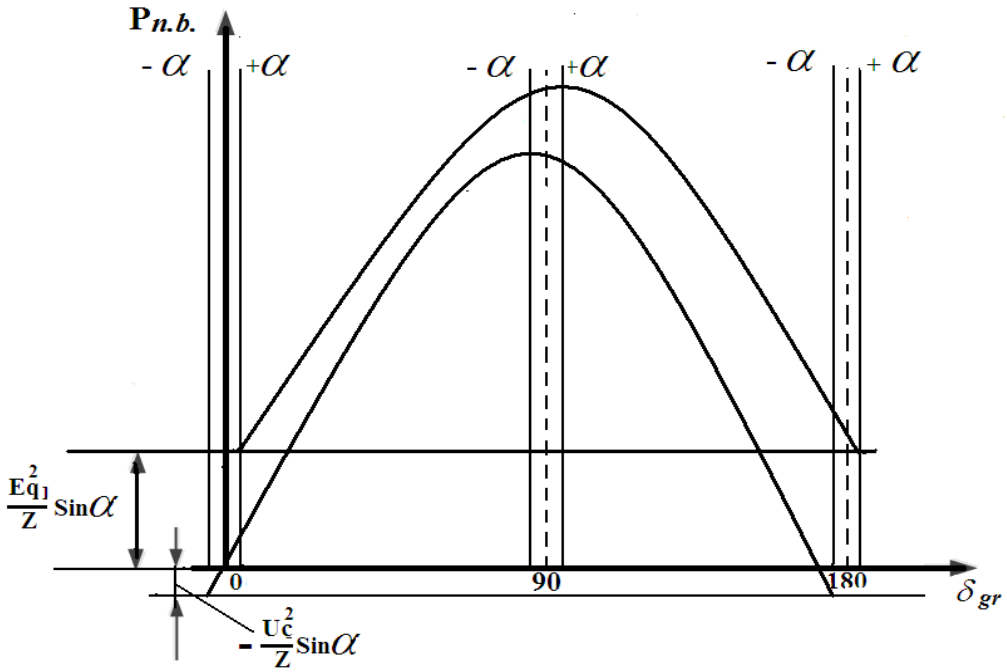
$$\mathrm{E}_q = \sqrt{(U_0 + \frac{Q_0\mathrm{X}_{d\Sigma} + \mathrm{P}_0 r_{Л}}{U_0})^2 + (\frac{\mathrm{P}_0\mathrm{X}_{d\Sigma} - Q_0 r_{Л}}{U_0})^2} =$$

$$\sqrt{(1 + \frac{0.251\cdot 1.146 + 1\cdot 0.07}{1})^2 + (\frac{1\cdot 1.146 - 0.251\cdot 0.07}{1})^2} = 1.765$$

$$\delta = arctg\frac{\mathrm{P}_0\mathrm{X}_{d\Sigma} - Q_0 r_{Л}}{U_0^2 + Q_0\mathrm{X}_{d\Sigma} + \mathrm{P}_0 r_{Л}} = arctg\frac{1\cdot 1.146 - 0.251\cdot 0.07}{1 + 0.251\cdot 1.146 + 1\cdot 0.07} = arctg\frac{1.128}{1.358} = 39.732^0$$

Elektr yurituvchi kuch va δning hisobiy qiymatini quvvat formulasiga qo‘yish yo‘li bilan tekshiramiz

$$\dot{\mathrm{P}}_C = -\frac{U_0^2}{\mathrm{Z}} Sin\alpha + \frac{\mathrm{E}_q U_0}{\mathrm{Z}} Sin(\delta + \alpha) = -\frac{1}{1.148} Sin3.49^0 + \frac{1.765\cdot 1}{1.148} Sin(39.732^0 + 3.49^0) = 0{,}9999 \approx 1$$



41-rasm. Sistema elementlarining burchak xarakteristikasiga ta’siri

Bu normal rejimda liniyadan sistemaga kirayotgan aktiv quvvat bo‘lib u boshlang‘ich rejimda berilayotgan quvvatga teng bo‘lishi kerak. Lekin gidravlik stansiyadan berilayotgan aktiv quvvat sistemaga kirayotgan aktiv quvvatdan katta bo‘lishi kerak (41-rasm).

$$P_{G1HOM} = \frac{E_{qG1}^2}{Z} Sin\alpha + \frac{E_{qG1} \cdot U_0}{Z} Sin(\delta + \alpha) = \frac{1.765^2}{1.148} Sin(3.49) + \frac{1.765 \cdot 1}{1.148} Sin(39.732 + 3.49) =$$

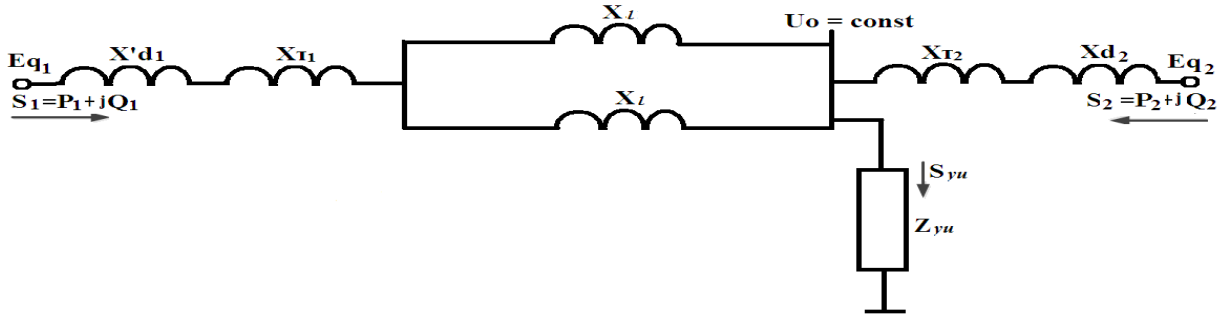
$$= 0.165 + 1.053 = 1.218$$

$$P_{G1MAX} = \frac{E_{qG1}^2}{Z} Sin\alpha + \frac{E_{qG1} \cdot U_0}{Z} = \frac{1.765^2}{1.148} Sin(3.49^0) + \frac{1.765 \cdot 1}{1.148} = 0.165 + 1.537 = 1.702$$

Sistema statik turg‘unligi koeffitsiyentining zaxirasini aniqlaymiz

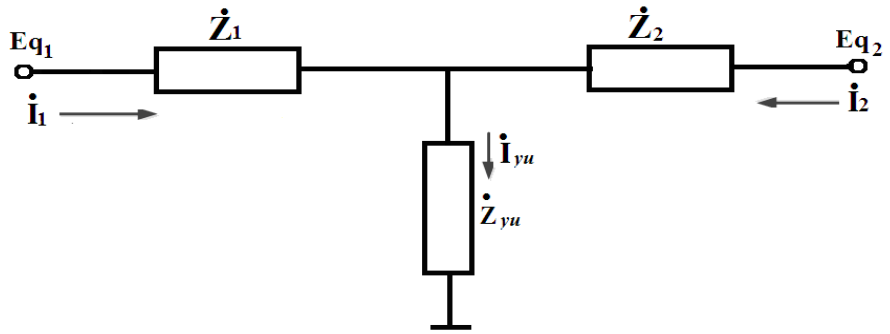
$$K_{CT} = \frac{P_{G1MAX} - P_{G1HOM}}{P_{\Gamma 1HOM}} \cdot 100\% = \frac{1.702 - 1.218}{1.218} \cdot 100\% = 39.74\%$$

5. Sistemaga uzatilayotgan aktiv quvvatning haqiqiy uzatilish chegarasini aniqlaymiz. Buning uchun sistemaning yuklama hisobga olingandagi almashtirish sxemasidan foydalanamiz (42-rasm).

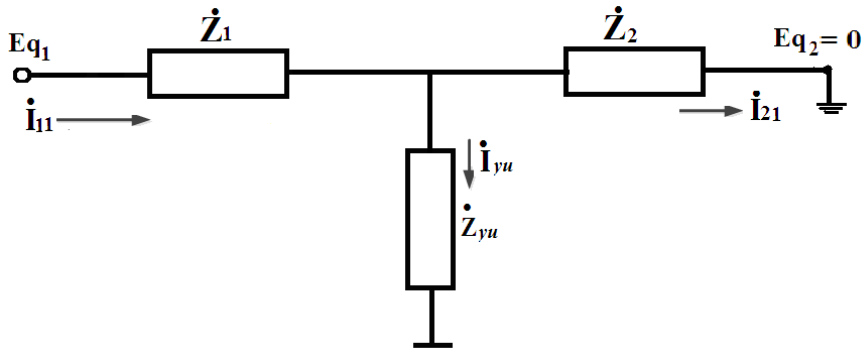


42-rasm. Uzatilayotgan aktiv quvvatning haqiqiy uzatilish chegarasini aniqlash almashtirish sxemasi

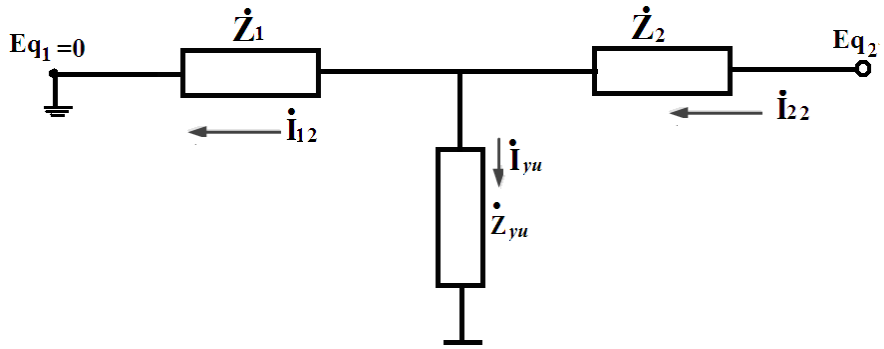
a)



b)



v)



43-rasm. Ustma – ust qo‘yilish sxemasining ko‘rinishi

$$\dot{Z}_1 = jX_{d1} + jX_{T1} + j\frac{X_l}{2} = j0.802 + j0.094 + j0.25 = j1.146$$

$$\overset{*}{Z}_2 = jX_{T2} + jX_{d2} = j0.035 + j0.646 = j0.681$$

$$Z_{yu} = 0.25 + j0.128 = 0.281e^{j27.11^0}$$

Ikkinchi generatorning yuklamaga berayotgan aktiv va reaktiv quvvatini aniqlaymiz.

$$P_{yu} = P_{G2} + P_0$$

$$Q_{yu} = Q_{G2} - Q_0$$

$$P_{G2} = P_{IO} - P_0$$

$$Q_{G2} = Q_{IO} - Q_0$$

$$P_{Yu} = \frac{P_{Yu}}{P_0} = \frac{840}{265} = 3.17; \quad Q_{Yu} = P_{Yu} tg\varphi_{Yu} = 3.17 tg 27.01^0 = 1.616$$

$$P_{G2} = P_{Yu} - P_0 = 3.17 - 1 = 2.17$$

$$Q_{G2} = Q_{Yu} - Q_0 = 1.616 - 0.251 = 1.365$$

Ikkinchi generatorning E_{q2} EYUK ni aniqlaymiz

$$E_{q2} = \sqrt{(U_0 + \frac{Q_{G2} X_{d\Sigma 2}}{U_0})^2 + (\frac{P_{G2} X_{d\Sigma 2}}{U_0})^2} = \sqrt{(1 + \frac{1.365 \cdot 0.681}{1})^2 + (\frac{2.17 \cdot 0.681}{1})^2} =$$

$$= \sqrt{(1.93)^2 + (1.478)^2} = 2.431$$

Yuklama ulangan tugun kuchlanishi bilan E_{q2} orasidagi burchakni, ya'ni ikkinchi generatorning yuklanish burchagini aniqlaymiz

$$\delta_{G2} = arctg \frac{P_{G2} \cdot X_{d\Sigma 2}}{U_0^2 + Q_{G21} \cdot X_{d\Sigma 2}} = arctg \frac{2.17 \cdot 0.681}{1 + 1.365 \cdot 0.681} = 37.447^0$$

Kompleks almashtirish sxemasidagi konturlarning to‘la va o‘zaro qarshiliklarni aniqlaymiz.

$$\dot{Z}_{11} = \dot{Z}_1 + \frac{\dot{Z}_2 \cdot \dot{Z}_{Yu}}{\dot{Z}_2 + \dot{Z}_{Yu}} = jX_{d\Sigma 1} + \frac{jX_{d\Sigma 2} \cdot Z_{Yu} \cdot e^{j27.01^0}}{jX_{d\Sigma 2} + R_{Yu} + jX_{Yu}} = j1.146 + \frac{j0.681 \cdot 0.281 e^{j27.11^0}}{j0.681 + 0.25 + j0.128} =$$

$$j1.146 + \frac{0.681 \cdot 0.286 e^{j117.11^0}}{0.25 + j0.809} = j1.146 + \frac{0.1948 e^{j117.11^0}}{0.847 e^{j72.828^0}} = j1.146 + 0.2299 e^{j44.282^0} =$$

$$j1.146 + j0.1605 + 0.1646 = 0.1646 + j1.3065 = 1.3168 e^{j82.82^0}$$

$$\alpha_{11} = 90 - 82.82 = 7.18$$

$$Z_{12} = Z_1 + Z_2 + \frac{Z_1 Z_2}{Z_{Yu}} = j1.146 + j0.681 + \frac{j1.146 \cdot j0.681}{0.281 e^{j27.11^0}} = j1.827 + \frac{0.78 e^{j180^0}}{0.281 e^{j27.11^0}} =$$

$$= j1.827 + 2.777 e^{j152.89} = j1.827 - 2.472 + j1.265 = 3.959 e^{j128.642}$$

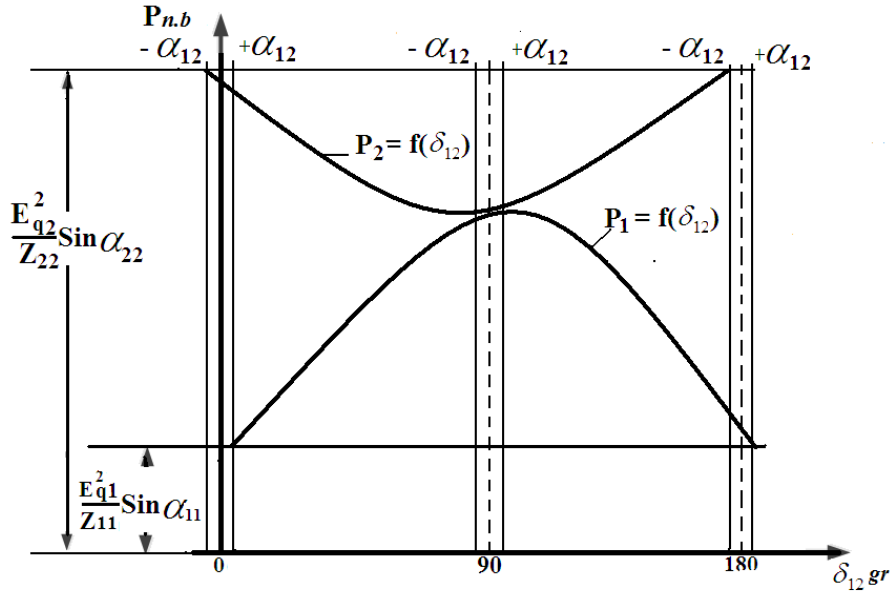
$$\alpha_{12} = 90 - \Psi_{12} = 90 - 128.642 = -38.6942$$

$$\delta_{12} = \delta_1 - \delta_2 = 41.67^0 - 37.447^0 = 4.223^0$$

Yuqorida bajarilgan EYUK E_q, konturning xususiy to‘la qarshiligi Z_{11} va konturlararo o‘zaro to‘la qarshilikning to‘g‘ri hisoblanganini tekshiramiz.

$$P_{\Gamma 1} = \frac{E_{qG1}^2}{Z_{11}} Sin\alpha_{11} + \frac{E_{qG1} \cdot E_{G2}}{Z_{12}} Sin(\delta_{12} - \alpha_{12}) = \frac{1.723^2}{1.3168} Sin 7.18 + \frac{1.723 \cdot 2.431}{3.959} Sin(4.223 + 38.6942) \approx 1.002$$

Uzatilayotgan aktiv quvvatning haqiqiy uzatilish chegarasini aniqlaymiz va uning grafigini quramiz (44-rasm).



44-rasm. Aktiv quvvatning haqiqiy uzatilish chegarasini aniqlash

$$P_{XCh} = \frac{E^2_{qG1}}{Z_{11}} Sin\alpha_{11} + \frac{E_{qG1} \cdot E_{\Gamma 2}}{Z_{12}} = \frac{1.723^2}{1.3168} Sin 7.18 + \frac{1.723 \cdot 2.431}{3.959} = 0.2818 + 1.058 = 1.34$$

Aktiv quvvatning haqiqiy uzatilish chegarasi bo‘yicha statik turg‘unlik koeffitsiyentining zaxirasini aniqlaymiz.

$$K_{CT} \quad \frac{P_{XCh} - P_0}{P_0} \cdot 100\% = \frac{1.34 - 1}{1} \cdot 100\% = 34\%$$

2.4.3. Sistemaning dinamik turgunligini tekshiramiz

2.4.3.1. Stansiya shinasining o‘chirgichidan keyin 3 fazali qisqa tutashuv uchun qisqa tutashuv o‘chirilish vaqtining chegaraviy vaqtini aniqlaymiz.

Rele ximoyasi shikastlangan zanjirni o‘chirgandan keyin sistemaning to‘la induktiv qarshiligini almashtirish sxemasidan aniqlaymiz.

$$X_{\Sigma II} = X'_{d\Sigma} = X'_d + X_{T1} + X_l = 0.289 + 0.094 + 0.50 = 0.883$$

Avariyadan keyingi rejimda sistemaga uzatilayotgan aktiv quvvatning maksimal qiymatini aniqlaymiz:

$$P_m^{II} = \frac{E'U_0}{X'_{d\Sigma}} = \frac{1.320 \cdot 1}{0.883} = 1.495$$

Uch fazali qisqa tutashuv stansiyaning shinasida (kuchaytiruvchi transformatordan keyin) sodir bo‘ldi. Shuning uchun stator tokining aperiodik tashkil etuvchisining ta’sirini sinxron generator rotoriga taxminan normal rejimda uzatilayotgan aktiv quvvatning 15% ga teng

bo‘lgan qo‘shimcha tormozlovchi moment ta’sir etayapti deb qabul qilamiz:

$$P_m^{III} = 0.15P_0$$

Burchak xarakteristikasidan burchakning kritik qiymatini aniqlaymiz:

$$\delta_{KR} = 180 - arcSin\frac{P_0}{P_m^{II}} = 180 - arcSin\frac{1}{1.495} = 138.015^0$$

Uch fazali qisqa tutashuvda S_{TEZ} va S_{TMM} tengligidan qisqa tutashuvni o‘chirish vaqtining chegaraviy qiymatini aniqlaymiz:

$$\delta_{o'chcheg} = arcCos\frac{\frac{\pi}{180}(\delta_{KR} - \delta_0)P_0 + P_m^{II}Cos\delta_{KR} - P_m^{III}Cos\delta_0}{P_m^{II} - P_m^{III}} =$$

$$= arcCos\frac{\frac{3.14}{180}(138.015^0 - 28.64^0)\cdot 1 + 1.495Cos138.015^0 - 0.15}{1.495 - 0.15} = \arccos\frac{1.91 - 1.111 - 0.15}{1.345} = 61.15^0$$

Sinxron generator rotorining mexanik inersion doimiysini nisbiy birlikka o‘tkazamiz:

$$T_J = T_J \cdot n \cdot \frac{S_{HOM}}{S_Б} = 7.6 \cdot 3 \cdot \frac{100}{265} = 8.604сек$$

Sinxron generator rotorining nisbiy harakatining differensial tenglamasini uch fazali qisqa tutashuv uchun analitik usul bilan yechib, rele himoyasining maksimal o‘rnatilish vaqti, qisqa tutashuv o‘chirish vaqtining chegaraviy qiymatini aniqlaymiz.

$$T_J\frac{d^2\delta}{dt^2} = \omega_0(P_0 - P_m^{III}Sin\delta)$$

Uch fazali qisqa tutashuvda generator sistemadan ajralgani sababli avariya rejimida sistemaga uzatilayotgan aktiv quvvat $P_m^{III} = 0$

$$T_J\frac{d^2\delta}{dt^2} = \omega_0 P_0$$

Tenglama chiziqli ko‘rinishga keldi, uni analitik usul bilan yechishimiz mumkin

$\frac{d\delta}{dt} = \Delta\omega$ (1) ; $\frac{d\Delta\omega}{dt} = a$ (2), bu tenglamani xosilaga nisbatan yechamiz

$d\Delta\omega = adt$ - bu ifodani integrallab, quyidagi ko‘rinishga keltiramiz $\Delta\omega = at + C_1$. Bu yerda C_1 - integrallash doimiysi bo‘lib, u nisbiy tezlikning o‘tkinchi jarayon boshlanishidagi qiymatini beradi, $C_1 = \Delta\omega_{t=0} = 0$ dan $\Delta\omega = at$ ni olamiz va uni (1) ifodaning o‘ng tomoniga qo‘yib integrallaymiz

$$\frac{d\delta}{dt} = \Delta\omega \ = at \rightarrow d\delta = atdt \rightarrow \delta = \frac{at^2}{2} + C_2$$
$$C_2 = \delta_{t=0} = \delta_0$$

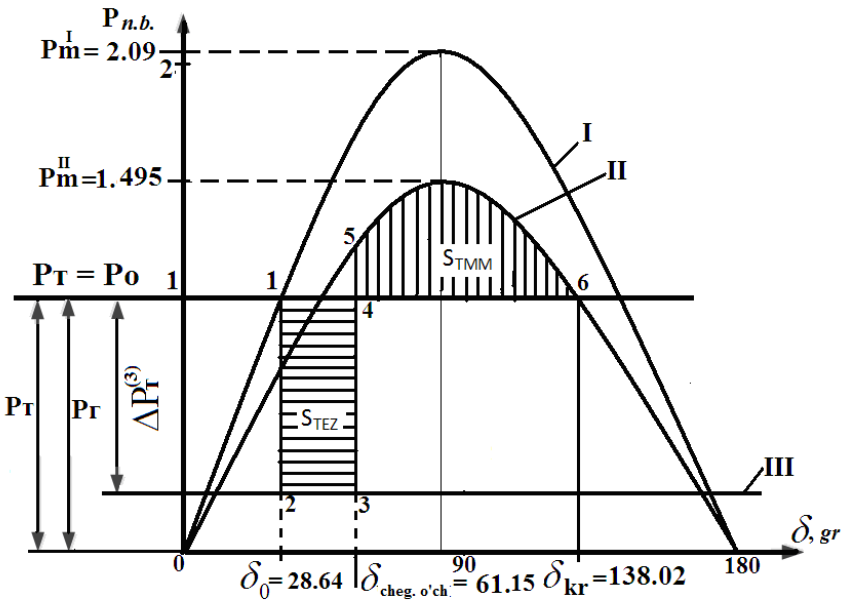
Natijada

$2(\delta - \delta_0) = at^2 \rightarrow t = \sqrt{\frac{2(\delta - \delta_0)}{a}}$, bu ifoda sinxron generator rotorining ma'lum tezlanish bilan harakatlanayotganda burchakning $\delta_0 \rightarrow \delta$ o'zgarishi uchun ketayotgan vaqtni bildiradi.

$a = \frac{\omega_0 \Delta P}{T_J} \rightarrow \Delta P = P_0$ u holda qisqa tutashuv tokining aperiodik tashkil etuvchisini hisobga olganimiz $E_q \wedge U_0 \rightarrow \delta = \delta_0 \rightarrow \delta_{уччег}$ o'zgarishi uchun ketadigan vaqtni aniqlaymiz

$$t_{o'chcheg} = \sqrt{\frac{T_J(\delta_{o'ch.cheg} - \delta_0)}{9000 \cdot 0.85 \cdot P_0}} = \sqrt{\frac{8.604 \cdot (61.15^0 - 28.64^0)}{9000 \cdot 0.85}} = 0.19 сек$$

Uch fazali qisqa tutashuv rejimi uchun burchak xarakteristikasini qurib uning dinamik turg'unlik zaxirasini baholaymiz (45-rasm).



45-rasm. Uch fazali qisqa tutashuv rejimi uchun burchak xarakteristikasi

2.4.3.2. Ikki fazali yerga qisqa tutashuv uchun o'chirilish burchagining chegaraviy qiymatini aniqlaymiz

Sistemaning tokning teskari va nolinchi ketma - ketligi uchun to'la qarshiligini aniqlash uchun sistemaning tokning teskari va nolinchi ketma ketligi uchun almashtirish sxemasini tuzib uni qisqa tutashuv nuqtasiga nisbatan yechamiz:

$$X_{\Sigma 2} = \frac{(X_{2G1} + X_{T1}^{(2)}) \cdot X_l^{(2)}}{X_{2G1} + X_{T1}^{(2)} + X_l^{(2)}} = \frac{(0.245 + 0.094) \cdot 0.25}{0.245 + 0.094 + 0.25} = 0.144$$

$$X_{\Sigma 0} = \frac{X_{T1}^{(0)} \cdot X_l^{(0)}}{X_{T1}^{(0)} + X_l^{(0)}} = \frac{0.094 \cdot (2 \cdot 0.25)}{0.094 + (2 \cdot 0.25)} = \frac{0.047}{0.594} = 0.079$$

Ikki fazali yerga qisqa tutashuv uchun qisqa tutashuv nuqtasida tokning teskari va nolinchi ketma - ketligiga bo‘lgan induktiv qarshiliklari o‘zaro parallel ulanadi, u vaqtda qisqa tutashuv turining sistema dinamik turg‘unligiga ta’sirini ifodalovchi shunt qarshiligining qiymatini aniqlaymiz.

$$X_{sh} = \frac{X_{\Sigma 2} \cdot X_{\Sigma 0}}{X_{\Sigma 2} + X_{\Sigma 0}} = \frac{0.144 \cdot 0.079}{0.144 + 0.079} = \frac{0.0114}{0.223} = 0.051$$

Sistemaning ikki fazali qisqa tutashuv uchun avariya rejimidagi to‘la induktiv qarshiligini topamiz:

$$X_{\Sigma III} = X_d^1 + X_{T1} + \frac{X_l}{2} + \frac{(X_d^{'} + X_{T1})X_l}{X_{sh}} = 0.289 + 0.094 + 0.25 + \frac{(0.289 + 0.094) \cdot 0.25}{0.051} = 2.51$$

Uzatuvchi stansiya generatoridan avariya rejimida uzatilayotgan maksimal quvvatni aniqlaymiz:

$$P_m^{III} = \frac{E' \cdot U_0}{X_{\Sigma III}} = \frac{1.32 \cdot 1}{2.51} = 0.526$$

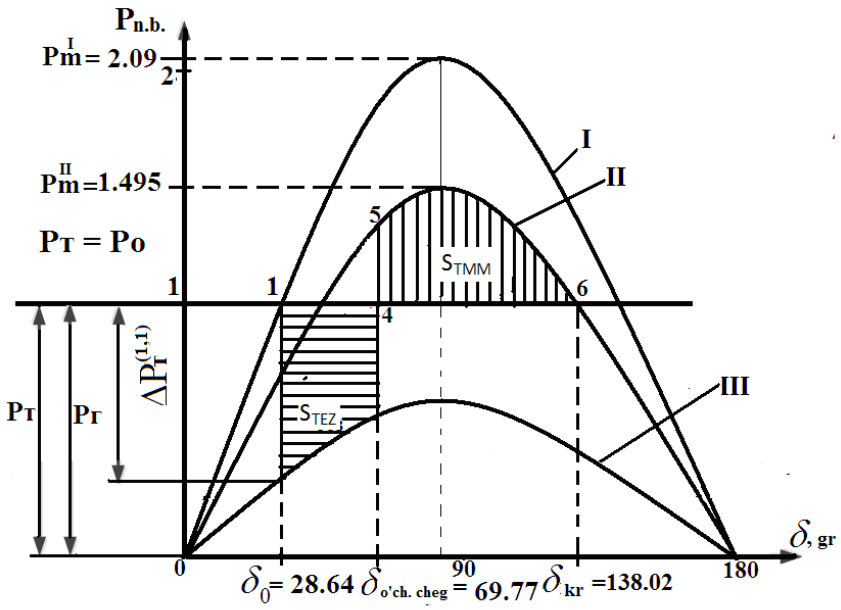
Ikki fazali yerga qisqa tutashuv uchun qisqa tutashuv o‘chirilish burchagining chegaraviy qiymatini aniqlaymiz:

$$\delta_{o'chcheg} = arcCos \frac{\frac{\pi}{180}(\delta_{kr} - \delta_0)P_0 + P_m^{II} Cos\delta_{kr} - P_m^{III} Cos\delta_0}{P_m^{II} - P_m^{III}} =$$

$$= arcCos \frac{\frac{3.14}{180}(138.015 - 28.64) \cdot 1 + 1.495 Cos 138.015 - 0.526 Cos 28.64}{1.495 - 0.526} = 69.77^0$$

Sistemaning ikki fazali qisqa tutashuv rejimi uchun burchak xarakteristikasini qurib uning dinamik turg‘unligini baholaymiz(46-rasm).

Uzatuvchi stansiya generatorining nisbiy harakat tenglamasini ketma – ket intervallar usuli bilan sonli integrallaymiz. Bu usulning ma’nosi shundan iboratki butun o‘tkinchi jarayonlar tekshirilayotgan vaqtni teng intervallarga bo‘lamiz ($\Delta t = 0.05 сек$). Har bir interval boshida topilgan quvvat (moment) orttirmasini interval davomida o‘zgarmas deb qabul qilib, intervalda olinayotgan burchak orttirmasini topamiz. Bu orttirmani interval boshidagi burchakning qiymatiga qo‘shib interval oxiridagi burchakni aniqlaymiz. Hisoblash ishlarini $\delta_n > \delta_{KP}$ gacha davom etiramiz. Sinxron generator rotorining nisbiy harakat tenglamasini yechib biz burchakning vaqt bo‘yicha o‘zgarishini aniqlaymiz $\delta = f(t)$.



46-rasm. Sistema shinasida sodir bo‘lgan ikki fazali yerga qisqa tutashuv rejimi uchun burchak xarakteristikasi

Burchakning vaqt bo‘yicha o‘zgarishini topishda fizikadan ma’lum bo‘lgan tekis tezlanishli harakatdagi yo‘l formulasidan foydalanamiz:

1. Interval boshidagi quvvat orttirmasi:

$$\Delta P_0 = P_0 - P_m^{III} Sin\delta_0 = 1 - 0.526 Sin 28.64 = 0.748$$

Birinchi intervalda olingan burchak orttirmasini topamiz:

$$\Delta\delta_1 = \Delta\omega_{(0)}\Delta t + \frac{a\Delta t^2}{2}$$

O‘tkinchi jarayon boshlanishida sistemada nominal burchak chastotasi mavjud ($\omega_\Gamma = \omega_0$), natijada nisbiy tezlik $\Delta\omega = \omega_\Gamma - \omega_0 = 0$

$$\Delta\delta_1 = \frac{a_{(0)}\Delta t^2}{2} = \frac{\omega_0 \cdot \Delta P_0}{T_j}\frac{\Delta t^2}{2} = \frac{\omega_0 \cdot \Delta t^2}{T_J}\frac{\Delta P_0}{2} = \frac{18000 \cdot 0.05^2}{8.604}\frac{0.749}{2} = 5.23 \cdot \frac{0.748}{2} = 1.96^0$$

$$K = \frac{\omega_0 \cdot \Delta t^2}{T_J} = \frac{18000 \cdot 0.05^2}{8.604} = 5.23$$

Birinchi interval oxiridagi burchakni aniqlaymiz:

$$\delta_1 = \delta_0 + \Delta\delta_1 = 28.64^0 + 1.96^0 = 30.6^0$$

Birinchi interval oxiridagi quvvat orttirmasini topamiz:

$$\Delta P_1 = P_0 - P_m^{III} Sin\delta_1 = 1 - 0.526 Sin 30.6^0 = 0.732$$

Ikkinchi intervalda olingan burchak orttirmasini topamiz:

$$\Delta\delta_2 = \Delta\omega_{(1)}\Delta t + \frac{a_{(1)}\Delta t^2}{2} = (\frac{a_{(0)} + a_{(1)}}{2})\Delta t + \frac{a_{(1)}\Delta t^2}{2} = \frac{a_{(0)}\Delta t^2}{2} + \frac{a_{(1)}\Delta t^2}{2} + \frac{a_{(1)}\Delta t^2}{2} =$$

$$= \frac{18000 \cdot \Delta t^2}{T_J}\frac{\Delta P_0}{2} + \frac{18000 \cdot \Delta t^2}{T_J} \cdot \Delta P_1 = \Delta\delta_1 + K \cdot \Delta P_1 = \Delta\delta_1 + K\Delta P_1 = 1.96^0 + 5.23 \cdot 0.732 = 5.788^0$$

Ikkinchi interval oxiridagi burchak:

$$\delta_2 = \delta_1 + \Delta\delta_2 = 30.6^0 + 5.788^0 = 36.388^0$$

Ikkinchi intenrval oxiridagi quvvat orttirmasini topamiz:

$$\Delta P_2 = P_0 - P_m^{III} Sin\delta_2 = 1 - 0.526 Sin 36.388^0 = 0.688$$

Uchinchi intervalda olingan burchak orttirmasi:

$$\Delta\delta_3 = \Delta\delta_2 + K \cdot \Delta P_2 = 5.788 + 5.23 \cdot 0.688 = 9.386^0$$

Uchinchi interval oxiridagi burchak

$$\delta_3 = \delta_2 + \Delta\delta_3 = 36.388^0 + 9.386 = 45.774^0$$

Uchinchi interval oxiridagi quvvat orttirmasi

$$\Delta P_3 = P_0 - P_m^{III} Sin\delta_3 = 1 - 0.526 Sin 45.774^0 = 0.623$$

To‘rtinchi intervalda olingan burchak orttirmasini topamiz:

$$\Delta\delta_4 = \Delta\delta_3 + K \cdot \Delta P_3 = 9.386^0 + 5.23 \cdot 0.623 = 12.644^0$$

To‘rtinchi interval oxiridagi burchak:

$$\delta_4 = \delta_3 + \Delta\delta_4 = 45.774^0 + 12.644^0 = 58.418^0$$

Turtinchi intenrval oxiridagi quvvat orttirmasini topamiz:

$$\Delta P_4 = P_0 - P_m^{III} Sin\delta_4 = 1 - 0.526 Sin 58.418^0 = 0.552$$

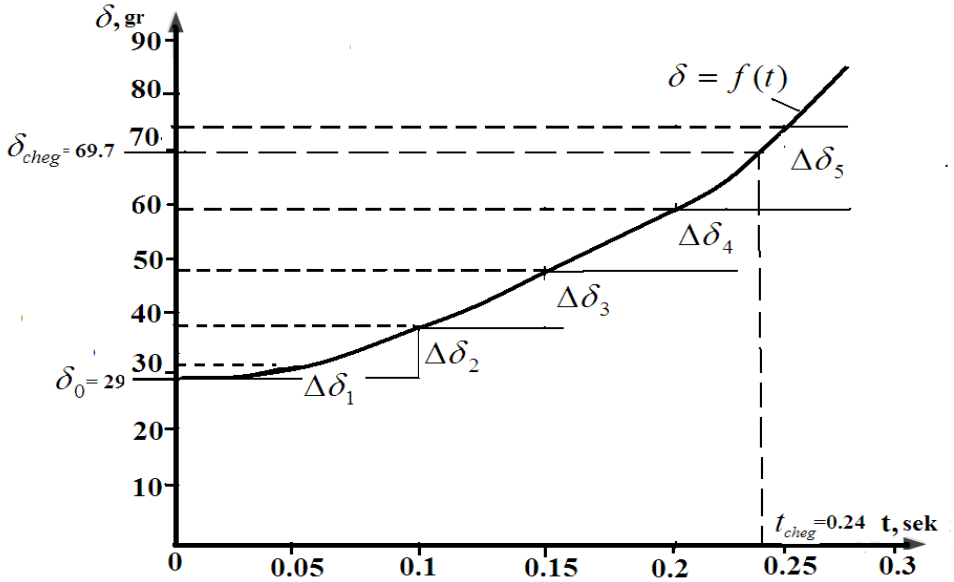
Beshinchi intervalda olingan burchak orttirmasini topamiz:

$$\Delta\delta_5 = \Delta\delta_4 + K \cdot \Delta P_4 = 12.644^0 + 5.23 \cdot 0.552 = 15.531^0$$

Beshinchi interval oxiridagi burchak:

$$\delta_5 = \delta_4 + \Delta\delta_5 = 58.418^0 + 15.531^0 = 72.949^0$$

Hisoblash natijasida olingan burchakning qiymati ikki fazali qisqa tutashuvni o‘chirish burchagining chegaraviy qiymatidan katta bo‘lganligi sababli to‘xtatamiz.



47-rasm. Burchakning vaqt bo‘yicha o‘zgarish grafigi

Olingan qiymatlar bo‘yicha burchakning vaqtga bog‘liqlik xarakteristikasini quramiz va grafikdan ikki fazali qisqa tutashuvni o‘chirish vaqtining chegaraviy qiymatini aniqlaymiz. Buning uchun burchakning $\delta_{o'ch.cheg}$ bo‘yicha abssissa o‘qiga parallel o‘tkazamiz va uning $\delta = f(t)$ xarakteristika bilan kesishish nuqtasidan perpendikulyar tushiramiz. Perpendikulyarning abssissa o‘qi bilan kesishgan nuqtasi

qisqa tutashuv o‘chirilish vaqtining chegaraviy qiymatini beradi (47-rasm).

2.4.3.3. Sistemaning «K» nuqtasida bir fazali qisqa tutashuv uchun fazalar bo‘yicha avtomatik qayta ulash imkoniyatini aniqlaymiz.

Hisoblash ishlarini bajarishda normal rejimda sistemada bitta elektr uzatish yo‘li bor deb olamiz va sistemaning almashtirish sxemasidan to‘la induktiv qarshilikni topamiz

$$X_{\Sigma I} = X'_{d\Sigma} = X'_d + X_{T1} + X_{Л} = 0.289 + 0.094 + 0.50 = 0.883$$

Sinxron generatorning o‘tkinchi induktiv qarshiligini topamiz:

$$E' = \sqrt{(U_0 + \frac{Q_0 X_{\Sigma I}}{U_0})^2 + (\frac{P_0 X_{\Sigma I}}{U_0})^2} = \sqrt{(1 + \frac{0.251 \cdot 0.883}{1})^2 + (\frac{1 \cdot 0.883}{1})^2} = 1.507$$

O‘tkinchi EYuK vektori bilan sistema kuchlanishi vektori orasidagi burchakni aniqlaymiz:

$$\delta' = arctg \frac{P_0 \cdot X_{\Sigma I}}{U_0^2 + Q_0 X_{\Sigma I}} = arctg \frac{1 \cdot 0.883}{1 + 0.251 \cdot 0.883} = 35.86^0$$

Normal rejimda sistemaga uzatilayotgan aktiv quvvatning maksimal qiymatini aniqlaymiz:

$$P_m^I = \frac{E' \cdot U_0}{X_{\Sigma I}} = \frac{1.507 \cdot 1}{0.883} = 1.71$$

Sistema almashtirish sxemasidan (42-rasm)sistemaning tokning teskari va nolinchi ketma – ketligining to‘la qarshiligini topamiz

$$X_{\Sigma 2} = \frac{(X_{2G1} + X_{T1}^{(2)}) \cdot X_l^{(2)}}{X_{2G1} + X_{T1}^{(2)} + X_l^{(2)}} = \frac{(0.245 + 0.094) \cdot 0.5}{0.245 + 0.094 + 0.5} = 0.202$$

$$X_{\Sigma 0} = \frac{X_{T1}^{(0)} \cdot X_l^{(0)}}{X_{T1}^{(0)} + X_l^{(0)}} = \frac{0.094 \cdot (4 \cdot 0.25)}{0.094 + (4 \cdot 0.25)} = \frac{0.094}{1.094} = 0.0859$$

Bir fazali qisqa tutashuvda tokning teskari va nolinchi ketma – ketligiga bo‘lgan induktiv qarshiliklar o‘zaro ketma – ket ulanadi:

$$X_{III} = X_{\Sigma 2} + X_{\Sigma 0} = 0.202 + 0.0859 = 0.2879$$

Bir fazali qisqa tutashuv rejimida sistema almashtirish sxemasining to‘la induktiv qarshiligi (48-rasm):

$$X_{\Sigma III} = X'_d + X_{T1} + X_l + \frac{(X'_d + X_{T1}) X_l}{X_{sh}} = 0.289 + 0.094 + 0.5 + \frac{(0.289 + 0.094) \cdot 0.5}{0.2879} = 1.548$$

Avariya rejimida shikastlanmagan faza orqali uzatilayotgan maksimal aktiv quvvatni aniqlaymiz:

$$P_m^{III} = \frac{E' \cdot U_0}{X_{\Sigma III}} = \frac{1.507 \cdot 1}{1.548} = 0.974$$

Bir faza o‘chirilganini hisobga olib sistemaning qisqa tutashuv tokining teskari va nolinchi ketma – ketligiga bo‘lgan induktiv qarshiligining yig‘indisini topamiz:

$$X_{\Sigma 0} = X_{T1} + X_l^{(0)} = 0.094 + 1 = 1.094$$

$$X_{\Sigma 2} = X_{2G1} + X_{T1} + X_l = 0.245 + 0.094 + 0.5 = 0.839$$

Sistemaning bir faza o‘chirilgan holatdagi avariyadan keyingi rejimdagi to‘la induktiv qarshiligi:

$$X_{\Sigma II} = X_d^{'} + X_{T1} + X_l + \frac{X_{\Sigma 2} \cdot X_{\Sigma 0}}{X_{\Sigma 2} + X_{\Sigma 0}} = 0.289 + 0.094 + 0.5 + \frac{0.839 \cdot 1.094}{0.839 + 1.094} = 1.358$$

Bir faza o‘chirilgandan keyingi avariyadan keyingi rejimdagi uzatilayotgan aktiv quvvatning maksimal qiymati:

$$P_m^{II} = \frac{E' \cdot U_0}{X_{\Sigma II}} = \frac{1.507 \cdot 1}{1.358} = 1.11$$

Sinxron generatorining nisbiy harakat tenglamasini qisqa tutashuv vaqtini $t_{q.t}$ va toksiz pauza t_{AQU} vaqtida yoy o‘z o‘zidan so‘nadi deb qabul qilamiz. Nisbiy harakat tenglamasini integralash qadami Δt bilan ketma – ket intervallar usuli bilan sonli integralaymiz.

Burchakning vaqt bo‘yicha o‘zgarishini topishda fizikadan ma’lum bo‘lgan tekis tezlanishli harakatdagi yo‘l formulasidan foydalanamiz:

2. Interval boshidagi quvvat orttirmasi:

$$\Delta P_0 = P_0 - P_m^{III} Sin\delta_0 = 1 - 0.974 Sin35.86^0 = 0.43$$

Birinchi intervalda olingan burchak orttirmasini topamiz:

$$\Delta\delta_1 = \Delta\omega_{(0)}\Delta t + \frac{a\Delta t^2}{2}$$

O‘tkinchi jarayon boshlanishida sistemada nominal burchak chastotasi mavjud ($\omega_G = \omega_0$), natijada nisbiy tezlik $\Delta\omega = \omega_\Gamma - \omega_0 = 0$

$$\Delta\delta_1 = \frac{a_{(0)}\Delta t^2}{2} = \frac{\omega_0 \cdot \Delta P_0}{T_j}\frac{\Delta t^2}{2} = \frac{\omega_0 \cdot \Delta t^2}{T_J}\frac{\Delta P_0}{2} = \frac{18000 \cdot 0.05^2}{8.604}\frac{0.43}{2} = 5.23\frac{0.43}{2} = 1.124^0$$

$$K = \frac{\omega_0 \cdot \Delta t^2}{T_J} = \frac{18000 \cdot 0.05^2}{8.604} = 5.23$$

Birinchi interval oxiridagi burchakni aniqlaymiz:

$$\delta_1 = \delta_0 + \Delta\delta_1 = 35.86^0 + 1.124^0 = 36.984^0$$

Birinchi interval oxiridagi quvvat orttirmasini topamiz:

$$\Delta P_1 = P_0 - P_m^{III} Sin\delta_1 = 1 - 0.974 Sin 36.984^0 = 0.414$$

Ikkinchi intervalda olingan burchak orttirmasini topamiz:

$$\Delta\delta_2 = \Delta\omega_{(1)}\Delta t + \frac{a_{(1)}\Delta t^2}{2} = (\frac{a_{(0)} + a_{(1)}}{2})\Delta t + \frac{a_{(1)}\Delta t^2}{2} = \frac{a_{(0)}\Delta t^2}{2} + \frac{a_{(1)}\Delta t^2}{2} + \frac{a_{(1)}\Delta t^2}{2} =$$

$$= \frac{18000 \cdot \Delta t^2}{T_J}\frac{\Delta P_0}{2} + \frac{18000 \cdot \Delta t^2}{T_J} \cdot \Delta P_1 = \Delta\delta_1 + K \cdot \Delta P_1 = 1.124^0 + 5.23 \cdot 0.414 = 3.289^0$$

Ikkinchi interval oxiridagi burchak:

$$\delta_2 = \delta_1 + \Delta\delta_2 = 36.984^0 + 3.289^0 = 40.273^0$$

Ikkinchi interval oxiridagi quvvat orttirmasini topamiz:

$$\Delta P_2 = P_0 - P_m^{III} Sin\delta_2 = 1 - 0.974 Sin 40.273^0 = 0.37$$

Uchinchi intervalda olingan burchak orttirmasi:

$$\Delta\delta_3 = \Delta\delta_2 + K \cdot \Delta P_2 = 3.289^0 + 5.23 \cdot 0.37 = 5.226^0$$

Uchinchi interval oxiridagi burchak

$$\delta_3 = \delta_2 + \Delta\delta_3 = 40.273^0 + 5.226^0 = 45.499^0$$

Uchinchi interval oxiridagi quvvat orttirmasi

$$\Delta P_3 = P_0 - P_m^{III} Sin\delta_3 = 1 - 0.974 Sin 45.499^0 = 0.305$$

To‘rtinchi intervalda olingan burchak orttirmasini topamiz:

$$\Delta\delta_4 = \Delta\delta_3 + K\Delta P_3 = 5.226^0 + 5.23 \cdot 0.305 = 6.821^0$$

To‘rtinchi interval oxiridagi burchak:

$$\delta_4 = \delta_3 + \Delta\delta_4 = 45.499^0 + 6.821^0 = 52.32^0$$

To‘rtinchi interval oxiridagi quvvat orttirmasini topamiz:

$$\Delta P_4 = P_0 - P_m^{III} Sin\delta_4 = 1 - 0.974 Sin 52.32^0 = 0.229$$

Beshinchi intervalda olingan burchak orttirmasini topamiz:

$$\Delta\delta_5 = \Delta\delta_4 + K \cdot \Delta P_4 = 6.821^0 + 5.23 \cdot 0.229 = 8.019^0$$

Beshinchi interval oxiridagi burchak:

$$\delta_5 = \delta_4 + \Delta\delta_5 = 52.32^0 + 8.019^0 = 60.339^0$$

Beshinchi interval oxiridagi quvvat orttirmasini topamiz

$$\Delta P_5 = P_0 - P_m^{III} Sin\delta_5 = 1 - 0.974 Sin 60.339^0 = 0.154$$

Oltinchi intervalda olingan burchak orttirmasini topamiz:

$$\Delta\delta_6 = \Delta\delta_5 + K \cdot \Delta P_5 = 8.019^0 + 5.23 \cdot 0.154 = 8.824^0$$

Oltinchi interval oxiridagi burchak:

$$\delta_6 = \delta_5 + \Delta\delta_6 = 60.339^0 + 8.824^0 = 69.163^0$$

Oltinchi interval oxirida rele himoyasi qisqa tutashgan fazani o‘chiradi va sistemaning rejimi avariya rejim xarakteristikasidan avariyadan keyingi rejim xarakteristikasiga o‘tadi. Bu nuqtada sinxron generator rotoriga qisman qo‘shimcha aylantiruvchi moment ta’sir etsa, qisman esa qushimcha tormozlovchi moment ta’sir etadi. Natijaviy moment ta’sirida sinxron generator rotorining olgan tezligi va burchakning o‘zgarishini quyidagi formuladan foydalanib topamiz:

Oltinchi interval oxiridagi quvvat orttirmasi:

$$\Delta P_6 = P_0 - P_m^{III} Sin\delta_6 = 1 - 0974 Sin 69.163^0 = 0.088$$

$$\Delta P_6' = P_0 - P_m^{II} Sin\delta_6 = 1 - 1.11 Sin 69.163^0 = -0.037$$

Yettinchi intervalda olingan burchak orttirmasini topamiz:

$$\Delta\delta_7 = \Delta\delta_6 + K \cdot \frac{\Delta P_6 + \Delta P_6'}{2} = 8.824^0 + 5.23 \cdot \frac{0.088 - 0.037}{2} = 8.957^0$$

yettinchi interval oxiridagi burchakni topamiz

$$\delta_7 = \delta_6 + \Delta\delta_7 = 69.163^0 + 8.957^0 = 78.12^0$$

Yettinchi interval oxiridagi quvvat orttirmasi:

$$\Delta P_7 = P_0 - P_m^{II} Sin\delta_7 = 1 - 1.11 Sin 78.12^0 = -0.086$$

Sakkizinchi intervalda olingan burchak orttirmasini topamiz:

$$\Delta\delta_8 = \Delta\delta_7 + K \cdot \Delta P_7 = 8.957^0 + 5.23 \cdot (-0.086) = 8.506^0$$

Sakkizinchi interval oxiridagi burchakni topamiz:

$$\delta_8 = \delta_7 + \Delta\delta_8 = 78.12^0 + 8.506 = 86.626^0$$

Sakkizinchi interval oxiridagi quvvat orttirmasini topamiz

$$\Delta P_8 = P_0 - P_m^{II} Sin\delta_8 = 1 - 1.11 Sin 86.626^0 = -0.108$$

To‘qqizinchi intervalda olingan burchak orttirmasini aniqlaymiz:

$$\Delta\delta_9 = \Delta\delta_8 + K \cdot \Delta P_8 = 8.626^0 + 5.23 \cdot (-0.108) = 8.061^0$$

To‘qqizinchi interval oxiridagi burchakni topamiz:

$$\delta_9 = \delta_8 + \Delta\delta_9 = 86.626^0 + 8.061 = 94.687^0$$

To’qqizinchi interval oxiridagi quvvat orttirmasini topamiz

$$\Delta P_9 = P_0 - P_m^{II} Sin\delta_9 = 1 - 1.11 Sin 94.687^0 = -0.106$$

O‘ninchi intervalda olingan burchak orttirmasini aniqlaymiz:

$$\Delta\delta_{10} = \Delta\delta_9 + K \cdot \Delta P_9 = 8.061^0 + 5.23(-0.106) = 7.505^0$$

O‘ninchi interval oxiridagi burchakni topamiz:

$$\delta_{10} = \delta_9 + \Delta\delta_{10} = 94.687^0 + 7.505 = 102.192^0$$

O‘ninchi interval oxiridagi quvvat orttirmasini topamiz

$$\Delta P_{10} = P_0 - P_m^{II} Sin\delta_{10} = 1 - 1.11 Sin 102.192^0 = -0.085$$

O‘nbirinchi intervalda olingan burchak orttirmasini aniqlaymiz:

$$\Delta\delta_{11} = \Delta\delta_{10} + K \cdot \Delta P_{10} = 7.505^0 + 5.23 \cdot (-0.085) = 7.061^0$$

O‘n birinchi interval oxiridagi burchakni topamiz:

$$\delta_{11} = \delta_{10} + \Delta\delta_{11} = 102.192^0 + 7.061 = 109.253^0$$

O‘n birinchi interval oxirida toksiz pauzadan keyin avtomatik qayta ulagich o‘chirilgan fazani qayta ulaydi. Sistemaning normal kommutatsiya sxemasi tiklanishi natijasida rejim avariyadan keyingi xarakteristikadan normal rejim xarakteristikasiga o‘tadi. Natijada sinxron generator rotoriga ta’sir etayotgan tormozlovchi moment oshadi.

O‘ninchi interval oxiridagi quvvat orttirmasini topamiz

$$\Delta P_{11} = P_1 - P_m^{II} Sin\delta_{11} = 1 - 1.11 Sin 109.253^0 = -0.0479$$

$$\Delta P'_{11} = P_0 - P_m^I Sin\delta_{11} = 1 - 1.71 Sin 109.253^0 = -0.614$$

O‘n ikkinchi intervalda olingan burchak orttirmasini topamiz:

$$\Delta\delta_{12} = \Delta\delta_{11} + K \cdot \frac{\Delta P_{11} + \Delta P'_{11}}{2} = 7.061^0 + 5.23 \cdot \frac{(-0.0479 - 0.614)}{2} = 5.33^0$$

O‘n ikkinchi interval oxiridagi burchakni topamiz:

$$\delta_{12} = \delta_{11} + \Delta\delta_{12} = 109.253^0 + 5.33^0 = 114.583^0$$

O‘n ikkinchi interval oxirida gi quvvat orttirmasini aniqlaymiz

$$\Delta P_{12} = P_0 - P_m^I Sin\delta_{12} = 1 - 1.71 Sin 114.583^0 = -0.555$$

O‘n uchinchi intervalda olingan burchak orttirmasini topamiz:

$$\Delta\delta_{13} = \Delta\delta_{12} + K \cdot \Delta P_{12} = 5.33^0 + 5.23 \cdot (-0.555) = 2.427^0$$

O‘n uchinchi interval oxiridagi burchakni aniqlaymiz

$$\delta_{13} = \delta_{12} + \Delta\delta_{13} = 114.583^0 + 2.427^0 = 117.01^0$$

O‘n uchinchi interval oxiridagi quvvat orttirmasini topamiz

$$\Delta P_{13} = P_0 - P_m^I Sin\delta_{13} = 1 - 1.71 Sin 117.01^0 = -0.523$$

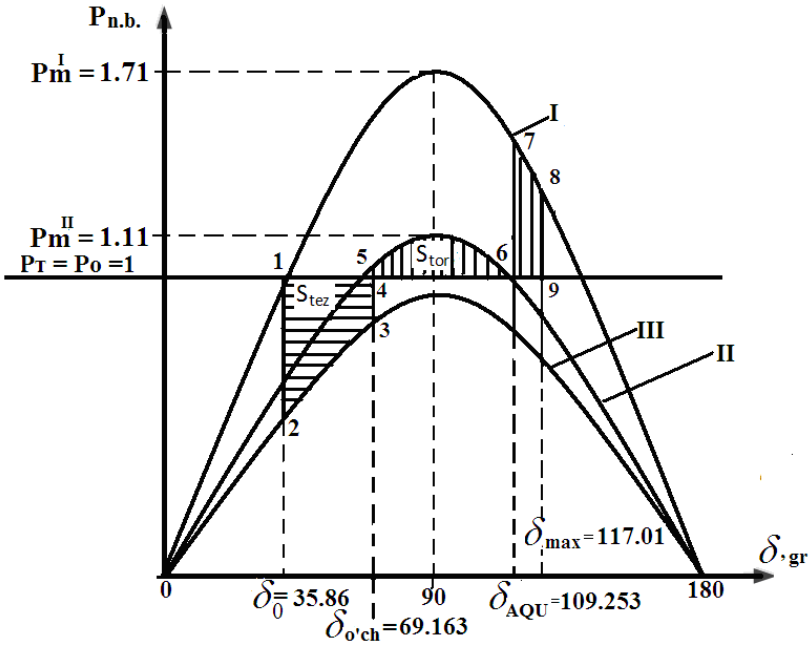
O‘n to‘rtinchi intervalda olingan burchak orttirmasini topamiz

$$\Delta\delta_{14} = \Delta\delta_{13} + K \cdot \Delta P_{13} = 2.427^0 + 5.23 \cdot (-0.523) = -0.308^0$$

O‘n to‘rtinchi interval oxiridagi burchakni topamiz

$$\delta_{14} = \delta_{13} + \Delta\delta_{14} = 117.01^0 - 0.308^0 = 116.701^0$$

Keyingi topilgan burchak $\delta_{14} \prec \delta_{13}$ oldingi intervalda topilgan burchakdan kichik, bu bizga avtomatik qayta ulashning muvafaqiyatli tugaganini bildiradi. Bu nuqtada $\delta_{AQU} \prec \delta_{MAX}$ (48-rasm).



48-rasm. Bir fazali qisqa tutashuv rejimining burchak xarakteristikasi

Sinov savollari

1. Sistemada o‘tkinchi jarayonlarga olib keladigan sabablar.
2. Ayon va noayon qutbli sinxron generatorlarning quvvat xarakteristikasini tushuntiring.
3. Oddiy elektr sistemaning vektor diagrammasini quring va undan rejim parametrlari orasidagi bog‘lanishlarni izohlang.
4. Sistema tarmog‘ining tokning simmetrik tashkil etuvchilariga bo‘lgan almashtirish sxemasini tuzishni tushuntiring.
5. Oddiy elektr sistemaning rejim va sistema parametrlari?
6. Sistemada aktiv quvvatning ideal va haqiqiy uzatish chegaralarini aniqlash tartibi?
7. Sistemaning nosimmetrik qisqa tutashuv rejimi uchun tok va kuchlanish vektor diagrammasini tuzish tartibini tushuntiring.
8. Aktiv quvvat uzatilish chegarasiga QARning ta’sirini izoxlab tushuntirib bering.
9. Nisbiy birliklar sistemasini qo‘llashning qulaylikligi?
10. Sinxron generator rotorining nisbiy harakat tenglamasini keltirib chiqaring.
11. Sinxron generator rotorining nisbiy harakat tenglamasini simmetrik va nosimmetrik qisqa tutashuv rejimi uchun yechish tartibi.
12. Sistemaning statik turg‘unlik koeffitsiyenti va mezoni?
13. Sistema dinamik turg‘unligiga QAR va AQUning ta’sirini tushuntiring.
14. Sistema dinamik turg‘unligiga qisqa tutashuv turi va vaqtining ta’sirini tushuntiring.
15. Aktiv quvvatning haqiqiy uzatilish chegarasining tanlash tartibini tushuntiring.

Foydalaniladigan asosiy darsliklar va o‘quv qo‘llanmalar ro‘yxati

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1-Ilova

1.Generatorlarning katalog parametrlari

№	Generator turlari	Nominal quvvat		$U_н, kV$	Cos φ	Generator qarshiliklari				
		To'liq $S_n\ MVA$	Aktiv $P_n\ MVt$			$x_d^{''}$	$x_d^{'}$	x_d	x_2	x_q
1	СВ-395/250-2	80	67	10,5	0,85	0,22	0,34	1,23	0,3	0,63
2	СВ-835/180-36	111	100	13,8	0,9	0,22	0,3	0,94	0,3	0,469
3	СВ-1500/200-88	127,8	115	13,8	0,85	0,15	0,2	0,52	0,147	0,332
4	СВФ-1500/130-88	160	128	13,8	0,8	0,4	0,56	1,75	0,147	0,8
5	СВ-1430/175-72	178	160	14,4	0,9	0,22	0,3	0,85	0,147	0,66
6	ТГВ-200	235,3	200	15,75	0,85	0,19	0,295	1,84	0,232	
7	ТВВ-200-2	235,3	200	15,75	0,85	0,181	0,272	2,106	0,22	
8	ТГВ-300	353	300	20	0,85	0,195	0,3	2,195	0,238	
9	ТВВ-320-2Еуз	375	320	20	0,85	0,173	0,258	1,698	0,211	

2-Ilova

2. Havo elektr uzatish liniyalari o'tkazgichlarining nomimal parametrlari.

№	O'tkazgichning markasi	1 km uz. to'g. keluvchi ak.qar. $(20^{\circ}C\ haroratdagi)$	1 km uzunlikka to'g'ri keluvchi reaktiv qarshiligi	
			110 kV	220 kV
		$r_0\ (Om/km)$	$x_0\ (Om/km)$	$x_0\ (Om/km)$
1	AC-185	0.162	0.413	-
2	AC-240	0.121	0.405	0.435
3	AC-300	0.098	-	0.429

3-Ilova

3. Transformatorlarning katalog parametrlari

№	Transformator turlari	Nominal to'la quvvati	Transfor-matorning nominal kuchlanishi	Chulg'amning kuchlanishi (kV)			Qisqa tutashuv kuchlanishi U_k%		
		S_n MVA	U_n	YuK	O'K	QK	Y-O'	Y-Q	O'-Q
1	ТРДН-40000/110	40	110	115		6,3/10,5		10,5	
2	ТДН-40000/110	40	110	115		6,3/10,5		10,5	
3	ТДН-63000/110	63	110	115		38,5		10,5	
4	ТДТН-63000/110	63	110	115	11/38,5	6,6/11	11	18,5	7
5	ТДТН-80000/110	80	110	115	11/38,5	6,6/11	11	18,5	7
6	ТДН-80000/110	80	110	115		38,5		10,5	
7	ТД-80000/220	80	220	242		6,3/10,5/13,8		11	
8	ТДЦ-125000/220	125	220	242		10,5/13,8		11	
9	ТЦ-160000/220	160	220	242		13,8/15,75		11	
10	ТДЦ-200000/220	200	220	242		13,8/15,75/18		11	
11	ТДЦ-250000/220	250	220	242		13,8/15,75		11	
12	ТДЦ-400000/220	400	220	242		13,8/15,75/20		11	
13	АТДЦТН-63000/220/110	63	220	230	121	11	11	35	22
14	АТДЦТН-160000/220/110	160	220	230	121	11	11	30	18
15	АТДЦТН-200000/220/110	200	220	230	121	11	11	32	20
16	АТДЦТН-250000/220/110	250	220	230	121	11	11	32	20

Mundarija