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

ISLOM KARIMOV NOMIDAGI
TOSHKENT DAVLAT TEXNIKA UNIVERSITETI

RELE HIMOYA

kurs loyihasi
uslubiy ko‘rsatma

TOSHKENT – 2022

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UDK. 621.316

Tuzuvchilar: kat.o‘q. Shamsutdinov H.F., ass. Normamatov N.N., ass. Ikramov T.A. “Releli himoya” fanidan uslubiy ko‘rsatma - Toshkent, ToshDTU, 2022 – 52 b.

Ushbu uslubiy ko‘rsatmalar «Rele himoyasi» fanidan kurs loyihasini bajarish uchun tuzilgan. Kurs loyihasini bajarish talabalarda elektr tizimi elementlarini releli himoya yordamida, turli shikastlanishlardan himoyalash to‘g‘risidagi bilimini chuqurlashtirishga yordam beradi.

Ushbu uslubiy ko‘rsatmada kurs loyihasi bo‘yicha kerakli nazariy ma‘lumotlar, topshiriqlar, ularni bajarish tartibi hamda katalog ma‘lumotlar keltirilgan.

Uslubiy qo‘llanma “60710600 - Elektr energetika” ta‘lim yo‘nalishi talabalari uchun mo‘ljallangan bo‘lib, keltirilgan kurs loyihasi mazkur fanning namunaviy dasturiga muvofiq keladi.

I.Karimov nomidagi Toshkent davlat texnika universiteti ilmiy-uslubiy kengashi qaroriga muvofiq chop etildi.(29.06.2022y. 10-sonli bayonnoma)

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Kirish

Elektr tizimlarining, elektr stansiyalarining elektr qurilma va asboblarida, elektr uzatish liniyalarida, elektr iste'molchilarida normal va ishdan chiqish, shikastlanish holatlarini uchratish mumkin. Ishdan chiqish yoki shikastlanish ko'p hollarda elektr tizimining elementlarida tokning me'yoridan oshib ketishi yoki kuchlanishning pasayishi bilan bog'langan, bu hodisalarni aytib o'tilgan faktorlar bilan kuzatish mumkin. Me'yoridan oshib ketgan tok katta miqdorda issiqlik ajralib chiqishiga olib keladi. Buning natijasida elektr uzatish liniyalari va qurilmalari xavfli darajada qizishi va shikastlanishi mumkin. Kuchlanishning normadan pasayishi elektr iste'molchilarning normal ishlashiga yo'l qo'ymaydi va parallel ishlayotgan generator va energetika tizmining turg'unligiga salbiy ta'sir ko'rsatadi. Shunday qilib, elektr qurilmalarining shikastlanishi energetika tizimlarining va elektr iste'molchilarning ish rejimiga salbiy ta'sir ko'rsatadi. Elektr tizimlarining normadan tashqari holatlari esa energetika tizimining shikastlanishiga yoki ishdan chiqishiga imkoniyat yaratadi.

Elektr tizimlarini va iste'molchilarning normal ishlashlari uchun shikastlangan qurilma, elektr liniyalari tezda aniqlanishi, o'chirilishi kerak va shu orqali qolgan elektr iste'molchilari va energetik tizimni normal ishlashiga sharoit yaratilishi kerak.

Normadan tashqari holatlar vaqtida aniqlanib, choralar ko'rilsa, xavfsizlik ta'minlanadi. Yuqorida ko'rsatilganlardan xulosa qilib shuni aytish mumkinki, elektr tizimlari va elektr iste'molchilarini shikastlanish va normadan tashqari holatlardan saqlash uchun uning elementlarini himoyalovchi avtomatik qurilmani qurish va ishlatishga elektr tizimlarining talabi katta.

Elektr tizimida dastavval himoya qurilmasi qilib eruvchan saqlagichlar qo'llaniladi. Quvvat va kuchlanish oshishi, elektr tizimlari ulanish sxemalarining murakkablashishi eruvchan saqlagichlarning ko'p kamchiliklarini namoyon qildi va buning oqibatida yangi himoyalovchi qurilma yaratildi. Bu himoyalovchi qurilma maxsus avtomat-rele yordamida amalga oshirildi va releli himoa deb nomlandi.

Releli himoya elektr avtomatikaning asosiy turi bo‘lib, usiz hozirgi zamon elektr tizimlari normal va mustahkam ishlay olmaydilar. U energetika tizimining barcha elementlarining holatlarini doimo tekshirib, nazorat qilib boradi.

Energetika tizimida shikastlanish bo‘lganda himoya uni aniqlaydi va shikastlangan energetika tizimining qismini maxsus katta tokka mo‘ljallangan kuch o‘chirgichlariga ta‘sir etib o‘chiradi.

Energetika tizimida nonormal sharoit yoki holat bo‘lganda himoya uni aniqlaydi va bu holatning xarakteriga qarab, normal sharoitni tiklash uchun kerakli bo‘lgan chora amallarni qo‘llaydi yoki navbatchi shaxsga xabar beradi.

Hozirgi zamon energetika tizimi releli himoyalar elektr ta‘minotini tez tiklovchi va tizimni normal holatga keltiruvchi mustahkam va aniq elektr avtomatikasi bilan ta‘minlangan.

Elektr avtomatikasining qurilmalariga qayta ulash avtomatikasi (AQU), chastota asosida signallash avtomatikasi (AChR) va zaxiradagi manbani ulash avtomatikasi (AVR) kiradi.

Kurs loyihasiga topshiriq va vazifalar

Elektr qurilmalarning tuzilishi qoidalariga (EKK) muvofiq liniyalar, transformatorlar va elektr motorlar releli himoyasini berilgan variant uchun tanlang; bu himoyalar va ZAU va AQU lar o'rnatmalarini tanlang; variantda ko'rsatilgan liniyaning (transformator) himoya sxemasi va ZAU yoki AQU ishlab chiqing.

Bajarish tartibi

Uch va ikki fazali qisqa tutashuvlarda toklarni hisoblab chiqing; tok va kuchlanish transformatorlarini va ularning transformatsiya koeffitsiyentini tanlang; himoya moslamalarining turlarini tanlang va [1,3] muvofiq ularning sezuvchanligini asoslab bering; ZAU va AKU o'rnatmalarini hisoblang; uch liniyali himoyaning sxemasini ishlab chiqing; ishlab chiqilgan sxema uchun relelar turlarini, o'lchov transformatorlarini tanlang va kerakli apparatura tavsifini (spetsifikatsiya) sxemada ko'rsating; o'rnatma kartasini tuzing, ya'ni tarmoqning uchastkasida qabul qilingan himoyalar turlarini, sistemali avtomatika moslamalarini va ularning o'rnatmalarini, hamda kuchlanish va tok transformatorlar o'rnatilish joyini va ularning transformatsiya koeffitsiyentlarini ko'rsating.

Bajarishga ko'rsatmalar

Hisoblashni boshlashdan oldin tarmoq uchastkasining sxemasini, uning konfiguratsiyasini diqqat bilan o'rganish kerak va iste'molchilarning ilojili ta'mir va avariyali ta'minot sxemalarini ko'z oldiga keltirish kerak. Himoyalanayotgan elementdan o'tadigan tok eng katta bo'lgan hisobiy sxemalarni va eng kichik qiymatga ega bo'lgan sxemalarni aniqlash kerak; bazisli solishtirma birliklarda ifodalab tarmoqning hamma elementlarining qarshiliklarini hisoblab chiqish kerak.

Ta'minlanayotgan shinalardagi qisqa tutashuv quvvatini bazisli deb olish maqsadga muvofiq. Qisqa tutashuv toklarning hamma hisoblari himoya yoki sistemani avtomatika moslamalari o'rnatilgan kuchlanish uchun bajariladi. Kurs ishida tarmoqning izolyatsiyalangan neytralli uchastkalari va sistemadan

ta'minlanish ko'rib chiqiladi, shuning uchun faqat uch-ikki fazali qisqa tutashuv toklarni hisoblash kerak va vaqt davomida ular o'zgarmas deb qabul qilish kerak. Ikki fazali qisqa tutashuvda tok quyidagi formula bo'yicha aniqlanadi:

$$I^{2}_{qt} = \frac{\sqrt{3}}{2} \cdot I^{(3)}_{qt}$$

Qisqa tutashuv hisobiy nuqtalar sifatida hamma podstansiyalarning shinalari qabul qilinadi. Qisqa tutashuv minimal va maksimal qiymatlarning hisoblash natijalari qisqa tutashuv nomeri va toklarning keltirilgan kuchlanishi hamda hisobiy sxemalar ko'rinishida A jadvalga keltirilishi kerak.

A jadval

Hisobiy sxemaning nomeri	Qisqa tutashuv hisoblash nuqtasi / Qisqa tutashuv toklari	K_1	K_2	K_3	K_4	K_5	K_6	K_7	K_8	va h. k.
1										
2										
va h. k.										

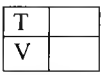
Elektr qurilmalarning tuzilish qoidalari (EKTK) ning talablari va podstansiyadagi operativ tokning turini hisobga olib, eng oddiy himoya moslamalarini qo'llash imkoniyatini aniqlab, himoya turlarini tanlash kerak. O'zgaruvchan operativ tokli podstansiyalarda to'g'ri ulanadigan releni yoki oddiy sxema bo'yicha tokdan chegaralangan bog'liqli sabr vaqtli releni qo'llash imkoniyatini aniqlash kerak. AKU (AVP) va ZAU (AVR) o'rnatmalarni hisoblash releli himoyaning o'rnatmalarini hisobidan keyin bajariladi va ular bilan kelishtiriladi.

Rasmiylashtirish tartibi

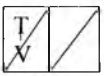
Kurs ishi tushuntirish xati va ikkita sxema kurinishida takdim etiladi.

Tushuntirish xati qisqa tutashuv toklarning hisobi, himoyalarning, o‘rnatmalarning va sezuvchanlik koeffitsiyentlari qabul qilingan yechimlarning to‘la isboti ZAU (AVR) va AKU (AVP) moslamalarning o‘rnatmalarini ichiga olish kerak. Sxemalar standart o‘lchovli millimetrli qog‘ozning orqa tomoniga chiziladi. Birinchi sxemaga tarmoqning berilgan qismi va o‘rnatma kartasi chiziladi, ikkinchiga esa kerakli apparatura (relelar, tok transformatorlari va h. k.) turlari, transformatsiya koeffitsiyentlari, soni ko‘rsatilgan ro‘yxati bilan ishlangan uch liniyali himoya va avtomatikaning sxemasi chiziladi.

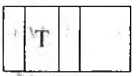
O‘rnatmalar kartasida himoya va avtomatika turlarining tasviri quyidagi belgilar yordamida bajariladi:



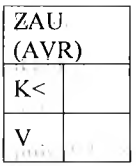
Sabr vaqtli maksimal tok himoyasi



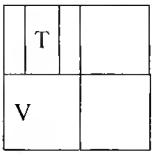
Sabr vaqtli rele



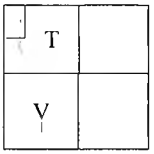
tokli kesim



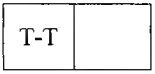
ZAU (AVR) moslamasi



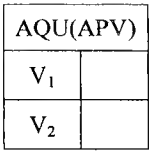
Sabr vaqtli tok kesim



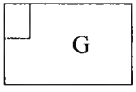
o‘ta yuklanishdan himoya



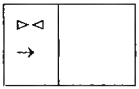
bo‘ylama dif. himoya



AQU(APV) moslamasi



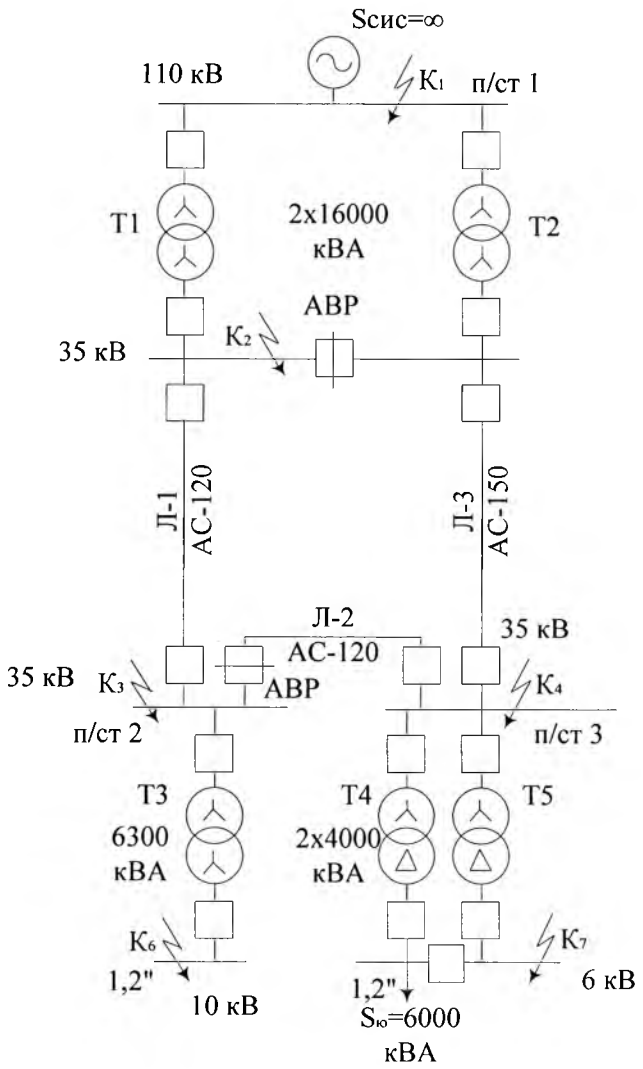
gazli himoya



ko‘ndalang yo‘naltirilgan dif. himoya.

Releli himoya va avtomatikaning variant va sxemalari

Sxema raqami	Variant raqami	Releli himoya va AQU ni uch chiziqli sxemasi tuzilishi kerak bo‘lgan liniyalarning raqami	Transformator himoyasi va (AVR bo‘lsa uni ham) sxemasini tuzish talab etiladigan nimstansiya raqami	TT ni transformatsiyalash koeffitsiyentining o‘zgarish oralig‘i, %	AD ni ishga tushirish koeffitsiyenti K_p	p/st dagi operativ tokning kuchlanishi, V					Liniyaning uzunligi, km		
						1	2	3	4	5	Л1	Л2	Л3
4	5		4	12,5	2	-220	~	~	~	~	20	10	20



1 – rasm. Berilgan elektr sxemasi

Elektr tizimida releli himoya va avtomatikadan hisoblashga doir misol.

Parametrlarni hisoblash uchun beriluvchi (ma'lumotlarni) qiymatlarni ma'lumotnomalardan olamiz:

a) havo va kabel liniyalar:

	U=35 kV	
AC-120	r_0=0,27 Om/km	x_0=0,43 Om/km
AC-150	r_0=0,21 Om/km	x_0=0,398 Om/km
AC-70	r_0=0,45 Om/km	x_0=0,42 Om/km
	U=10 kV	
AAIIIв-70	r_0=0,443 Om/km	x_0=0,086 Om/km

b) transformatorlar:

ТДН – 16000/110	
S_n=16 MVA	$P_{q.t}$ =85 kVt
U_{yu}=115 kV	$U_к$= 10,5 %
$U_п$=35 kV	±9 x 1,78 %
TMH – 6300 kVA	
S_n=6,3 MVA	$P_{q.t.}$ =46,5 kVt
U_{yu}=35 kV	$U_к$= 7,5 %
$U_п$=11 kV	±6 x 1,5 %
TMH – 4000 кВА	
S_n=4 MVA	$P_{q.t.}$ =33,5 kVt
U_{yu}=35 kV	$U_к$= 7,5 %
$U_п$=6.3 kV	±6 x 1,5 %

Liniya va transformatorlarning qarshiliklarini hisoblashni nisbiy birlikda olib boramiz. Buning uchun bazisli shartlarini qabul qilamiz:

S_b= 100 MVA, U_{bI}= 115 kV, U_{bII}= 37 kV, U_{bIII}= 10,5 kV, U_{bIV}= 6,3 kV

L1 liniya uchun

$$r_{L1}^{b} = r_0 \cdot l \cdot \frac{S_{baz}}{U^2_{bi}} = 0{,}27 \cdot 20 \cdot \frac{100}{37^2} = 0{,}394$$

$$x_{L1}^{b} = x_0 \cdot l \cdot \frac{S_{baz}}{U^2_{bi}} = 0{,}43 \cdot 20 \cdot \frac{100}{37^2} = 0{,}628$$

$$z_{L1}^{b} = r_{L1}^{b} + jx_{L1}^{b} = 0{,}394 + j0{,}628$$

L2 liniya uchun

$$r_{L1}^{b} = r_0 \cdot l \cdot \frac{S_{baz}}{U^2_{bi}} = 0{,}27 \cdot 10 \cdot \frac{100}{37^2} = 0{,}197$$

$$x_{L1}^{b} = x_0 \cdot l \cdot \frac{S_{baz}}{U^2_{bi}} = 0{,}43 \cdot 10 \cdot \frac{100}{37^2} = 0{,}314$$

$$z_{L1}^{b} = r_{L1}^{b} + jx_{L1}^{b} = 0{,}197 + j0{,}314$$

L3 liniya uchun

$$r_{L1}^{b} = r_0 \cdot l \cdot \frac{S_{baz}}{U^2_{bi}} = 0{,}21 \cdot 20 \cdot \frac{100}{37^2} = 0{,}307$$

$$x_{L1}^{b} = x_0 \cdot l \cdot \frac{S_{baz}}{U^2_{bi}} = 0{,}398 \cdot 20 \cdot \frac{100}{37^2} = 0{,}581$$

$$z_{L1}^{b} = r_{L1}^{b} + jx_{L1}^{b} = 0{,}307 + j0{,}581$$

L4 liniya uchun

$$r_{Л1}^{б} = r_0 \cdot l \cdot \frac{S_{баз}}{U^2_{бі}} = 0{,}45 \cdot 10 \cdot \frac{100}{37^2} = 0{,}329$$

$$x_{Л1}^{б} = x_0 \cdot l \cdot \frac{S_{баз}}{U^2_{бі}} = 0{,}42 \cdot 10 \cdot \frac{100}{37^2} = 0{,}307$$

$$z_{Л1}^{б} = r_{Л1}^{б} + jx_{Л1}^{б} = 0{,}329 + j0{,}307$$

L5 liniya uchun

$$r_{L1}^{b} = r_0 \cdot l \cdot \frac{S_{baz}}{U^2_{bi}} = 0{,}443 \cdot 3 \cdot \frac{100}{10{,}5^2} = 1{,}205$$

$$x_{L1}^b = x_0 \cdot l \cdot \frac{S_{baz}}{U^2_{bi}} = 0{,}086 \cdot 3 \cdot \frac{100}{10{,}5^2} = 0{,}234$$

$$z_{L1}^b = r_{L1}^b + jx_{L1}^b = 1{,}205 + j0{,}234$$

T1 (T2) transformatorlar uchun

$$U_{at} = \frac{P_{qt}}{S_{nom}} \cdot 100\% = \frac{85}{16000} \cdot 100\% = 0{,}531\%$$

$$U_{rt} = \sqrt{U_\kappa^2 - U_{at}^2} = \sqrt{10{,}5^2 - 0{,}531^2} = 10{,}487\%$$

$$r_{T1(T2)}^b = \frac{U_{at}}{100} \cdot \frac{S_{baz}}{S_{nom}} = \frac{0{,}531 \cdot 100}{100 \cdot 16} = 0{,}033$$

$$x_{T1(T2)}^b = \frac{U_{rt}}{100} \cdot \frac{S_{baz}}{S_{nom}} = \frac{10{,}487 \cdot 100}{100 \cdot 16} = 0.655$$

$$z_{T1}^b = r_{T1}^b + jx_{T1}^b = 0{,}033 + j0.655$$

T3 transformator uchun

$$U_{at} = \frac{P_{qt}}{S_{nom}} \cdot 100\% = \frac{46.5}{6300} \cdot 100\% = 0{,}738\%$$

$$U_{rt} = \sqrt{U_\kappa^2 - U_{at}^2} = \sqrt{7.5^2 - 0{,}738^2} = 7.464\%$$

$$r_{T1(T2)}^b = \frac{U_{at}}{100} \cdot \frac{S_{baz}}{S_{nom}} = \frac{0{,}738 \cdot 100}{100 \cdot 6.3} = 0{,}117$$

$$x_{T1(T2)}^b = \frac{U_{rt}}{100} \cdot \frac{S_{baz}}{S_{nom}} = \frac{7.464 \cdot 100}{100 \cdot 6.3} = 1.185$$

$$z_{T1}^b = r_{T1}^b + jx_{T1}^b = 0{,}117 + j1.185$$

T4 transformator uchun

$$U_{at} = \frac{P_{qt}}{S_{nom}} \cdot 100\% = \frac{33{,}5}{4000} \cdot 100\% = 0{,}838\%$$

$$U_{rt} = \sqrt{U_\kappa^2 - U_{at}^2} = \sqrt{7{,}5^2 - 0{,}838^2} = 7.45\%$$

$$r_{T1(T2)}^b = \frac{U_{at}}{100} \cdot \frac{S_{baz}}{S_{nom}} = \frac{0{,}838 \cdot 100}{100 \cdot 4} = 0{,}209$$

$$x^{6}_{T1(T2)} = \frac{U_{pm}}{100} \cdot \frac{S_{baz}}{S_{nom}} = \frac{7.45 \cdot 100}{100 \cdot 4} = 1{,}863$$

$$z^{b}_{T1} = r^{b}_{T1} + jx^{b}_{T1} = 0{,}209 + j1{,}863$$

T6 transformator uchun

$$U_{at} = \frac{P_{qt}}{S_{nom}} \cdot 100\% = \frac{46.5}{6300} \cdot 100\% = 0{,}738\%$$

$$U_{rt} = \sqrt{U_{k}^{2} - U_{at}^{2}} = \sqrt{7.5^{2} - 0{,}738^{2}} = 7.464\%$$

$$r^{b}_{T1(T2)} = \frac{U_{at}}{100} \cdot \frac{S_{baz}}{S_{nom}} = \frac{0{,}738 \cdot 100}{100 \cdot 6.3} = 0{,}117$$

$$x^{b}_{T1(T2)} = \frac{U_{rt}}{100} \cdot \frac{S_{baz}}{S_{nom}} = \frac{7.464 \cdot 100}{100 \cdot 6.3} = 1.185$$

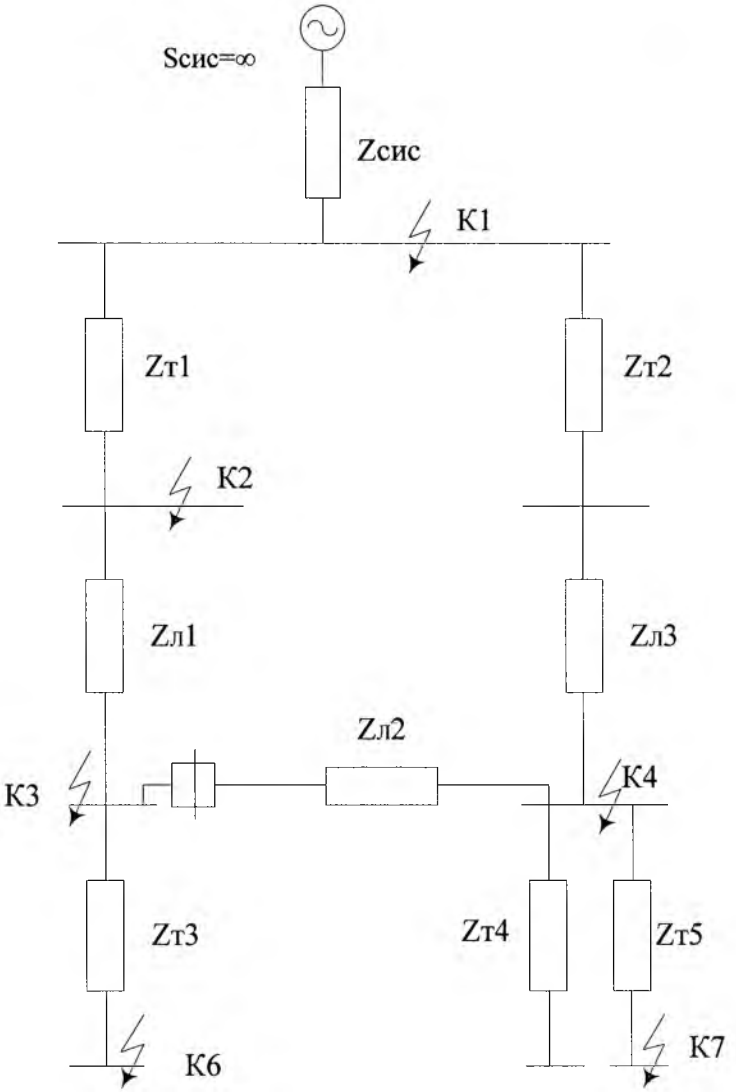
$$z^{b}_{T1} = r^{b}_{T1} + jx^{b}_{T1} = 0{,}117 + j1.185$$

Elektr prinsipial sxemaga mos ekvivalent almashtirish sxemasini tuzib, taqsimlash qurilmalari shinalarida qabul qilingan va hisoblanishi shart bo‘lgan K1 – K8 nuqtalarda qisqa tutashuv toklarini belgilaymiz.

T1 (T2) transformatorlarning yuqori kuchlanish tomoniga o‘chirgich tanlaymiz. Buning uchun transformatorlarning nominal toklarini hisoblaymiz:

$$I_{n} = \frac{S_{tr}}{\sqrt{3} \cdot U_{n}} = \frac{16000}{\sqrt{3} \cdot 110} = 83{,}9A$$

Jadvaldan foydalanib МКП-110Б-630-20У1 turidagi moyli o‘chirgichni tanlaymiz va o‘chirgichning o‘chirish tokini $I_{o'chir}$= 20 kA. O‘chirgichdan $S_{max}=\sqrt{3} \cdot I_{o'chir} \cdot U_{n}=\sqrt{3} \cdot 20 \cdot 110=3811$ MVA maksimal quvvat o‘tadi. Minimal rejimda esa $S_{min}=0{,}6 \cdot S_{max}=0{,}7 \cdot 3811=2667$ MVA.



2 – rasm. Berilgan elektr sxemasining almashtirish sxemasi

a) sistemaning maksimal ish rejimi

Sistemaning qarshiligini quyidagicha hisoblaymiz:

$$x_{sis} = \frac{S_{baz}}{S_{qt}} = \frac{100}{3811} = 0{,}026$$

$$z_{sis} = x_{sis} = j0{,}026$$

Manbadan K-1 qisqa tutashuv nuqtasigacha bo'lgan qarshiliklar yig'indisi quyidagiga teng: $z_{ekv1} = z_{sis} = j0{,}026$

Qisqa tutashuv nuqtasida bazis kuchlanishdagi tok quyidagi formula yordamida aniqlanadi:

$$I_{k1} = \frac{S_b}{\sqrt{3} \cdot Z_{ekv1} \cdot U_{b1}} = \frac{100}{\sqrt{3} \cdot 0{,}026 \cdot 115} = 19{,}13 \text{ kA}$$

K-2 nuqta

$$z_{ekv2} = z_{ekv1} + z_{T1} = j0{,}026 + 0{,}033 + j0.655 = 0{,}033 + j0.682$$

$$| z_{ekv2} | = \sqrt{0{,}033^2 + 0.682^2} = 0.682$$

$$I_{k2} = \frac{S_б}{\sqrt{3} \cdot Z_{экв2} \cdot U_{б2}} = \frac{100}{\sqrt{3} \cdot 0.682 \cdot 37} = 2{,}286 \text{ kA}$$

K-3 nuqta

$$z_{ekv3} = z_{ekv2} + z_{L1} = 0{,}033 + j0.682 + 0{,}394 + j0{,}628 = 0{,}428 + j1.31$$

$$| z_{ekv3} | = \sqrt{0{,}428^2 + 1.31^2} = 1.378$$

$$I_{k3} = \frac{S_b}{\sqrt{3} \cdot Z_{ekv3} \cdot U_{б2}} = \frac{100}{\sqrt{3} \cdot 1.378 \cdot 37} = 1.132 \text{ kA}$$

K-3' nuqta

$$z_{ekv3} = z_{ekv2} + z_{L2} + z_{l3} = 0{,}033 + j0.682 + 0{,}197 + j0.314 + 0{,}307 + j0.581 =$$

$$= 0{,}537 + j1.577$$

$$| z_{ekv2} | = \sqrt{0{,}537^2 + 1.577^2} = 1.666$$

$$I_{k3} = \frac{S_b}{\sqrt{3} \cdot Z_{ekv3} \cdot U_{b2}} = \frac{100}{\sqrt{3} \cdot 1.666 \cdot 37} = 0{,}937 \text{ kA}$$

K-4 nuqta

$$z_{ekv4} = z_{ekv2} + z_{L3} = 0{,}033 + j0.682 + 0{,}307 + j0.581 = 0{,}34 + j1{,}263$$

$$| z_{экв4} | = \sqrt{0{,}34^2 + 1{,}263^2} = 1{,}308$$

$$I_{к4} = \frac{S_b}{\sqrt{3} \cdot Z_{ekv4} \cdot U_{b2}} = \frac{100}{\sqrt{3} \cdot 1{,}308 \cdot 37} = 1.193 \text{ kA}$$

K-4" nuqta

$$z_{ekv4} = z_{ekv3} + z_{L1} + z_{l2} = 0{,}033 + j0.682 + 0{,}394 + j0{,}628 + 0{,}197 + j0.314 =$$
$$= 0{,}625 + j1.624$$

$$| z_{ekv4} | = \sqrt{0{,}625^2 + 1.624^2} = 1.74$$

$$I_{к4} = \frac{S_b}{\sqrt{3} \cdot Z_{ekv4} \cdot U_{b2}} = \frac{100}{\sqrt{3} \cdot 1.74 \cdot 37} = 0{,}897 \text{ kA}$$

K-5 nuqta

$$z_{ekv5} = z_{ekv4} + z_{L4} = 0{,}34 + j1{,}263 + 0{,}329 + j0{,}307 = 0{,}669 + j1{,}57$$

$$| z_{ekv5} | = \sqrt{0{,}669^2 + 1{,}57^2} = 1{,}706$$

$$I_{к5} = \frac{S_b}{\sqrt{3} \cdot Z_{ekv5} \cdot U_{b2}} = \frac{100}{\sqrt{3} \cdot 1{,}706 \cdot 37} = 0{,}914 \text{ kA}$$

K-6 nuqta

$$z_{ekv6} = z_{ekv3} + z_{T3} = 0{,}428 + j1.31 + 0{,}117 + j1{,}18 = 0{,}545 + j2{,}495$$

$$| z_{ekv6} | = \sqrt{0{,}545^2 + 2{,}495^2} = 2{,}553$$

$$I_{к6} = \frac{S_b}{\sqrt{3} \cdot Z_{ekv6} \cdot U_{b3}} = \frac{100}{\sqrt{3} \cdot 2{,}553 \cdot 10.5} = 2{,}153 \text{ kA}$$

K-7 nuqta

$$z_{ekv7} = z_{ekv4} + z_{T4} = 0{,}34 + j1{,}263 + 0{,}209 + j1{,}863 = 0{,}549 + j3{,}126$$

$$| z_{ekv7} | = \sqrt{0{,}549^2 + 3{,}126^2} = 3{,}174$$

$$I_{к2} = \frac{S_b}{\sqrt{3} \cdot Z_{ekv2} \cdot U_{б2}} = \frac{100}{\sqrt{3} \cdot 3{,}174 \cdot 6{,}3} = 2{,}887 \text{ kA}$$

K-8 nuqta

$$z_{ekv8} = z_{ekv5} + z_{T6} = 0{,}669 + j1{,}57 + 0{,}117 + j1{,}185 = 0{,}786 + j2{,}755$$

$$| z_{ekv2} | = \sqrt{0{,}786^2 + 2{,}755^2} = 2{,}864$$

$$I_{k2} = \frac{S_b}{\sqrt{3} \cdot Z_{ekv2} \cdot U_{b2}} = \frac{100}{\sqrt{3} \cdot 2{,}864 \cdot 10{,}5} = 1{,}92 \text{ kA}$$

K-9 nuqta

$$z_{ekv9} = z_{ekv6} + z_{L5} = 0{,}545 + j2{,}495 + 1{,}205 + j0{,}234 = 1{,}75 + j2{,}729$$

$$| z_{ekv2} | = \sqrt{1{,}75^2 + 2{,}729^2} = 3{,}242$$

$$I_{k2} = \frac{S_b}{\sqrt{3} \cdot Z_{ekv2} \cdot U_{b2}} = \frac{100}{\sqrt{3} \cdot 3{,}242 \cdot 10{,}5} = 1{,}696 \text{ kA}$$

b) sistemaning minimal ish rejimi

$$x_{sis} = \frac{S_{baz}}{S_{qt}} = \frac{100}{2667} = 0{,}037$$

$$z_{sis} = x_{sis} = j0{,}037$$

Manbadan K-1 qisqa tutashish nuqtasigacha bo`lgan qarshiliklar yig`indisi quyidagiga teng: $z_{ekv1} = z_{sis} = j0{,}037$

Qisqa tutashish nuqtasida bazis kuchlanishdagi tok quyiagi formula yordamida aniqlanadi:

$$I_{k1} = \frac{S_b}{\sqrt{3} \cdot Z_{ekv1} \cdot U_{b1}} = \frac{100}{\sqrt{3} \cdot 0{,}037 \cdot 115} = 13.391 \text{ kA}$$

K-2 nuqta

$$z_{ekv2} = z_{ekv1} + z_{T1} = j0{,}037 + 0{,}033 + j0.655 = 0{,}033 + j0.693$$

$$| z_{ekv2} | = \sqrt{0{,}033^2 + 0.693^2} = 0.694$$

$$I_{k2} = \frac{S_b}{\sqrt{3} \cdot Z_{ekv2} \cdot U_{b2}} = \frac{100}{\sqrt{3} \cdot 0.694 \cdot 37} = 2.249 \text{ kA}$$

K-3 nuqta

$$z_{ekv3} = z_{ekv2} + z_{L2} + z_{L3} = 0{,}033 + j0.693 + 0{,}197 + j0{,}314 + 0{,}307 + j0{,}581 =$$
$$= 0{,}537 + j1.588$$

$$| z_{ekv3} |= \sqrt{0{,}537^2 + 1.588^2} = 1.677$$

$$I_{к3} = \frac{S_b}{\sqrt{3} \cdot Z_{ekv3} \cdot U_{б2}} = \frac{100}{\sqrt{3} \cdot 1.677 \cdot 37} = 0.931 \text{ kA}$$

K-3‘ nuqta

$$z_{ekv3'} = z_{ekv2} + z_{L1} = 0{,}033 + j0.693 + 0{,}394 + j0{,}628 = 0{,}428 + j1.321$$

$$| z_{ekv3'} |= \sqrt{0{,}428^2 + 1.321^2} = 1.389$$

$$I_{к3'} = \frac{S_b}{\sqrt{3} \cdot Z_{ekv3'} \cdot U_{b2}} = \frac{100}{\sqrt{3} \cdot 1.389 \cdot 37} = 1.124 \text{ kA}$$

K-4 nuqta

$$z_{ekv4} = z_{ekv2} + z_{L1} + z_{L2} = 0{,}033 + j0.693 + 0{,}394 + j0{,}628 + 0{,}197 + j0{,}314 =$$
$$= 0{,}625 + j1.635$$

$$| z_{ekv4} |= \sqrt{0{,}625^2 + 1.635^2} = 1.751$$

$$I_{к4} = \frac{S_b}{\sqrt{3} \cdot Z_{ekv4} \cdot U_{b2}} = \frac{100}{\sqrt{3} \cdot 1.751 \cdot 37} = 0.891 \text{ kA}$$

K-4" nuqta

$$z_{ekv4}' = z_{ekv2} + z_{L3} = 0{,}033 + j0.693 + 0{,}307 + j0{,}581 = 0{,}34 + j1.274$$

$$| z_{ekv4'} |= \sqrt{0{,}34^2 + 1.274^2} = 1.319$$

$$I_{к4'} = \frac{S_b}{\sqrt{3} \cdot Z_{ekv4'} \cdot U_{б2}} = \frac{100}{\sqrt{3} \cdot 1.319 \cdot 37} = 1{,}183 \text{ kA}$$

K-5 nuqta

$$z_{ekv5} = z_{ekv4} + z_{L4} = 0{,}625 + j1.635 + 0{,}329 + j307 = 0{,}954 + j1.942$$

$$| z_{ekv5} |= \sqrt{0{,}95459^2 + 1.942^2} = 2.163$$

$$I_{к5} = \frac{S_b}{\sqrt{3} \cdot Z_{ekv5} \cdot U_{б2}} = \frac{100}{\sqrt{3} \cdot 2.163 \cdot 37} = 0.721 \text{ kA}$$

K-8 nuqta

$$z_{ekv8} = z_{ekv5} + z_{T6} = 0{,}954 + j1.942 + 0{,}117 + j1.185 = 1.071 + j3.127$$

$$| z_{ekv8} | = \sqrt{1.701^2 + 3.127^2} = 3.305$$

$$I_{к8} = \frac{S_b}{\sqrt{3} \cdot Z_{ekv8} \cdot U_{b2}} = \frac{100}{\sqrt{3} \cdot 3.305 \cdot 10.5} = 1.664 \text{ kA}$$

K-7 nuqta

$$z_{ekv7} = z_{ekv4} + z_{T4} = 0{,}625 + j1.635 + 0{,}209 + j1.863 = 0.834 + j3.498$$

$$| z_{ekv7} | = \sqrt{0.834^2 + 3.498^2} = 3.597$$

$$I_{к7} = \frac{S_b}{\sqrt{3} \cdot Z_{ekv7} \cdot U_{b2}} = \frac{100}{\sqrt{3} \cdot 3.597 \cdot 6.3} = 2{,}548 \text{ kA}$$

K-6 nuqta

$$z_{ekv6} = z_{ekv3} + z_{T3} = 0{,}537 + j1.588 + 0.117 + j1.185 = 0.654 + j2.773$$

$$| z_{ekv6} | = \sqrt{0.654^2 + 2.773^2} = 2.849$$

$$I_{к6} = \frac{S_b}{\sqrt{3} \cdot Z_{ekv6} \cdot U_{b2}} = \frac{100}{\sqrt{3} \cdot 2.849 \cdot 10.5} = 1.93 \text{ kA}$$

K-9 nuqta

$$z_{ekv9} = z_{ekv6} + z_{L5} = 0.654 + j2.773 + 1.205 + j0.234 = 1.86 + j3.007$$

$$| z_{ekv9} | = \sqrt{1.86^2 + 3.007^2} = 3.536$$

$$I_{к9} = \frac{S_b}{\sqrt{3} \cdot Z_{ekv9} \cdot U_{b2}} = \frac{100}{\sqrt{3} \cdot 3.536 \cdot 10.5} = 1.555 \text{ kA}$$

Uch fazali $I_{qtj}^{(3)}$ QT tokidan foydalangan holda, ikki fazali QT tokining qiymatini aniqlash mumkin:

$$I_{qtj}^{(2)} = \frac{\sqrt{3}}{2} I_{qtj}^{(3)}$$

Hisoblash natijalari tok qaysi hisobiy sxemalar va kuchlanishlarga keltirilgan bo‘lsa uni ko‘rsatgan holda jadvalga kiritiladi.

Hisobiy sxemaning raqami	QT ning hisobiy nuqtasi / QT toki		K1	K2	K3	K‘3	K4	K‘4	K6	K7
7	$I_{qtj}^{(3)}$	Maks	19,130	2,286	1,132	0,937	1,193	0,897	2,153	2,887
		Min	13,391	2,249	1,124	0,931	1,183	0,891	1,930	2,548
	$I_{qtj}^{(2)}$	Maks	16,567	1,980	0,980	0,811	1,033	0,777	1,864	2,500
		Min	11,597	1,948	0,973	0,806	1,024	0,772	1,671	2,207

Rele himoyasining turlarini tanlash va ularni o‘rnatmalarini hisoblash

Elektr sistemalarining alohida himoyalarining turini tanlash Elektr uskunalaridan foydalanish qoidalari (ПУЭ) talablariga asosan amalga oshiriladi. Himoyaning sxemasini va hisobiy o‘rnatmalarini tanlash “Rele himoyasi bo‘yicha ustuvor ko‘rsatma”ga mos ravishda amalga oshiriladi.

Himoyaning turini tanlashga nominal kuchlanish, tarmoq konfiguratsiyasi, zaminlagich neytralning rejimi, operativ tok manbasining turi xizmat ko‘rsatuvchi personalning mavjudligi yoki yo‘qligi, kommutatsion apparatlarining turi va h.k. ta‘sir ko‘rsatadi.

Rele himoyasi o‘rnatmalarini tarmoqning oxiridan boshlab hisoblaymiz.

T-3 transformator himoyasi

Transformatorning quvvati 6300 kVA bo‘lganiligi uchun tokli kesimning o‘rniga differensial himoya o‘rnatamiz.

Bo‘ylama differensial tokli himoya

Transformatorning bo‘ylama differensial himoyasini ta‘minlovchi TT ni transformatsiyalash koeffitsiyentini tanlash. Kuch transformatorining yuqori va past kuchlanish tomondagi nominal toklarini hisoblashdan boshlanadi:

$$I_{nom.yu} = \frac{S_{nom.tr}}{\sqrt{3} \cdot U_{yu}} = \frac{6300}{\sqrt{3} \cdot 35} = 103{,}923 \text{ A}$$

$$I_{nom.pk} = \frac{S_{nom.tr}}{\sqrt{3} \cdot U_{pk}} = \frac{6300}{\sqrt{3} \cdot 10} = 363{,}731 \text{ A}$$

TT larning birlamchi nominal toklari quyidagi shartlarga javob berishi kerak:

$$I_{nom.TT.yu} \geq I_{nom.yu} \text{ demak, } 150 \geq 103{,}923$$

$$I_{nom.TT.pk} \geq I_{nom.pk} \text{ demak, } 400 \geq 363{,}731$$

Yuqori va past tomondagi TT larni transformatsiyalash koeffitsiyenti quyidagiga teng:

$$n_{Tyu} = \frac{I_{nom.TT.yu}}{5} = \frac{150}{5} = 30$$

$$n_{Tpk} = \frac{I_{nom.TT.pk}}{5} = \frac{400}{5} = 80$$

Yuqori va past tomondagi TT lardan differensial himoyaning yelkalarigada oqadigan toklar hisoblanadi.

$$I_{dyu} = \frac{I_{nom.yu}}{n_{Tyu}} = \frac{103{,}923}{30} = 3{,}464 \text{ A}$$

$$I_{dpk} = \frac{I_{nom.pk}}{n_{Tpk}} = \frac{63{,}73}{80} = 4{,}547 \text{ A}$$

Differensial tokli kesim hisobi. Differensial tokli kesimning ishlash toki ikki shartdan tanlanadi:

- Magnitlanish tokining sakrashidan to‘g‘rilash:

$$I_{hi} = k_{z1} \cdot I_{nom.tr} = 3 \cdot 103{,}923 = 311{,}769 \text{ A}$$

- Maksimal nobalans tokidan to‘g‘rilash:

$$I_{nbTT} = k_a \cdot k_{bir.tip} \cdot f_i \cdot I^{(3)}_{qt.max\ tashq} = 1,5 \cdot 1 \cdot 0,1 \cdot 2153 \cdot \frac{10}{35} = 92.292 \text{ A}$$

$$I_{nb.rost} = \frac{\Delta N}{100} \cdot I^{(3)}_{qt.max\ tashq} = \frac{9}{100} \cdot 2153 \cdot \frac{10}{35} = 55.375 \text{ A}$$

$$I_{nb.komp} = \frac{|I_{dyu} - I_{dpl}|}{I_{dyu(n)}} \cdot I^{(3)}_{qt.max\ tashq} = \frac{|3,464 - 4,547|}{3,464} \cdot 2153 \cdot \frac{10}{35} = 192.275 \text{ A}$$

$$I_{sin.max} = I_{nbTT} + I_{nb.rost} + I_{nb.komp} = 92.292 + 55.375 + 192.275 = 339,942 \text{ A}$$

$$I_{hi} = k_{z2} \cdot I_{nb.max} = 1,3 \cdot 399,942 = 441.924 \text{ A}$$

Himoyaning sezgirligi quyidagicha:

$$k_{sez} = \frac{k_{\sum sx} I^{(2)}_{qt.min\ old}}{I_{hi}} = \frac{1671 \cdot \frac{10}{35}}{441,924} = 1.08 < 2$$

Himoyaning sezgirligi yetarli darajada emas, shuning uchun differensial himoyada PHT–560 turidagi rele sxemasi qo‘llaniladi.

PHT–560 turidagi releli differensial himoyani hisoblash. Himoyaning ishlash toki ikki shartdan tanlanadi:

- Magnitlanish tokining sakrashidan to‘g‘rilash:

$$I_{hi} = k_{z1} \cdot I_{nom.tr} = 1,3 \cdot 103,923 = 135,1 \text{ A}$$

- Maksimal nobalans tokidan to‘g‘rilash:

$$I_{nbTT} = k_a \cdot k_{bir.tip} \cdot f_i \cdot I^{(3)}_{qt.max\ tashq} = 1 \cdot 1 \cdot 0,1 \cdot 2153 = 215.348 \text{ A}$$

$$I_{nb.rost} = \frac{\Delta N}{100} \cdot I^{(3)}_{qt.max\ tashq} = \frac{9}{100} \cdot 2153 = 193.813 \text{ A}$$

$$I_{nb.komp} = 0$$

$$I_{nb.max} = I_{nbTT} + I_{nb.rost} + I_{nb.komp} = 215.348 + 193.813 + 0 = 409.161 \text{ A}$$

$$I_{hi} = k_{z2} \cdot I_{nb.max} = 1,3 \cdot 409.161 = 531.909 \text{ A}$$

Himoyaning sezgirligi quyidagicha:

$$k_{sez} = \frac{k_{\sum sx} I^{(2)}_{qt.min\ old}}{I_{hi}} = \frac{1 \cdot 1671}{531.909} = 3.14 > 2$$

Kuch transformatori himoyasining ikkilamchi ishlash toki:

$$I_{ri} = k_{sx} \cdot \frac{I_{hi}}{n_{TT}} = 1 \cdot \frac{531.909}{80} = 6.649 \text{ A}$$

“Asosiy” tomonga ulangan PHT chulg‘amining hisobiy o‘ramlar soni:

$$W_{as} = \frac{F_{ri}}{I_{ri}} = \frac{100}{I_{ri}} = \frac{100}{6.649} = 15.04$$

Eng yaqin butun kichik $W'_{as} = 15$ soniga yaxlitlaymiz
Birlamchi va ikkilamchi ishlash tokining haqiqiy qiymati topiladi:

$$I'_{ri} = \frac{100}{W'_{as}} = \frac{100}{15} = 6.667 \text{ A}$$

$$I'_{hi} = \frac{I'_{ri} \cdot n_{TT}}{k_{sx.as}} = \frac{6.667 \cdot 80}{1} = 533.33 \text{ A}$$

Himoyaning sezgirlik koeffitsiyenti

$$k_{sez} = \frac{I^{(2)}_{qt.min\ tashq}}{I'_{him}} k_{\sum sx} = \frac{1671}{533.33} \cdot 1 = 3.13 > 2$$

PHT ning “asosiy bo‘lmagan” chulg‘amining hisobiy o‘ramlar sonini quyidagicha aniqlanadi:

$$W_{as.b} = \frac{W'_{as} \cdot I_{d.as}}{I_{d.as.bo'l}} = \frac{15 \cdot 4,547}{3,464} = 19.68$$

Eng yaqin butun $W'_{as.bo'l} = 20$ ga yaxlitlanadi. Tokning nobalans tashkil etuvchisi aniqlanadi:

$$I_{nb\ komp} = \frac{|W_{as.ba'l} - W'_{as.bo'l}|}{W_{as.ba'l}} I^{(3)}_{qt.max\ tashqi} = \frac{|19.68 - 20|}{19.68} \cdot 1671 = 34.18 \text{ A}$$

Nobalanslik va himoyaning ishlash tokining yangi qiymati topiladi:

$$I'_{nb.max} = I_{nb.TT} + I_{nb.rost} + I_{nb.komp} = I_{nb.max} + I_{nb.komp} =$$
$$= 215.348 + 193.813 + 34.18 = 443.343\,A$$

$$I''_{hi} = k_z I'_{nb.max} = 1{,}3 \cdot 443.343 = 576.346 \text{ A}$$

$I'_{hi} < I''_{hi}$ bo'lganiligi uchun hisoblashni davom ettiramiz
Kuch transformatori himoyasining ikkilamchi ishlash toki:

$$I_{ri} = k_{sx} \cdot \frac{I_{him}}{n_{TT}} = 1 \cdot \frac{576.346}{80} = 7.204 \text{ A}$$

"Asosiy" tomonga ulangan PHT chulg'amining hisobiy o'ramlar soni:

$$W_{as} = \frac{F_{ri}}{I_{ri}} = \frac{100}{I_{ri}} = \frac{100}{7.104} = 13.881$$

Eng yaqin butun kichik $W'_{as} = 13$ soniga yaxlitlaymiz.
Birlamchi va ikkilamchi ishlash tokining haqiqiy qiymati topiladi:

$$I'_{ri} = \frac{100}{W'_{as}} = \frac{100}{13} = 7.69 \text{ A}$$

$$I'_{hi} = \frac{I'_{ri} \cdot n_{TT}}{k_{sx.as}} = \frac{7.69 \cdot 80}{1} = 615.36 \text{ A}$$

Himoyaning sezgirlik koeffitsiyenti

$$k_{sez} = \frac{I^{(2)}_{qt.min\ tashq}}{I'_{hi}} k_{\Sigma sx} = \frac{1671}{615.36} \cdot 1 = 2.7 > 2$$

PHT ning "asosiy bo'lmagan" chulg'amining hisobiy o'ramlar sonini quyidagicha aniqlanadi:

$$W_{as\,b} = \frac{W'_{as} \cdot I_{d.as}}{I_{d.as.bo'l}} = \frac{13 \cdot 4{,}547}{3{,}464} = 17.06$$

Eng yaqin bo'lgan $W'_{as.bo'l} = 17$ ga yaxlitlanadi. Tokning nobalans tashkil etuvchisi aniqlanadi:

$$I_{b.komp} = \frac{\left|W_{as.bo'l} - W'_{as.bo'l}\right|}{W_{as.bo'l}} I^{(3)}_{qt.max.tashq} = \frac{|17.06 - 17|}{17.06} \cdot 1671 = 7.88 \text{ A}$$

Nobalanslik va himoyaning ishlash tokini yangi qiymati topiladi:

$$I'_{nb.max} = I_{nb.TT} + I_{nb.rost} + I_{nb.komp} = I_{nb.max} + I_{nb.komp} =$$
$$= 215.348 + 193.813 + 7.88 = 417.049\,A$$

$$I''_{him} = k_z I'_{nb.max} = 1{,}3 \cdot 417.049 = 542.16 \text{ A}$$

$I'_{him} > I''_{him}$ bo'lganligi uchun hisoblash tugatiladi

Maksimal tokli himoya. Himoya PT – 40 relesi orqali bajarilgan. MTH ning ishlash toki quyidagi ifodadan aniqlanadi:

$$I^{II}_{him} = \frac{k_z \cdot k_{o'z.II}}{k_k} I_{ish.max} = \frac{1{,}2 \cdot 1{,}5}{0{,}8} \cdot 103{,}923 = 233{,}827 \text{ A}$$

Relening ishlash toki quyidagi ifodadan aniqlanadi:

$$I^{II}_{ri} = \frac{k_{sx} \cdot I^{II}_{him}}{n_{TT}} = \frac{1 \cdot 233{,}827}{30} = 7{,}794 \text{ A}$$

Sezgirlik koeffitsiyenti:

Asosiy zona uchun

$$k_{sez} = k_{\sum sz} \cdot \frac{I^{(2)}_{qt.min\,tashq}}{I^{II}_{ri} \cdot n_{tt}} = 1 \cdot \frac{1671 \cdot \frac{10}{35}}{7{,}794 \cdot 30} = 2{,}04 > 1.5$$

Zaxira zona uchun

$$k_{sez} = k_{\sum sx} \cdot \frac{I^{(2)}_{qt.min\,tashq}}{I^{II}_{ri} \cdot n_{tt}} = 1 \cdot \frac{1347 \cdot \frac{10}{35}}{7{,}794 \cdot 30} = 1.65 > 1.2$$

Himoyaning ishlash vaqti

$$t = t_{\text{ish.odlingi}} + \Delta t = 1{,}2" + 0{,}5 = 1{,}7" \text{ c.}$$

O'ta yuklanishdan humoya. Himoya xohlagan fazaga bitta rele ulanishi orqali bajariladi. Uning ishlash toki quyidagicha bo'ladi:

$$I_{him} = \frac{k_z}{k_k} \cdot I_{nomn} = \frac{1{,}05}{0{,}8} \cdot 103{,}923 = 136{,}399 \text{ A}$$

bu yerda, $k_z = 1.05$.

Himoya PT–40 relesi bilan bajarilgan, himoyaning ishlash vaqti t_{hi} = 9 s ga teng bo‘ladi.

T–4 (T-5) transformator himoyasi

Transformatorning quvvati 4000 kVA bo‘lganligi uchun tokli kesimning o‘rniga differensial himoya o‘rnatamiz.

Bo‘ylama differensial tokli himoya.

Transformatorning bo‘ylama differensial himoyasini ta‘minlovchi TT ni transformatsiyalash koeffitsiyentini tanlash. Kuch transformatorining yuqori va past kuchlanish tomondagi nominal toklarini hisoblashdan boshlanadi:

$$I_{nom.yu} = \frac{S_{nom.tr}}{\sqrt{3} \cdot U_{yu}} = \frac{4000}{\sqrt{3} \cdot 35} = 65{,}983 \text{ A}$$

$$I_{nom.pk} = \frac{S_{nom.tr}}{\sqrt{3} \cdot U_{pk}} = \frac{4000}{\sqrt{3} \cdot 6} = 384{,}9 \text{ A}$$

TT larning birlamchi nominal toklari quyidagi shartlarga javob berishi kerak:

$I_{nomTT.yu} \geq \cdot I_{nom.yu}$ demak, $150 \geq \sqrt{3} \cdot 65{,}983$

$I_{nomTT.pk} \geq I_{nom.pk}$ demak, $400 \geq \cdot 384{,}9$

Yuqori va past tomondagi TT larni transformatsiyalash koeffitsiyenti quyidagiga teng:

$$n_{Tyu} = \frac{I_{nomTT.yu}}{5} = \frac{150}{5} = 30$$

$$n_{Tpast} = \frac{I_{nomTT.past}}{5} = \frac{400}{5} = 80$$

Yuqori va past tomondagi TT lardan differensial himoyaning yelkalarida oqadigan toklar hisoblanadi.

$$I_{dyu} = \frac{I_{nom.yu}}{n_{tyu}} = \frac{\sqrt{3} \cdot 65{,}983}{30} = 3{,}81 \text{ A}$$

$$I_{dp} = \frac{I_{nom.pk}}{n_{tp}} = \frac{384{,}9}{80} = 4{,}811 \text{ A}$$

Differensial tokli kesim hisobi. Diffrensial tokli kesimning ishlash toki ikki shartdan tanlanadi:

- Magnitlanish tokining sakrashidan to‘g‘irlash:

$$I_{him} = k_{z1} \cdot I_{nom.tr} = 3 \cdot 65,983 = 197,949 \text{ A}$$

- Maksimal nobalans tokidan to‘g‘rilash:

$$I_{nb.TT} = k_a \cdot k_{bir.tip} \cdot f_i \cdot I^{(3)}_{qt.max.tash} = 1,5 \cdot 1 \cdot 0,1 \cdot 2887 \cdot \frac{6}{35} = 74.238 \text{ A}$$

$$I_{nb.rost} = \frac{\Delta N}{100} \cdot I^{(3)}_{qt.max.tash} = \frac{9}{100} \cdot 2887 \cdot \frac{6}{35} = 44.543 \text{ A}$$

$$I_{nb.komp} = \frac{\left|I_{dyu} - I_{dp}\right|}{I_{dyu(n)}} \cdot I^{(3)}_{qt.max.tash} = \frac{\left|3,81 - 4,81\right|}{3,81} \cdot 2887 \cdot \frac{6}{35} = 130.142 \text{ A}$$

$$I_{nb.max} = I_{nb.TT} + I_{nb.rost} + I_{nb.komp} = 74.238 + 44.543 + 130.142 = 248.923 \text{ A}$$

$$I_{him} = k_{z2} \cdot I_{nb.max} = 1,3 \cdot 248.923 = 323.6 \text{ A}$$

Himoyaning sezgirligi quyidagicha:

$$k_{sez} = \frac{k_{\sum xx} I^{(2)}_{qt.min.old}}{I_{him}} = \frac{\frac{2}{\sqrt{3}} \cdot 2548 \cdot \frac{6}{35}}{323.6} = 1,3 < 2$$

Himoyaning sezgirligi yetarli darajada emas, shuning uchun differensial himoyada PHT–560 turidagi rele sxemasi qo‘llaniladi.

PHT–560 turidagi releli differensial himoyani hisoblash. Himoyaning ishlash toki ikki shartdan tanlanadi:

- Magnitlanish tokining sakrashidan to‘g‘rilash:

$$I_{him} = k_{z1} \cdot I_{nom.tr} = 1,3 \cdot 384.9 = 500.37 \text{ A}$$

- Maksimal nobalans tokidan to‘g‘rilash:

$$I_{nb.TT} = k_a \cdot k_{bir.tip} \cdot f_i \cdot I^{(3)}_{qt.max.tash} = 1 \cdot 1 \cdot 0,1 \cdot 2887 = 288.705 \text{ A}$$

$$I_{nb.rost} = \frac{\Delta N}{100} \cdot I^{(3)}_{qt.max.tash} = \frac{9}{100} \cdot 2887 = 259.835 \text{ A}$$

$$I_{nb.komp} = 0$$

$$I_{nb.max} = I_{nb.TT} + I_{nb.rost} + I_{nb.komp} = 288.705 + 259,835 + 0 = 548.54 \text{ A}$$

$$I_{him} = k_{z2} \cdot I_{nb.max} = 1{,}3 \cdot 548.54 = 713.102 \text{ A}$$

Himoyaning sezgirligi quyidagicha:

$$k_{sez} = \frac{k_{\sum sx} I^{(2)}_{qt.min\ old}}{I_{him}} = \frac{\frac{2}{\sqrt{3}} \cdot 2207}{713.102} = 3{,}5 > 2$$

Kuch transformatori himoyasining ikkilamchi ishlash toki:

$$I_{ri} = k_{sx} \cdot \frac{I_{him}}{n_{IT}} = \sqrt{3} \cdot \frac{713.102}{80} = 15.439 \text{ A}$$

"Asosiy" tomonga ulangan PHT chulg'amining hisobiy o'ramlar sonini:

$$W_{as} = \frac{F_{ri}}{I_{ri}} = \frac{100}{I_{ri}} = \frac{100}{15.439} = 6.477$$

Eng yaqin butun kichik $W_{as}^{'} = 6$ soniga yaxlitlaymiz.
Birlamchi va ikkilamchi ishlash tokining haqiqiy qiymati topiladi:

$$I_{ri}^{'} = \frac{100}{W_{as}^{'}} = \frac{100}{6} = 16.66 \text{ A}$$

$$I_{him}^{'} = \frac{I_{ri}^{'} \cdot n_{tt}}{k_{sx.as}} = \frac{16.66 \cdot 80}{\sqrt{3}} = 769.8 \text{ A}$$

Himoyaning sezgirlik koeffitsiyenti

$$k_{sez} = \frac{I^{(2)}_{qt.min\ tashq}}{I_{him}^{'}} k_{\sum cx} = \frac{2207}{769.8} \cdot \frac{2}{\sqrt{3}} = 3.3 > 2$$

PHT ning "asosiy bo'lmagan" chulg'amining hisobiy o'ramlar sonini quyidagicha aniqlanadi:

$$W_{as.b} = \frac{W_{as}^{'} \cdot I_{d.as}}{I_{d.as.bo'l}} = \frac{6 \cdot 4{,}811}{3{,}81} = 7.578$$

Eng yaqin butun $W'_{as\,bo'l} = 8$ ga yaxlitlanadi. Tokning nobalans tashkil etuvchisi aniqlanadi:

$$I_{nb.komp} = \frac{\left|W_{as.bo'l} - W'_{as.bo'l}\right|}{W_{as.bo'l}} I^{(3)}_{qt.max\ tash} = \frac{|7{,}578 - 8|}{7{,}578} \cdot 2887 = 160.88 \text{ A}$$

Nobalanslik va himoyaning ishlash tokini yangi qiymati topiladi:

$$I'_{nb.max} = I_{nb.tt} + I_{nb.rost} + I_{nb.komp} = I_{nb.max} + I_{nb.komp} =$$
$$= 288.705 + 259{,}835 + 160.88 = 709.4A$$

$$I''_{him} = k_z I'_{nb.max} = 1{,}3 \cdot 709.4 = 922.2 \text{ A}$$

$I'_{him} < I''_{him}$ bo'lganligi uchun hisoblashni davom ettiramiz
Kuch transformatori himoyasining ikkilamchi ishlash toki:

$$I_{ri} = k_{sx} \cdot \frac{I_{him}}{n_{tt}} = \sqrt{3} \cdot \frac{922.2}{80} = 16.967 \text{ A}$$

"Asosiy" tomonga ulangan PHT chulg'amining hisobiy o'ramlar sonini:

$$W_{as} = \frac{F_{ri}}{I_{ri}} = \frac{100}{I_{ri}} = \frac{100}{16.967} = 5.008$$

Eng yaqin butun kichik $W'_{as} = 5$ soniga yaxlitlaymiz.
Birlamchi va ikkilamchi ishlash tokining qiymati topiladi:

$$I'_{ri} = \frac{100}{W'_{as}} = \frac{100}{5} = 20 \text{ A}$$

$$I'_{him} = \frac{I'_{ri} \cdot n_{tt}}{k_{sx.as}} = \frac{20 \cdot 80}{\sqrt{3}} = 923.76 \text{ A}$$

Himoyaning sezgirlik koeffitsiyenti

$$k_{sez} = \frac{I^{(2)}_{qt.min.tashq}}{I'_{him}} k_{\Sigma sx} = \frac{2207}{923.76} \cdot \frac{2}{\sqrt{3}} = 2.7 > 2$$

PHT ning "asosiy bo'lmagan" chulg'amining hisobiy o'ramlar sonini quyidagicha aniqlanadi:

$$W_{as.b} = \frac{W'_{as} \cdot I_{d.as}}{I_{d.as.bo'l}} = \frac{5 \cdot 4{,}811}{3{,}81} = 6.31$$

Eng yaqin butun $W'_{as.bo'l} = 6$ ga yaxlitlanadi. Tokning nobalans tashkil etuvchisi aniqlanadi:

$$I_{nb.komp} = \frac{|W_{as.bo'l} - W'_{as.bo'l}|}{W_{as.bo'l}} I^{(3)}_{qt.max.tashq} = \frac{|6.31-6|}{6.31} \cdot 2887 = 143.909 \text{ A}$$

Nobalanslik va himoyaning ishlash tokini yangi qiymati topiladi:

$$I'_{nb.max} = I_{nb\,tt} + I_{nb.rost} + I_{nb.komp} = I_{nb.max} + I_{nb.komp} =$$
$$= 288.705 + 259{,}835 + 143.909 = 692.449\,A$$

$$I''_{him} = k_z I'_{nb.max} = 1{,}3 \cdot 692.449 = 900.2 \text{ A}$$

$I'_{him} > I''_{him}$ bo'lganligi uchun hisbolash shu yerda tugatiladi.

Maksimal tokli himoya

Himoya PT – 40 relesi orqali bajarilgan. MTH ning ishlash toki quyidagi ifodadan aniqlanadi:

$$I^{II}_{him} = \frac{k_z \cdot k_{o'z.tt}}{k_\kappa} I_{ish.max} = \frac{1{,}2 \cdot 1.5}{0{,}8} \cdot 65{,}983 = 148.46 \text{ A}$$

Relening ishlash toki quyidagi ifodadan aniqlanadi:

$$I^{II}_{ri} = \frac{k_{sx} \cdot I^{II}_{him}}{n_{TT}} = \frac{\sqrt{3} \cdot 148.46}{30} = 8.57 \text{ A}$$

Sezgirlik koeffitsiyenti:

$$k_{sez} = k_{\Sigma sx} \cdot \frac{I^{(2)}_{qt.min.tashq}}{I^{II}_{ri} \cdot n_{tt}} = \sqrt{3} \cdot \frac{2207 \cdot \frac{6}{35}}{8.57 \cdot 30} = 2.54 > 1.5$$

Himoyaning ishlash vaqti

$$t = t_{ish.oldingi} + \Delta t = 1{,}2" + 0{,}5 = 1{,}7" \text{ c.}$$

O'ta yuklanishdan himoya. Himoya xohlagan fazaga bitta rele ulanishi orqali bajariladi. Uning ishlash toki quyidagiga teng bo'ladi:

$$I_{him} = \frac{k_z}{k_\kappa} \cdot I_{nom.tr} = \frac{1{,}05}{0{,}8} \cdot 65{,}983 = 86{,}603 \text{ A}$$

Bu yerda, $k_z = 1.05$.

Himoya PT–40 relesi bilan bajarilgan, himoyaning ishlash vaqti $t_{him} = 9$ s ga teng bo'ladi.

L–3 liniya himoyasi

Liniya uchun tok transformatorini tanlaymiz:

$$I_{ntl} \geq I_{rux}$$

Liniya uchun ruxsat etilgan tok I_{rux}=390 A bo‘lgani uchun I_{ntl}=400 A tok transformatorini tanlaymiz. U holda, $n_{tt} = \frac{I_{ntl}}{5} = \frac{400}{5} = 80$

Sabr vaqtsiz tokli kesim (himoyaning birinchi pog‘onasi). Himoya PT–40 relesi orqali bajarilgan. Sabr vaqtsiz tokli kesimning birlamchi ishlash toki quyidagi ifodadan topiladi:

$$I_{him}^{I} = k_z \cdot I_{qt.max}^{(3)} = 1{,}2 \cdot 1193 = 1432 \text{ A}$$

Tok transormatorlari va relelarning to‘liq bo‘lmagan yulduz sxemasiga ulangan $k_{sx} = 1$, $k_{\Sigma sx} = 1$. Kesimning ikkilamchi ishlash toki (relening ishlash toki) barcha tokli ximoya uchun bir hil hisoblanadi va u quyidagicha aniqlanadi:

$$I_{ri}^{I} = \frac{k_{sx} \cdot I_{him}^{I}}{n_{TT}} = \frac{1 \cdot 1432}{80} = 17.894 \text{ A}$$

Uch pog‘onali himoyalar, ya‘ni kuchlanishi 20 – 35 kV li liniyalarda tokli kesim qo‘shimcha himoya hisoblanadi va uning sezgirligi esa sezgirlik koeffitsiyenti orqali aniqlanadi:

$$k_{sez} = k_{\Sigma sx} \frac{I_{qt.max}^{(3)}}{I_{ri} \cdot n_{TT}} = 1 \cdot \frac{2286}{17.894 \cdot 80} = 1{,}6 \succ 1{,}2$$

Sabr vaqtli tokli kesim (himoyaning ikkinchi pog‘onsi). Sabr vaqtli tokli kesimning ishlash toki quyidagi ifodadan topiladi:

$$I_{him}^{II} = k_z \cdot I_{him.old.max}^{I} = 1{,}1 \cdot 2887 \frac{6}{35} = 544.415 \text{ A}$$

Relening ishlash toki quyidagi ifodadan aniqlanadi:

$$I_{ri}^{II} = \frac{k_{sx} \cdot I_{him}^{II}}{n_{TT}} = \frac{1 \cdot 544.415}{80} = 6.8 \text{ A}$$

Ikkinchi pog‘onaning sezgirligi himoya qilinayotgan liniyaning oxiridagi ikki fazali QT ning minimal tokidan aniqlanadi:

$$k_{sez} = k_{sx} \frac{I^{(2)}_{qt.\min}}{I^{II}_{ri} \cdot n_{TT}} = 1 \cdot \frac{1025}{6.8 \cdot 80} = 1.88 > 1,5$$

Maksimal tokli himoya. MTH ning ishlash toki quyidagi ifodadan aniqlanadi:

$$I^{III}_{him} = \frac{k_z \cdot k_{o'z.it}}{k_k} I_{ish.max} = \frac{1,2 \cdot 1,5}{0,8} \cdot 169.9 = 382.28 \text{ A}$$

Bu yerda,

$$I_{ish.max} = \frac{S_{yuk}}{\sqrt{3} \cdot U_n} = \frac{(4000 + 6300)}{\sqrt{3} \cdot 35} = 169.9 \text{ A.}$$

Relening ishlash toki quyidagi ifodadan topiladi:

$$I^{III}_{ri} = \frac{k_{sx} \cdot I^{III}_{him}}{n_{TT}} = \frac{1 \cdot 382.28}{80} = 4.77 \text{ A}$$

MTH ning sezgirligi quyidagi formuladan aniqlanadi:

$$k_{sez} = \frac{I^{(2)}_{qt.\min}}{I^{III}_{ri} \cdot n_{TT}} = \frac{1025}{4.77 \cdot 80} = 2.7 > 1,5$$

Himoyaning ishlash vaqti

$$t = t_{ish.old} + \Delta t = 1,7" + 0,5 = 2,2" \text{ c.}$$

L–1 liniyaning himoyasi

Liniya uchun tok transformatorini tanlaymiz:

$$I_{ntt} \geq I_{rux}$$

Liniya uchun ruxsat etilgan tok I_{rux} =390 A bo'lgani uchun I_{ntt}=400 A tok transformatorini tanlaymiz. U holda, $n_{tt} = \frac{I_{ntt}}{5} = \frac{400}{5} = 80$

Sabr vaqtsiz tokli kesim (himoyaning birinchi pog'onasi). Himoya PT–40 relesi orqali bajarilgan. Sabr vaqtsiz tokli kesimning birlamchi ishlash toki quyidagi ifodadan topiladi:

$$I^{I}_{him} = k_z \cdot I^{(3)}_{qt.max} = 1,2 \cdot 1132 = 1359 \text{ A}$$

Tok transformatorlari va relelarning to'liq bo'lmagan yulduz sxemasiga ulangan $k_{sx}=1$, $k_{\Sigma sx}=1$. Kesimning ikkilamchi ishlash toki (relening ishlash toki) barcha tokli himoya uchun bir xil hisoblanadi va u quyidagicha aniqlanadi:

$$I_{ri}^{I}=\frac{k_{sx}\cdot I_{him}^{I}}{n_{TT}}=\frac{1\cdot 1359}{80}=16.987\ \text{A}$$

Uch pog'onali himoyalar, ya'ni kuchlanishi 20 – 35 kV li liniyalarda tokli kesim qo'shimcha himoya hisoblanadi va uning sezgirligi esa sezgirlik koeffitsiyenti orqali aniqlanadi:

$$k_{sez}=k_{\Sigma sx}\frac{I_{qt.\max}^{(3)}}{I_{ri}\cdot n_{TT}}=1\cdot\frac{2286}{16.987\cdot 80}=1,7\succ 1,2$$

Sabr vaqtli tokli kesim (himoyaning ikkinchi pog'onsi). Sabr vaqtli tokli kesimning ishlash toki quyidagi ifodadan topiladi:

$$I_{him}^{II}=k_{z}\cdot I_{him.old.\max}^{I}=1,1\cdot 2153\frac{10}{35}=676\ \text{A}$$

Relening ishlash toki quyidagi ifodadan topiladi:

$$I_{ri}^{II}=\frac{k_{sx}\cdot I_{him}^{II}}{n_{TT}}=\frac{1\cdot 676}{80}=8.1\ \text{A}$$

Ikkinchi pog'onaning sezgirligi himoya qilinayotgan liniyaning oxiridagi ikki fazali QT ning minimal tokidan aniqlanadi:

$$k_{sez}=k_{sx}\frac{I_{qt.\min}^{(2)}}{I_{ri}^{II}\cdot n_{TT}}=1\cdot\frac{973}{8.1\cdot 80}=1.5\geq 1,5$$

Maksimal tokli himoya. MTH ning ishlash toki quyidagi ifodadan aniqlanadi:

$$I_{him}^{III}=\frac{k_{z}\cdot k_{o'z.it}}{k_{k}}I_{ish.\max}=\frac{1,2\cdot 1,5}{0,8}\cdot 169.9=382.28\ \text{A}$$

Bu yerda,

$$I_{ish.\max}=\frac{S_{yuk}}{\sqrt{3}\cdot U_{n}}=\frac{(4000+6300)}{\sqrt{3}\cdot 35}=169.9\ \text{A}.$$

Relening ishlash toki quyidagi ifodadan topiladi:

$$I_{ri}^{III} = \frac{k_{sx} \cdot I_{him}^{III}}{n_{TT}} = \frac{1 \cdot 382.28}{80} = 4.77 \text{ A}$$

MTH ning sezgirligi quyidagi formuladan aniqlanadi:

$$k_{sez} = \frac{I_{qt.min}^{(2)}}{I_{ri}^{III} \cdot n_{TT}} = \frac{973}{4.77 \cdot 80} = 2.54 > 1{,}5$$

$$k_{sez} = \frac{I_{qt.min}^{(2)}}{I_{ri}^{III} \cdot n_{TT}} = \frac{1671\frac{10}{35}}{4.77 \cdot 80} = 1.25 > 1{,}5$$

Himoyaning ishlash vaqti

$$t = t_{ish.old} + \Delta t = 1{,}7\text{"}+0{,}5 = 2{,}2\text{" c.}$$

T – 1, T – 2 transformator himoyasi

Transformatorning quvvati 16000 kVA bo‘lganligi uchun tokli kesimning o‘rniga differensial himoya o‘rnatamiz.

Bo‘ylama differensial tokli himoya

Transformatorning bo‘ylama differensial himoyasini ta‘minlovchi TT ni transformatsiyalash koeffitsiyentini tanlash. Kuch transformatorining yuqori va past kuchlanish tomondagi nominal toklarini hisoblashdan boshlanadi:

$$I_{nom.yu} = \frac{S_{nom.tr}}{\sqrt{3} \cdot U_{yu}} = \frac{16000}{\sqrt{3} \cdot 110} = 80.327 \text{ A}$$

$$I_{nom.pk} = \frac{S_{nom.tr}}{\sqrt{3} \cdot U_{pk}} = \frac{16000}{\sqrt{3} \cdot 35} = 263.932 \text{ A}$$

TT larning birlamchi nominal toklari quyidagi shartlarga javob berishi kerak:

$I_{nom.tt.yu} \geq \cdot I_{nom.yu}$ демак, $100 \geq 80.327$

$I_{nom.tt.pk} \geq I_{nom.pk}$ демак, $300 \geq 263.932$

Yuqori va past tomondagi TT larni transformatsiyalash koeffitsiyenti quyidagiga teng:

$$n_{tyu} = \frac{I_{nom.tt.yu}}{5} = \frac{100}{5} = 20$$

$$n_{tpk} = \frac{I_{nom.tt.pk}}{5} = \frac{300}{5} = 60$$

Yuqori va past tomondagi TT lardan differensial himoyaning yelkalarida oqadigan toklar hisoblanadi.

$$I_{dyu} = \frac{I_{nom.yu}}{n_{tyu}} = \frac{80.327}{20} = 4.016 \text{ A}$$

$$I_{dpk} = \frac{I_{nom.pk}}{n_{tpk}} = \frac{263.932}{60} = 4.399 \text{ A}$$

Differensial tokli kesim hisobi. Diffrensial tokli kesimning ishlash toki ikki shartdan tanlanadi:

- Magnitlanish tokining sakrashidan to‘g‘rilash:

$$I_{him} = k_{z1} \cdot I_{nom.tr} = 3 \cdot 80.327 = 240.981 \text{ A}$$

- Maksimal nobalans tokidan to‘g‘rilash:

$$I_{nb.tt} = k_a \cdot k_{bir.min} \cdot f_i \cdot I^{(3)}_{qt.max.tashq} = 1,5 \cdot 1 \cdot 0,1 \cdot 2286 \cdot \frac{35}{110} = 109.126 \text{ A}$$

$$I_{nb.rost} = \frac{\Delta N}{100} \cdot I^{(3)}_{qt.max\ tashq} = \frac{15,93}{100} \cdot 2286 \cdot \frac{35}{110} = 115.891 \text{ A}$$

$$I_{nb.komp} = \frac{|I_{dyu} - I_{dpk}|}{I_{dyu(n)}} \cdot I^{(3)}_{qt.max\ tashq} = \frac{|4,016 - 4.399|}{4,016} \cdot 2286 \cdot \frac{35}{110} = 69.286 \text{ A}$$

$$I_{nb.max} = I_{nb.II} + I_{nb.rost} + I_{nb.komp} = 109.126 + 115.891 + 69.286 = 294.303 \text{ A}$$

$$I_{him} = k_{z2} \cdot I_{nb.max} = 1,3 \cdot 294.303 = 382.594 \text{ A}$$

Himoyaning sezgirligi quyidagicha:

$$k_{sezi} = \frac{k_{\Sigma sx} I^{(2)}_{qt.minold}}{I_{him}} = \frac{1 \cdot 1948 \cdot \frac{35}{110}}{382.594} = 2,5 \succ 2$$

Relening ishlash toki

$$I_{ri} = \frac{k_{sx} I_{him}}{n_{TT}} = \frac{1 \cdot 382.592}{20} = 19.13$$

Himoyaning sezgirligi yetarli darajada.

Maksimal tokli himoya

Himoya PT – 40 relesi orqali bajarilgan. MTH ning ishlash toki quyidagi ifodadan aniqlanadi:

$$I^{II}_{him} = \frac{k_z \cdot k_{o'z.II}}{k_\kappa} I_{ish.max} = \frac{1,2 \cdot 1,5}{0,8} \cdot 80.327 = 180.736 \text{ A}$$

Relening ishlash toki quyidagi ifodadan aniqlanadi:

$$I_{ri}^{II} = \frac{k_{ss} \cdot I^{II}_{him}}{n_{IT}} = \frac{1 \cdot 180.736}{20} = 9{,}037 \text{ A}$$

Sezgirlik koeffitsiyenti:

$$k_{sez} = k_{\Sigma ss} \cdot \frac{I^{(2)}_{qt.min.tashq}}{I^{II}_{ri} \cdot n_{tt}} = 1 \cdot \frac{1948 \cdot \frac{35}{110}}{9{,}037 \cdot 20} = 3{,}43 > 1.5$$

Himoyaning ishlash vaqti

$$t = t_{\text{ish.oldingi}} + \Delta t = 2{,}2\text{"}+0{,}5 = 2{,}7\text{"c.}$$

O'ta yuklanishdan himoya. Himoya xohlagan fazaga bitta releni ulanish orqali bajariladi. Uning ishlash toki quyidagiga teng bo'ladi:

$$I_{him} = \frac{k_z}{k_k} \cdot I_{nom.tr} = \frac{1{,}05}{0{,}8} \cdot 80.327 = 105.42 \text{ A}$$

bu yerda, $k_z = 1.05$.

Himoya PT–40 relesi bilan bajarilgan, himoyaning ishlash vaqti t_{him} = 9 s ga teng bo'ladi.

Avtomatik qayta ulash (AQU) uskunasi

PUE ga asosan AQU uskunasi quyidagilarda jihozlangan bo'lishi kerak:

– 1000 V dan yuqori barcha havo va aralash (kabelli havoli) liniyalarda;

– 35 kV va undan kichik kuchlanishli kabel liniyalarida, agar liniya bir necha nimstansiyalarni ta'minlansa, bundan tashqari himoyasining noselektiv ishlashini to'g'rilash maqsadida;

– quvvati 1 MVA dan yuqori ta'minot tomonida o'chirgich va MTH bo'lgan barcha bittalik pasaytiruvchi transformatorlarni o'chirilishi iste'molchilar energiya ta'minotida uzilishlarga olib kelishi mumkin. Alohida holatlarda esa differensial himoya ishlatilgan bo'lsa ham AQU ni ishlatish ruxsat etiladi.

AQU ning sabr vaqti yuritmaning tayyor bo'lish vaqti (0,1-0,2 s) o'chirgichning tayyor bo'lish vaqti (0,2 – 2 s) va QT joyi atrofining deionizatsiya

vaqti (0,1 – 0,3 s) dan katta bo‘lishi kerak. Amaliyotda o‘chirgichning turiga bog‘liq holda t_{AQU} = 0,8 – 3 s bo‘ladi

AQU uskunasini ishga tushish, qoidaga asosan boshqaruv kaliti va o‘sha o‘chirgichni vaziyatining nomutanosibligi asosida amalga oshiriladi.

Ishlash vaqtlarini tanlash:

$$t_{AQU\ L1,\ I3} = 0{,}8"$$

$$t_{AQU\ T3,\ T4(T5),} = 1{,}3"$$

Zaxirani avtomatik ulash (ZAU) qurilmasi

PUE ga asosan ZAU qurilmasi bir yoki bir necha ta‘minlash manbasi mavjud bo‘lgan taqsimlovchi tarmoqlar va podstansiyalarda qo‘llaniladi, lekin ular bir tomondan ta‘minlanadigan sxema bo‘yicha ishlaydi, agar ishchi manba o‘chsa iste‘molchilarning uzilishiga yoki ular yukining kamayishiga olib keladi.

ZAU qurilmasi quyidagi talablarga amal qilgan holda bajarilishi kerak:

– ZAU ishga tushishi uchun zahiralanatoygan elementda kuchlanish yo‘qolishini sababidan qat‘i nazar, hattoki unda QT bo‘lsa ham ishga tushishi kerak;

– ZAU bir marta ishlashni ta‘minlashi kerak;

– agarda o‘chirgichni QT bo‘lganda qo‘shilsa ham ZAU qurilmasi ishga tushganda qoidaga asosan ushbu o‘chirgichning himoyasi ishini tezlashtirishni nazarga olish kerak.

Dvigatellarning o‘z – o‘zini ishga tushishi va uzoqdagi QTda kuchlanish pasayishini sozlash zaruriyatidan kelib minimal kuchlanish relesining ishlash kuchlanishi quyidagiga teng:

$$U_{him.min} = (0{,}25 \div 0{,}4) \cdot U_{nom}$$

Maksimal kuchlanish relesi esa

$$U_{him.max} = (0,6 \div 0,65) \cdot U_{nom}$$

ZAU ishga tushirish organining sabr vaqti himoyaning tashqi QT dan o‘chirish vaqtidan katta bo‘lishi kerak, bunda kuchlanish $U_{ri.min}$ gacha pasayishi mumkin va qoidaga asosan, ta‘minot tomondagi AQU ishlash vaqtidan katta bo‘lishi kerak:

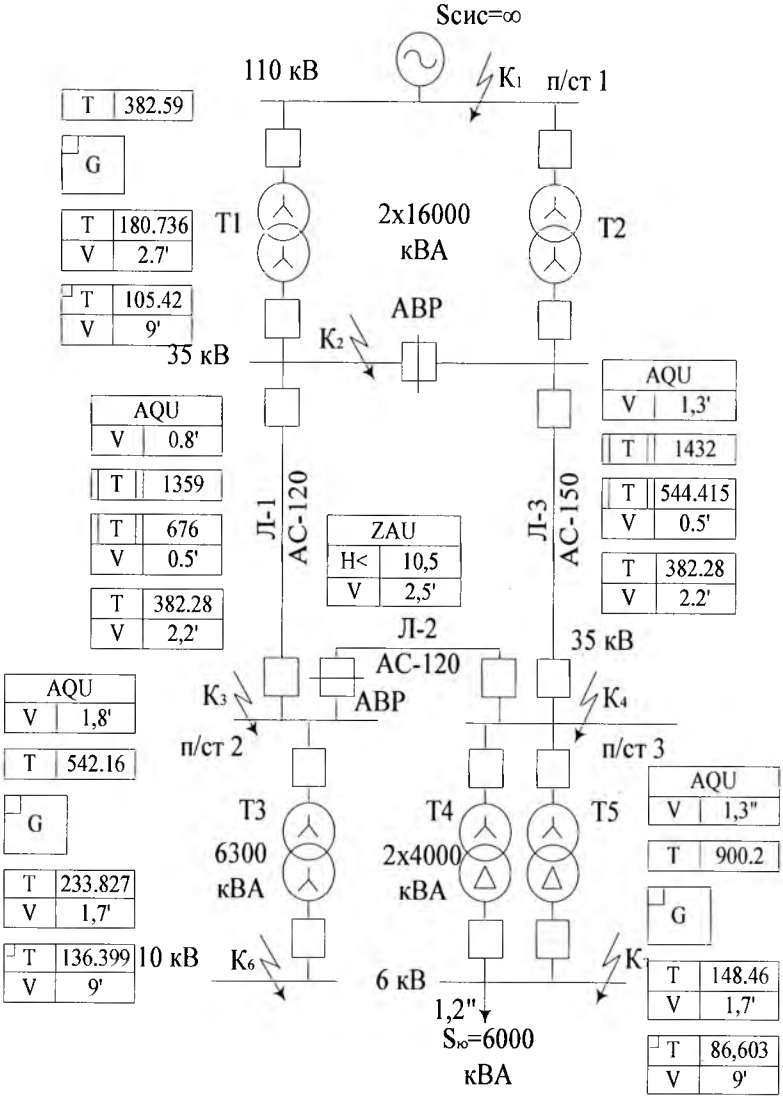
$$t_{ZAU} > t_{him} + \Delta t,\ t_{ZAU} > t_{AQU} + \Delta t$$

Bu yerda, t_{him} – zaxiralanadigan shinadan va ishchi manba kirishi ulangan shinadan ta‘minlanuvchi birlashmalarning eng sekin ishlovchi himoyasining ishlash vaqti; t_{AQU} – ishchi kirish ta‘minoti AQU ning ishlash vaqti; Δt – zahira vaqti, 0,5 s.

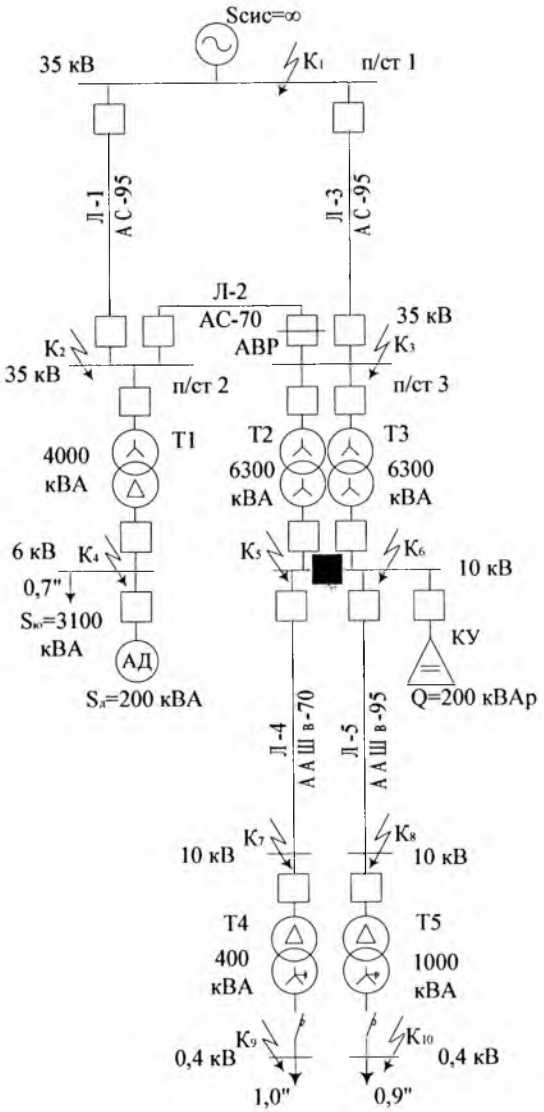
$$U_{him.min} = 0,3 \cdot U_{nom} = 0,3 \cdot 35 = 10,5 \text{ kV}$$

$$t_{ZAU} = 3 \text{ s}$$

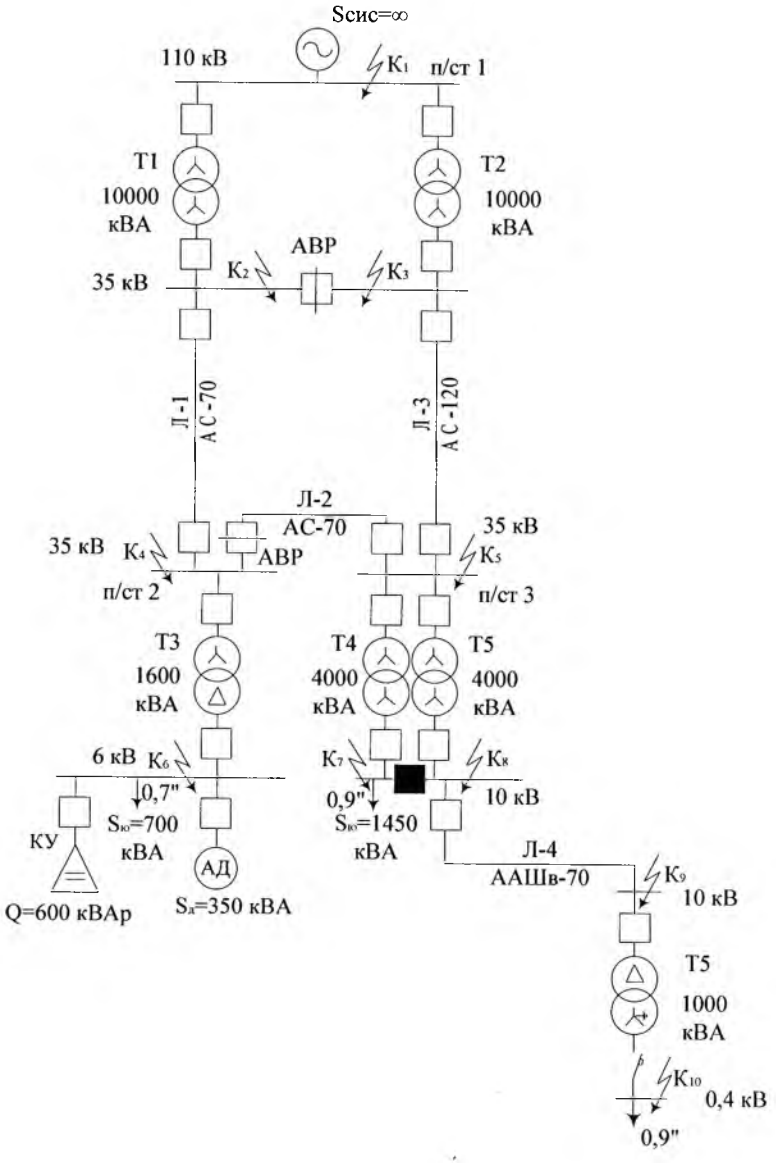
Hisoblab topilgan qiymatlar asosida o‘rnatmalar kartasini tuzib, unda hamma TT va QT, ularning koeffitsiyenti, shartli belgilari va himoyani ishga tushirish toklari va vaqtlarini ko‘rsatamiz.



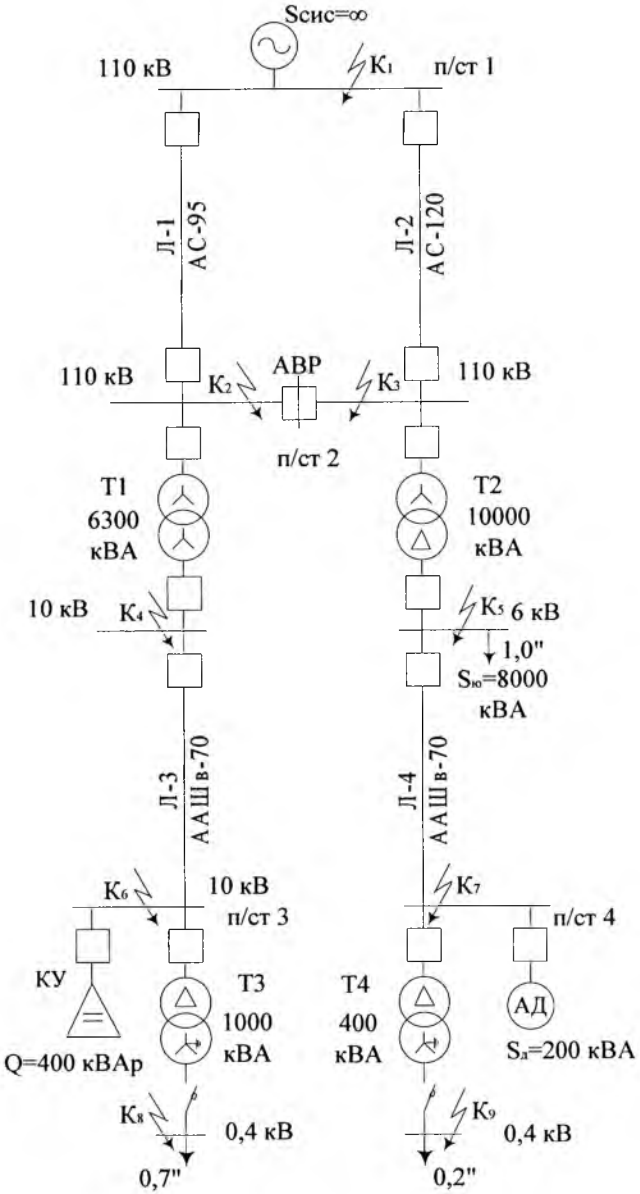
3 – rasm. Berilgan elektr sxemasi



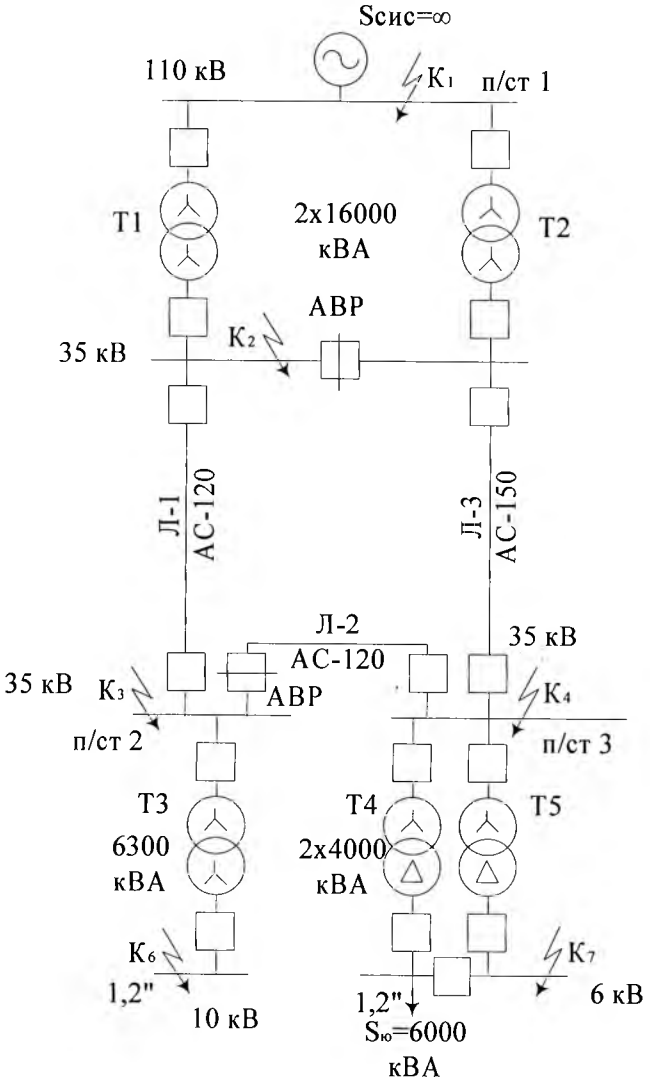
4 – rasm. Berilgan topshirqning 1 – elektr sxemasi



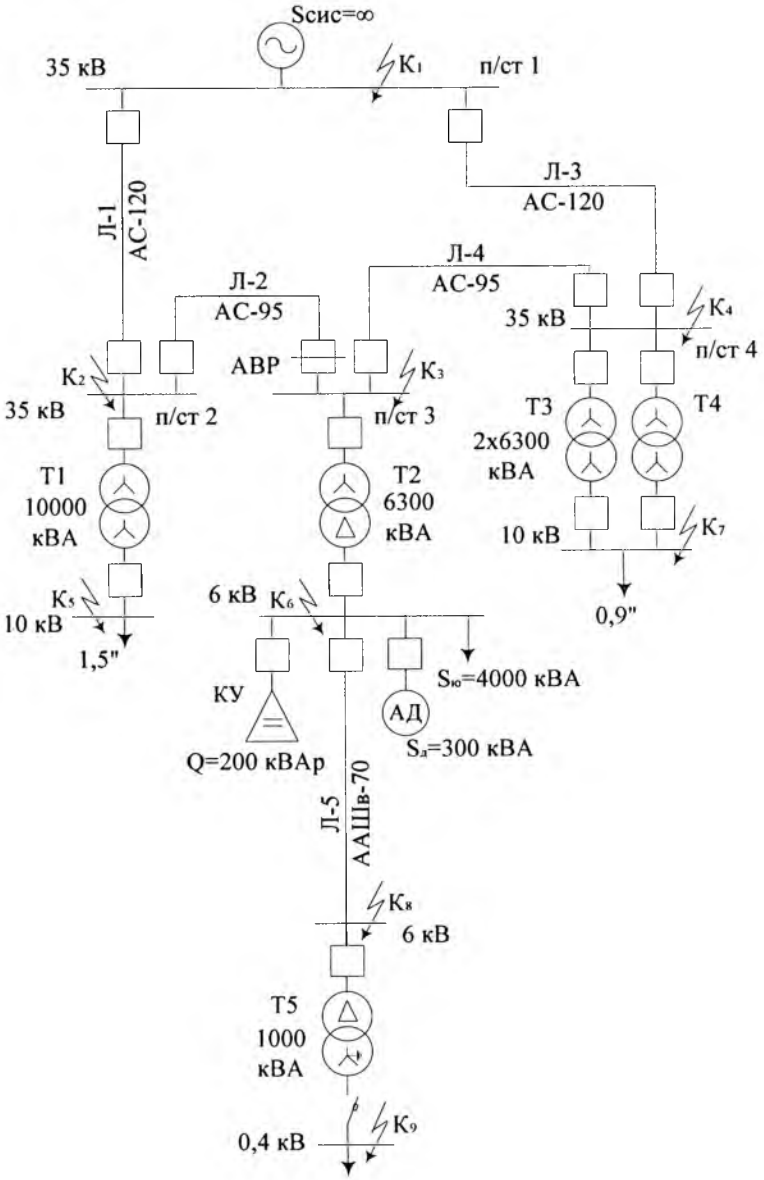
5 – rasm. Berilgan topshirqning 2 – elektr sxemasi



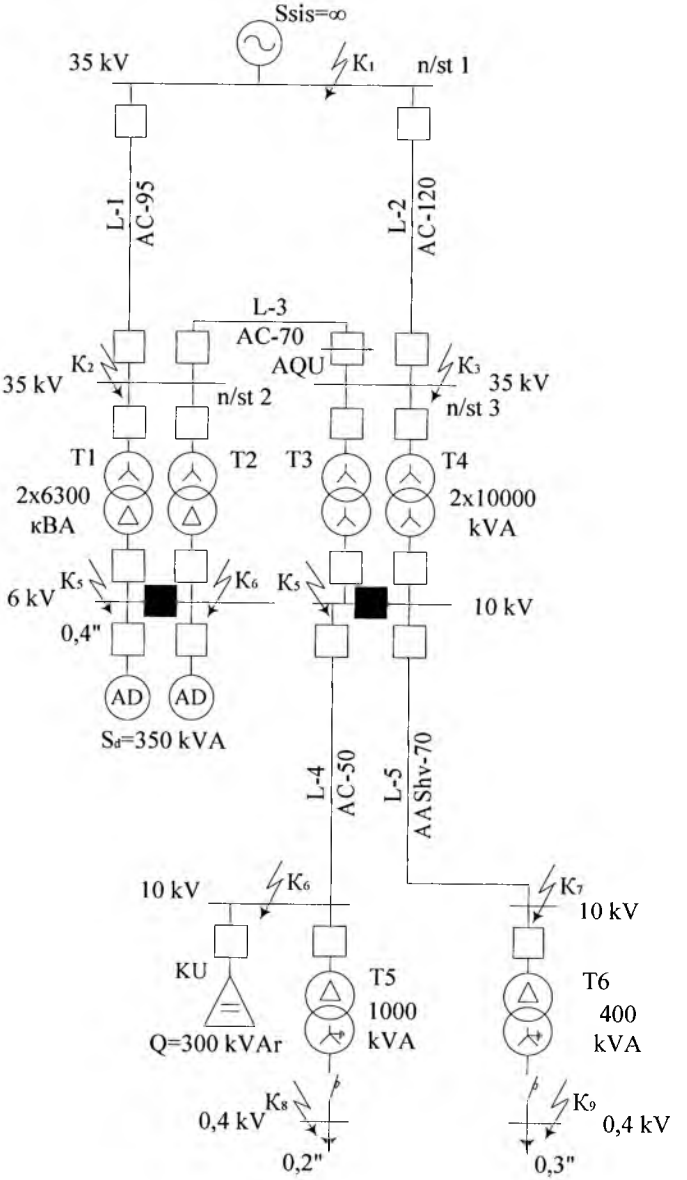
6 – rasm. Berilgan topshirqning 3 – elektr sxemasi



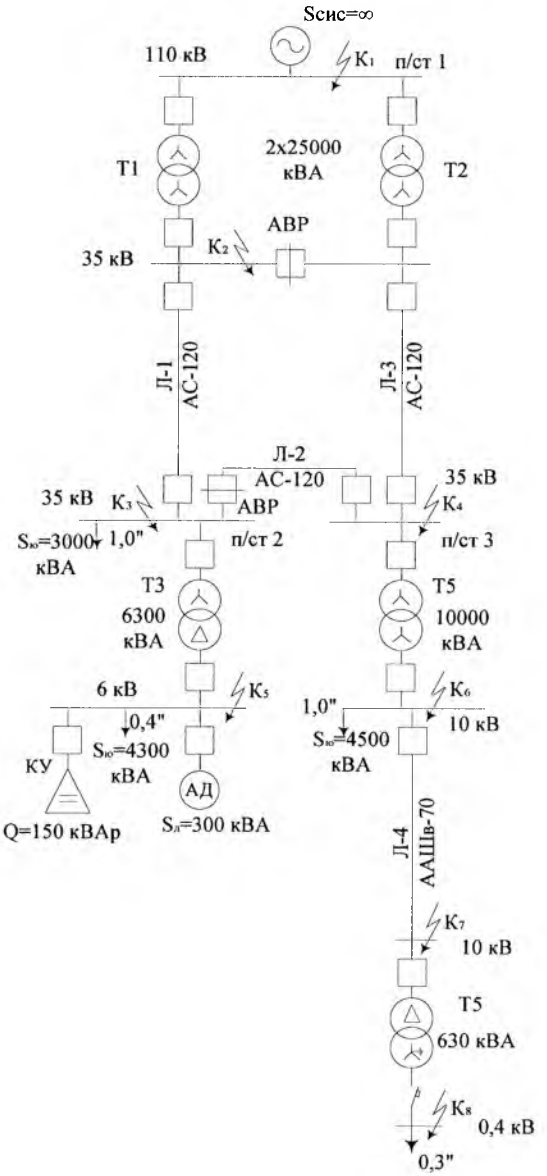
7 – rasm. Berilgan topshirqning 4 – elektr sxemasi



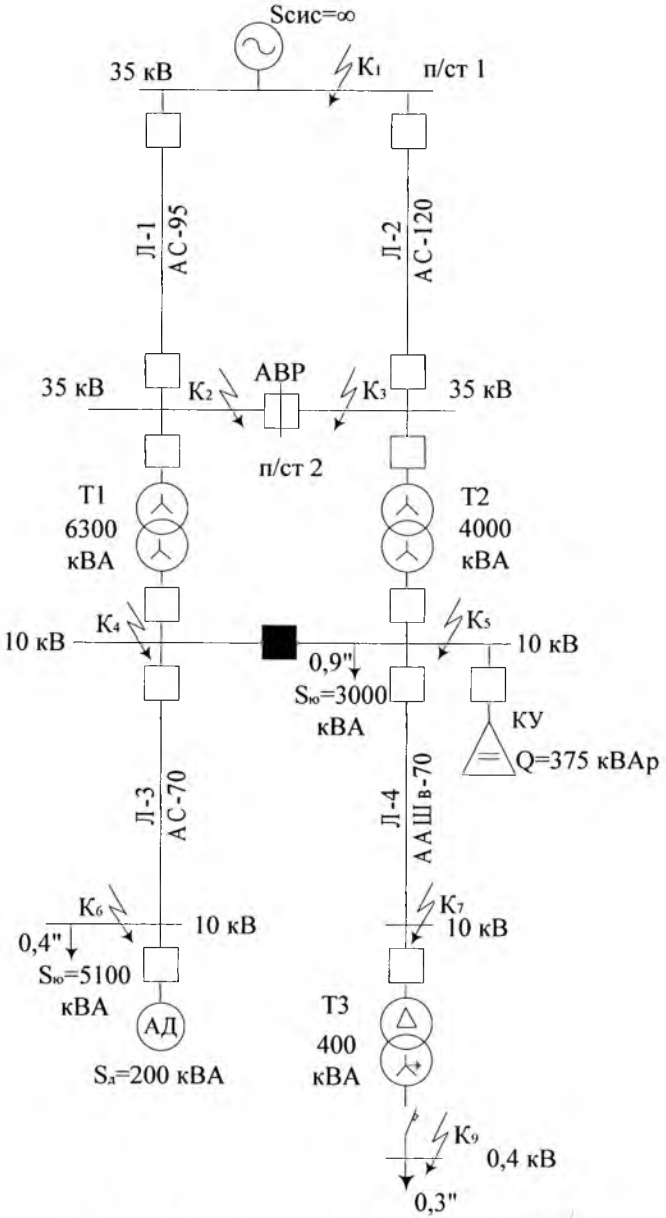
8 – rasm. Berilgan topshirqning 5 – elektr sxemasi



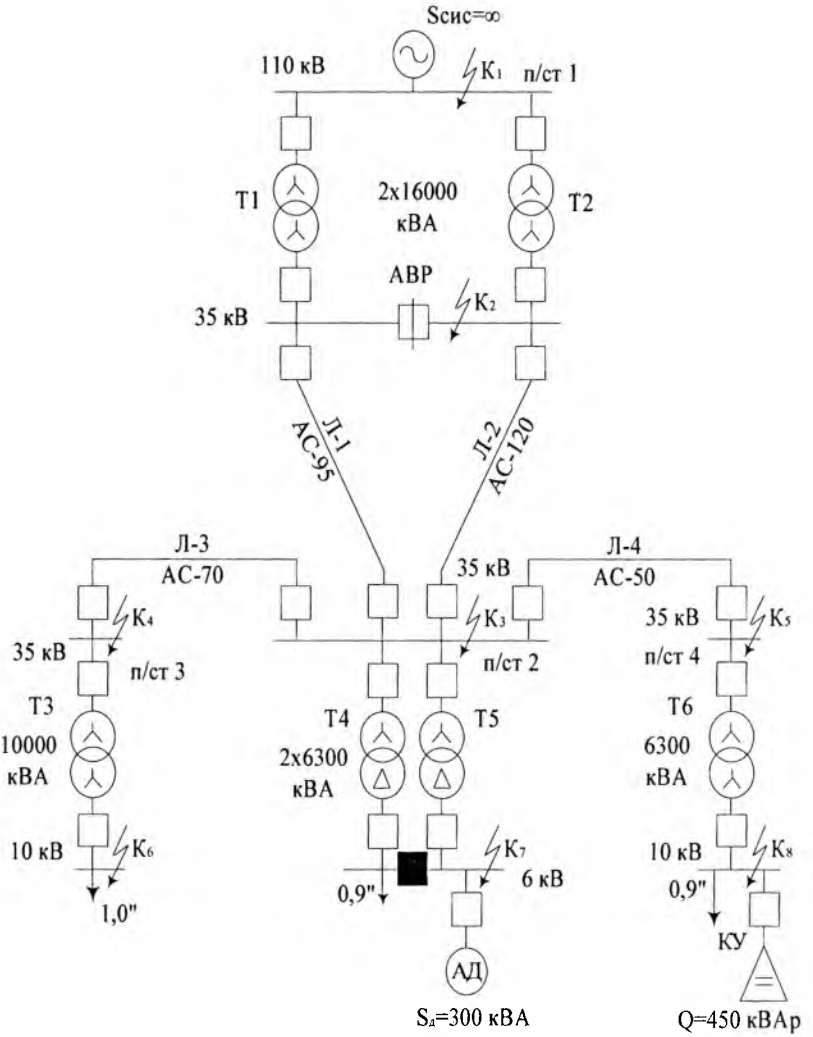
9 – rasm. Berilgan topshirqning 6 – elektr sxemasi



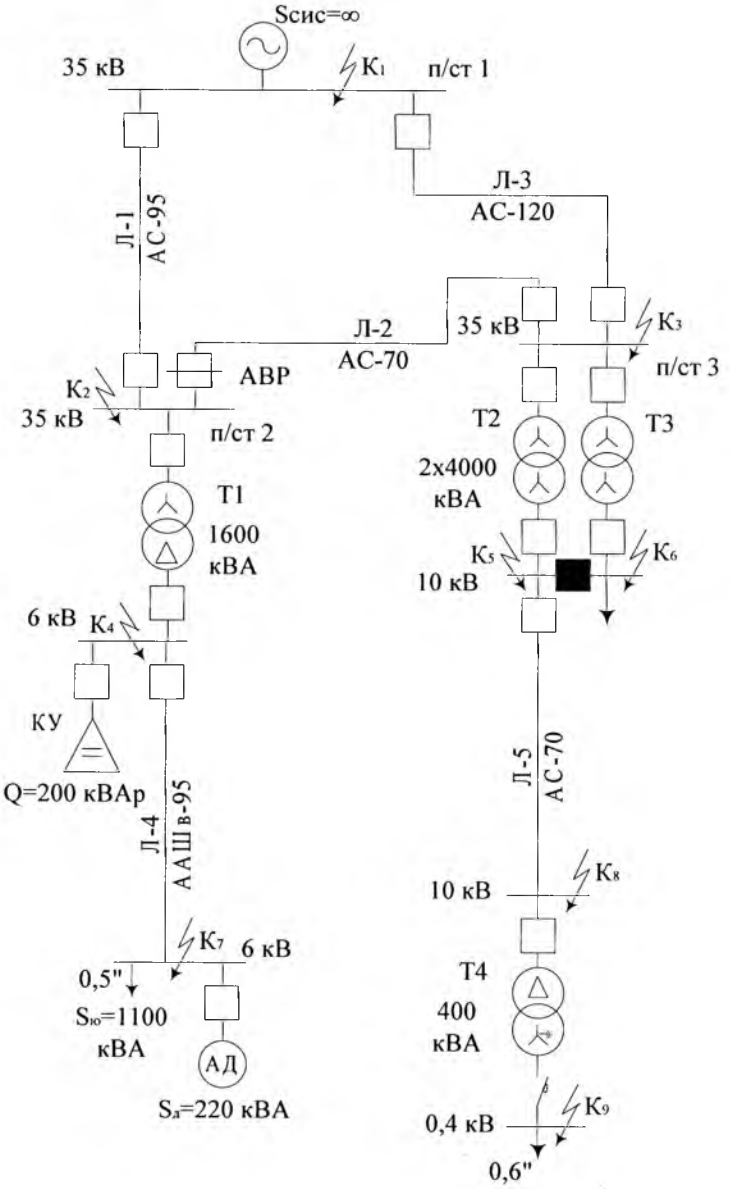
10 – rasm. Berilgan topshirqning 7 – elektr sxemasi



11 – rasm. Berilgan topshirqning 8 – elektr sxemasi



12 – rasm. Berilgan topshirqning 9 – elektr sxemasi



13 – rasm. Berilgan topshirqning 10 – elektr sxemasi

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Mundarija

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