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

TOSHKENT AVTOMOBIL – YO’LLAR INSTITUTI

“Elektromexanika va avtomatika” kafedrasi

5521300 “Elektrotexnika, elektromexanika va elektrotexnologiyalar” bakalavr tayyorlash yo’nalishidagi *“Elektrotexnika va elektronika asoslari”* fanidan

AMALIY MASHG’ULOTLAR

TOSHKENT-2010

“Elektrotexnika, elektromexanika va elektrotexnologiya” bakalavr yo’nalishi talabalari uchun amaliy mashg’ulotlar «Elektromexanika va avtomatika» kafedrasining 2010 yil 26-yanvaridagi majlisida muhokama qilingan va ma’qullangan (majlis bayoni № 12)

Kafedra mudiri v.b. dots. Ahmedov A.P.

Uslubiy ko’rsatma ATF ilmiy-uslubiy Kengashining 2010 yil «___» _____ yig’ilishida (majlis bayoni № ____) muhokama qilingan va tasdiqlangan

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KIRISH

“Elektrotexnika va elektronika asoslari” fanining o’quv dasturida amaliy mashg’ulotlarni o’tish ko’zda tutilgan. Amaliy mashg’ulotlar bir semestr jami 18 soat o’tiladi. Amaliy mashg’ulotlarda ma’ruza darslarida o’tilgan mavzularni mustahkamlash maqsadida misol va masalalar yechiladi. Mavzuga taaluqli ba’zi masalalar yechimi darsda o’qituvchi tomonidan ko’rsatib o’tiladi. Masalalar yechishda talabalar ishtiroki ham zarurdir, chunki masalalarni to’g’ri hal qilish olingan bilimlarni chuqurlashishiga olib keladi. Uslubiy ko’rsatma o’z ichiga ushbu fanda quyidagi bo’limlarni oladi:

1. O’zgarmas tok elektr zanjirlari
2. Bir fazali o’zgaruvchan tok zanjirlari
3. Uch fazali o’zgaruvchan tok zanjirlari
4. Bir fazali transformatorlar
5. O’zgarmas tok generator
6. Asinxron generator
7. Sinxron generator
8. O’zgaruvchan tokni o’zgarmas tokka to’g’rilash
9. Elektr yuritmalar

Har bir mavzuga taaluqli masalalarning yechimi batafsil sharxlab berilgan. Talabalarga uyga vazifa masalalar to’plamidan tanlab beriladi.

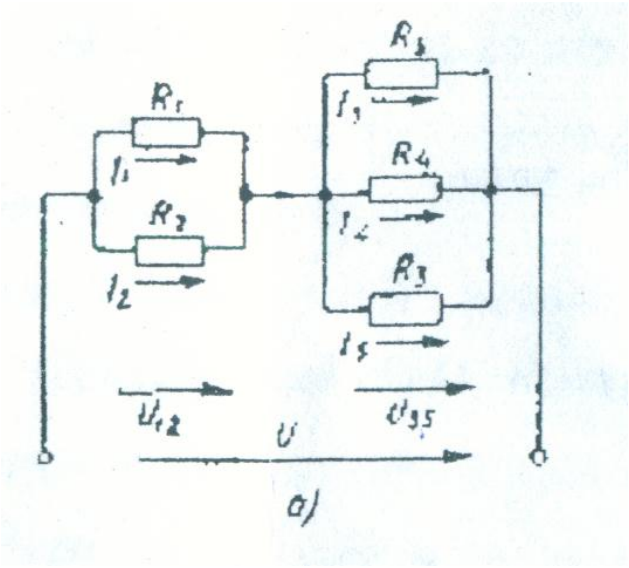
1. O’ZGARMAS TOK ELEKTR ZANJIRLARI

1.1-masala. 1.1-rasm, a da ko’rsatilgan murakkab elektr zinjiri uchun quyidagilar: $U = 36V,\ R_1 = 8Om,\ R_2 = 2Om,\ R_3 = R_4 = 5Om,\ R_5 = 10Om$ ma’lum bo’lsa, zanjirning tarmoqlaridagi I_1, I_2, I_3, I_4, I_5 toklarning qiymati aniqlansin.

Yechilishi:

Zanjirdagi R_1 va R_2 qarshiliklar o’zaro parallel ulangani uchun ularning ekvivalent qarshiligi

$$R_{1,2} = \frac{R_1 \cdot R_2}{R_1 + R_2} = \frac{8 \cdot 2}{8 + 2} = \frac{16}{10} = 1{,}6\,Om$$



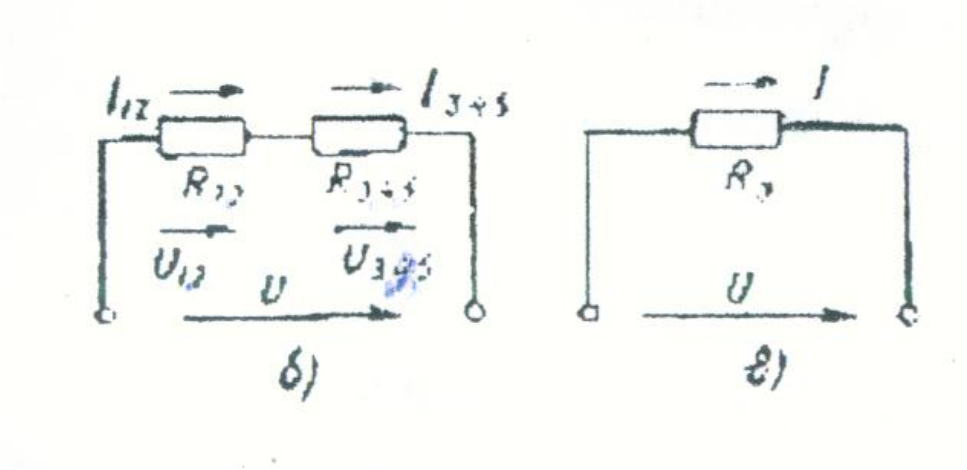
1.1- rasm, a

R_3, R_4, R_5 qarshiliklar o’zaro parallel ulangani uchun ularning ekvivalent o’tkazuvchanligi

$$G = \frac{1}{R_{3,4,5}} = \frac{1}{R_3} + \frac{1}{R_4} + \frac{1}{R_5} = \frac{1}{5} + \frac{1}{5} + \frac{1}{10} = \frac{5}{10} = 0{,}5\,Om$$

Bundan

$$R_{3,4,5} = \frac{1}{G} = \frac{1}{0{,}5} = 2\,Om$$



1.1-rasm, b, v

Qarshiliklar $R_{1,2}$ va $R_{3,4,5}$ o'zaro ketma-ket ulangani uchun (1.1-rasm, b) zanjirning ekvivalent qarshiligi (1.1-rasm, v):

$$R_{ekv} = R_{1,2} + R_{3,4,5} = 1{,}6 + 2 = 3{,}6\,Om$$

U holda zanjirdagi tok

$$I = \frac{U}{R_{ekv}} = \frac{36}{3{,}6} 10\,A$$

Zanjirning qismlaridagi kuchlanish esa

$$U_{1,2} = I \cdot R_{1,2} = 10 \cdot 1{,}6 = 16V$$
$$U_{3,4,5} = I \cdot R_{3,4,5} = 10 \cdot 2 = 20V$$

U holda tarmoqlardagi toklarning qiymati:

$$I_1 = \frac{U_{1,2}}{R_1} = \frac{16}{8} = 2\,A, \quad I_2 = \frac{U_{1,2}}{R_2} = \frac{16}{2} = 8\,A,$$
$$I_3 = I_4 = \frac{U_{3,4,5}}{R_3} = \frac{20}{5} = 4\,A, \quad I_5 = \frac{U_{3,4,5}}{R_5} = \frac{20}{10} = 2\,A.$$

1.2-masala. 1.3-rasm, a da ko'rsatilgan elektr zanjirlar uchun

$$E_1 = 100V;\ E_2 = 70V;\ E_3 = 92V;$$
$$R_1 = 7\,Om;\ R_2 = 9\,Om;\ R_3 = 9{,}5\,Om;\ R_4 = 2\,Om;$$
$$R_5 = 6\,Om;\ R_6 = R_7 = 7\,Om;\ R_8 = 8\,Om.$$

ekanligi ma'lum bo'lsa, Kirxgof qonunlari bevosita qo'llash usuli yordamida zanjirdagi toklarning taqsimlanishi aniqlansin.

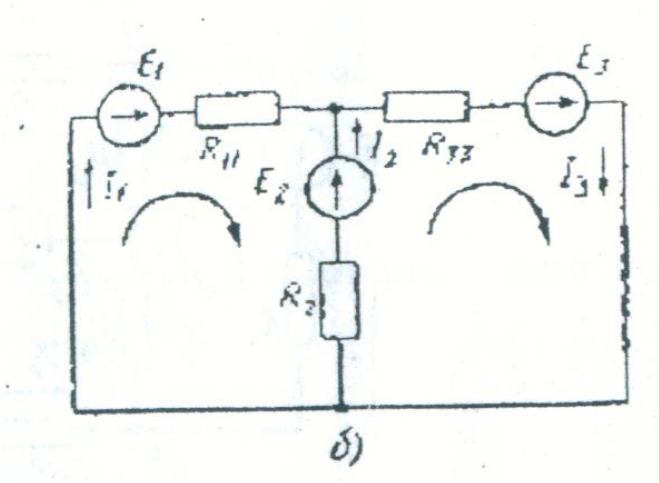
Yechilishi:

Avval R_4, R_5, R_6 va R_7, R_8 qarshiliklarning ekvivalent qarshiligini aniqlab, berilgan sxemani soddaroq ko'rinishga (1.2-rasm, a) keltiramiz:

$$R_{11} = 7 + 7 + 8 = 22\,Om;\ R_{33} = 7 + 9 + \frac{2 \cdot 6}{2 + 6} = 18\,Om$$

EYuK lar (E_1, E_2, E_3) va tarmoqdagi toklar (I_1, I_2, I_3) ning ixtiyoriy musbat yo'nalishlarini 1.2-rasm, b da ko'rsatilgandek qabul qilamiz. So'ngra EYuK va qarshiliklarning ma'lum qiymatlarini tenglamalar sistemasiga qo'yamiz:

$$\begin{cases} I_1 + I_2 = I \\ 30 = 22I_1 - 9I_2 \\ 162 = 9I_2 + 18I_1 \end{cases}$$



1.2-rasm,b

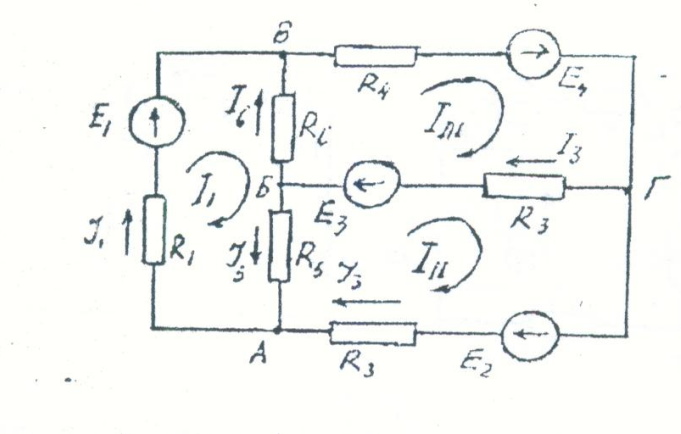
Mazkur tenglamalar sistemasi yechib, $I_1 = 3A, I_2 = 4A$ va $I = 7A$ ekanligini topamiz.

Demak, aniqlangan barcha toklarning ishorasi musbat bo'lib chiqdi, chunki tarmoqdagi toklarning haqiqiy yo'nalishi ularning 1.2-rasmda, v ко'rsatilgan

yo’nalishlariga mos keladi. I_3 toki o’zaro parallel bo’lgan va R_4 va R_5 tarmoqlarda taqsimlanib, ularning qarshiligi teskari proporsilnal ravishda o’zgaradi, ya’ni:

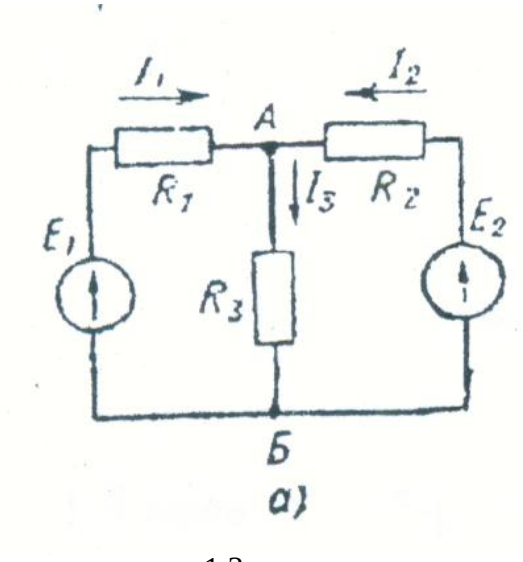
$$I_4 = I_3 \cdot \frac{R_5}{R_4 + R_5} = 7 \cdot \frac{6}{8} = 5{,}25\,A$$

$$I_5 = I_3 \cdot \frac{R_4}{R_4 + R_5} = 7 \cdot \frac{2}{8} = 1{,}75\,A$$



1.2-rasm, v

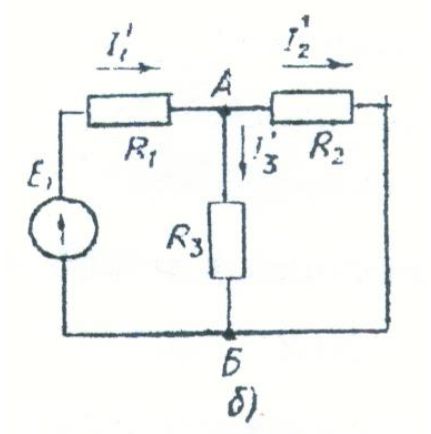
1.3-masala. Agar 1.3-rasm, a da berilgan elektr zanjiri uchun quyidagilar: $E_1 = 99V,\ E_2 = 66V,\ R_1 = 12Om,\ R_2 = 6Om,\ R_3 = 18Om$ ekanligi ma'lum bo'lsa, zanjir tarmoqlaridagi toklar ustlash usuli yordamida aniqlansin.



1.3-rasm, a

Yechilishi:

Agar elektr zanjirida EYuK E_1 ning ta'siri mavjud desak (1.3-rasm, b), u holda zanjirning umumiy qaoshiligi:



1.3-rasm, b

$$R_{10} = R_1 + \frac{R_2 \cdot R_3}{R_2 + R_3} = 12 + \frac{6 \cdot 18}{6 + 18} = 16{,}5\,Om$$

Zanjirning tarmoqlanmagan qismidagi tok:

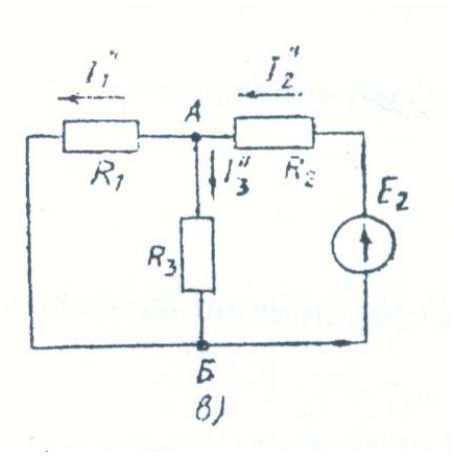
$$I_1 = \frac{E_1}{R_{10}} = \frac{99}{16{,}5} = 6\,A$$

Tarmoqlardagi xususiy toklar:

$$I_2 = I_1 \cdot \frac{R_3}{R_2 + R_3} = 6 \cdot \frac{18}{6+18} = 4{,}5\,A$$

$$I_3 = I_1 \cdot \frac{R_2}{R_2 + R_3} = 6 \cdot \frac{6}{6+18} = 1{,}5\,A$$

Agar zanjirda faqat EYuK E_2 ning ta’siri mavjud desak (1.3-rasm, v), u holda zanjirning umumiy qarshiligi:



1.3-rasm, v

$$R_{20} = R_2 + \frac{R_1 \cdot R_3}{R_1 + R_3} = 6 + \frac{12 \cdot 8}{12+8} = 6 + 7{,}2 = 13{,}2\,Om$$

Zanjirning tarmoqlanmagan qismidagi tok:

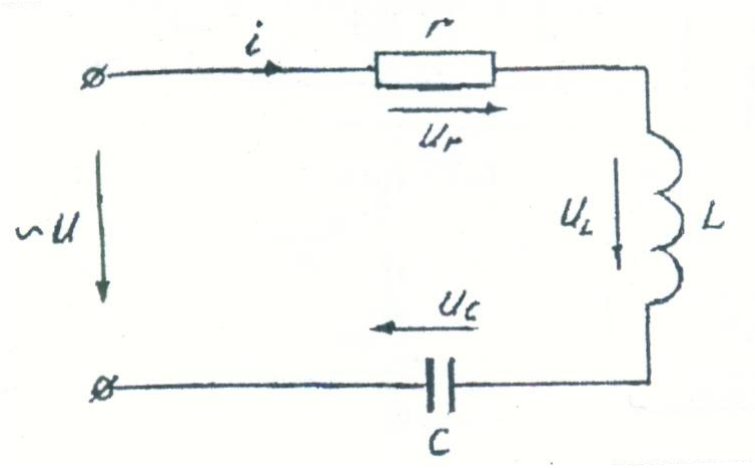
$$I_2 = \frac{E_2}{R_{20}} = \frac{66}{13{,}2} = 5\,A$$

Tarmoqlardagi xususiy toklar:

$$I_1 = I_2 \cdot \frac{R_3}{R_1 + R_3} = 5 \cdot \frac{18}{12+18} = 3\,A$$

$$I_3 = I_2 \cdot \frac{R_1}{R_1 + R_3} = 5 \cdot \frac{12}{12+18} = 2\,A$$

2. BIR FAZALI O'ZGARUVCHAN TOK ZANJIRLARI



2.1-rasm

2.1-misol. 2.1-rasmdagi zanjirga $u = 160\sin(314t - \frac{\pi}{4})$ kuchlanish berilgan. $r = 20\,Om,\ L = 0{,}1\,Gn$ va $C = 48{,}4\,mkF$; zanjir elementlaridagi tok va kuchlanishning oniy qiymatlari aniqlansin.

Yechilishi:

Zanjirning induktiv, sig'imiy va to'la qarshiliklari tegishlicha quyidagicha:

$$X_L = \omega L = 314 \cdot 0{,}1 = 31{,}4\,Om$$

$$X_C = \frac{1}{\omega C} = \frac{10^6}{314 \cdot 48{,}4} = 66\,Om$$

$$I_2 = I_0 \cdot \frac{Z_1}{Z_1 + Z_2} = 10e^{-t56^0 30} \cdot \frac{5 - j5}{20 - j15} = 2\sqrt{2e^{25^0 20}}\ A$$

r_0 qarshilikdagi va $\nu_1 b$ tugunlar orasidagi kuchlanishlarning komplekslari tegishlicha

$$U_0 = I_0 \cdot r_0 = 6e^{-t56^0 30}\, V$$

$$U_{ab} = I_0 \cdot Z_{ab} = I_1 Z_1 = 50\sqrt{2e^{27^0 50}}\, V$$

bo’ladi.

Tok va kuchlanishlarning oniy qiymatlariga o’tib, quyidagilarni hosil qilamiz:

toklar uchun

$$i_0 = \sqrt{2} \cdot 10 \sin(400t - 56^0 30) = 14{,}1 \sin(400t - 56^0 30)\, A$$

$$i_1 = 14{,}1 \sin(400t - 72^0 50)\, A$$

$$i_2 = 4 \sin(400t - 25^0 20)\, A$$

kuchlanishlar uchun

$$u_0 = \sqrt{2} \cdot 6 \sin(400t - 56^0 30) = 8{,}4 \sin(400t - 56^0 30) V$$

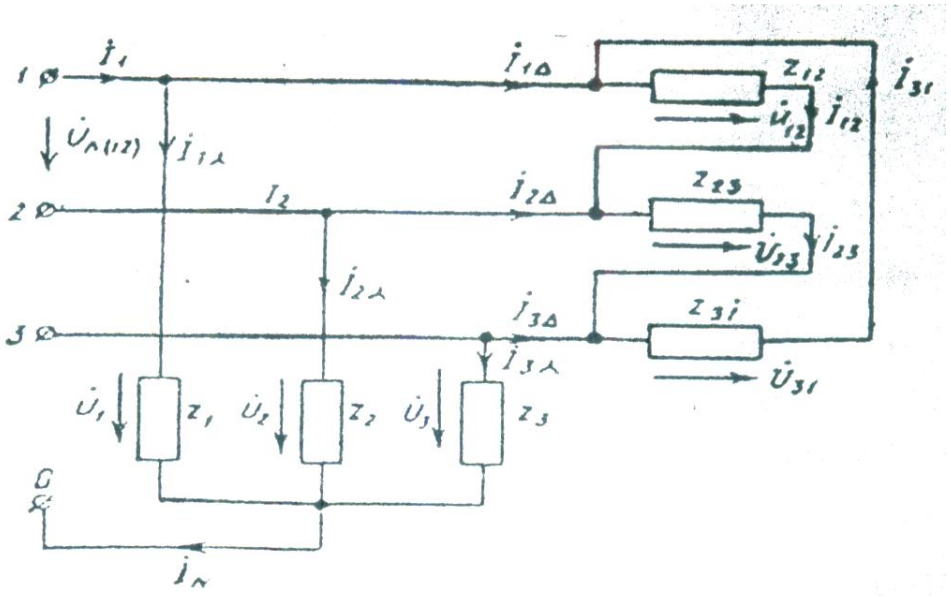
$$u_{ab} = u_1 = u_2 = 100 \sin(400t - 27^0 50) V$$

3. UCH FAZALI O'ZGARUVCHAN TOK ZANJIRLARI

3.1-misol. Liniya kuchlanishi $U = 360V$ bo'lgan simmertik uch fazali generatorga tegishlicha nolь simli yulduz va uchburchaklik usulida ikki gruppa iste'molchi ulangan 3.1-rasmda iste'molchilarning faza qarshiliklari quyidagicha:

$$Z_1 = 55Om, Z_2 = (33 - j44)Om,\ Z_3 = (44 + j33)Om,\ Z_{12} = Z_{23} = Z_{31} = Z_\Delta = 38e^{j30}\ Om$$

(liniya va neytral simlarning qarshiliklari e'tiborga olinmaydi); butun sistemasining to'la, aktiv va reaktiv quvvatlari aniqlansin.



3.1-rasm

Yechilishi:

1. Generatorning faza kuchlanishlarining komplekslari

$$U_1 = 220V,\ U_2 = 220e^{\pi 20}V,\ U_3 = 220e^{j120}V$$

chunki

$$U_f = \frac{U_K}{\sqrt{3}} = \frac{380}{\sqrt{3}} = 220V$$

2. Zanjirning kirish qismlaridagi liniya kuchlanishlarining komplekslari esa:

$$U_{12} = 380e^{j30}\,V,\ U_{23} = 380e^{j90}\,V,\ U_{31} = 380e^{j150}\,V$$

3. Uchburchaklik usulida ulangan iste'molchilarning faza toklari

$$I_{12} = \frac{U_{12}}{Z_{\Delta}} = \frac{380e^{j30}}{38e^{j30}} = 10\,A$$

$$I_{23} = \frac{U_{23}}{Z_{\Delta}} = \frac{380e^{j90}}{38e^{j30}} = 10e^{j150}\,A$$

$$I_{31} = \frac{U_{31}}{Z_{\Delta}} = \frac{380e^{j150}}{38e^{j30}} = 10e^{j120}\,A$$

4. Shu nagruzkani iste'mol qilayotgan liniya toklari esa:

$$I_{1\Delta} = I_{12} - I_{31} = \sqrt{3}\cdot 10e^{j30}\,A$$
$$I_{2\Delta} = I_{23} - I_{12} = \sqrt{3}\cdot 10e^{j150}\,A$$
$$I_{3\Delta} = I_{31} - I_{23} = \sqrt{3}\cdot 10e^{j90}\,A$$

5. Yulduz usulida ulangan iste'molchilarning faza (liniya) toklari tegishlicha

$$I_1 = \frac{U_1}{Z_1} = \frac{220}{55} = 4\,A$$

$$I_2 = \frac{U_2}{Z_2} = \frac{220e^{j120}}{55e^{-j53^{10}}} = 4e^{-j66^{0}50}\,A$$

$$I_3 = \frac{U_3}{Z_3} = \frac{220e^{-j120}}{55e^{j36^{0}50}} = 4e^{j83^{0}10}\,A$$

Neytral simdagi tok esa:

$$I_{\Delta} = I_1 + I_2 + I_3 = 4(1 + e^{-j66^{0}50} + e^{j83^{0}10}) = 4(1{,}513 + j0{,}07) \approx 6{,}04\,A$$

6. Liniya simlaridagi yig'indi toklar (yoki generatorning faza toklari)

$$I_1 = I_1 + I_{1\Delta} = 4 + 17{,}3e^{-j30} = 19 - j8{,}65 = 20{,}8e^{-j24^0 30}\ A$$
$$I_2 = I_2 + I_{2\Delta} = 1{,}58 - j3{,}68 - 15 - j8{,}65 = 18{,}3e^{-j137^0 30}\ A$$
$$I_3 = I_3 + I_{3\Delta} = 0{,}48 + j3{,}96 + j1{,}73 = 21{,}3e^{j90}\ A$$

7. Generatorning fazalari bo'yicha quvvatlarning kompleksi:

$$a)\ S_1 = U_1 I_1 = 220 \cdot 20{,}8e^{-j24^0 30} = 4580e^{-j24^0 30} = 4180 - j1900 = P_1 - jQ$$
$$\left[P = 4{,}18kVt,\ \ Q = 1{,}9\,kVar\,(induktiv\ xarakterli)\ va\ S_1 = 4{,}58\,kVar\right]$$

$$b)\ S_2 = U_2 I_2 = 220e^{j120} \cdot 18{,}3e^{-j137^0 30} = 4026e^{-j17^0 30} = 3840 - j1208 = P_2 - IQ_2$$
$$\left[P_2 = 3{,}84\,kVt,\ \ Q_2 = 1{,}2\,kVar\,(induktiv\ xarakterli)\ va\ S_2 = 4{,}03\,kVA\right]$$

$$v)\ S_3 = U_3 I_3 = 220e^{-j120} \cdot 21{,}3e^{j90} = 4686e^{-j30} = 4060 - j2343 = P_3 - Q_3$$
$$\left[\left[P_3 = 4{,}06\,kVt,\ \ Q_3 = 2{,}34\,kVar\,(induktiv\ xarakterli)\ va\ S_3 = 4{,}69\,kVA\right]\right]$$

g) Butun zanjirning to'la (yoki fazaviy) quvvati

$$S = S_1 + S_2 + S_3 = 13{,}3\,kVA$$

Butun zanjirning aktiv quvvati:

$$P = P_1 + P_2 + P_3 = 12{,}08\,kVt$$

Butun zanjirning reaktiv (induktiv xarakterli) quvvati:

$$Q = Q_1 + Q_2 + Q_3 = 5{,}45\,kVAr$$

4. BIR FAZALI TRANSFORMATORLAR

4.1- masala. TM-100/1_0 transformatorning pasportida quyidagi texnikaviy ma’lumotlar ko’rsatilgan:

Nominal to’la quvvati $S_{nom}=100\,kVA$, yuqori kuchlanishi $U_{1nom}=10\,kV$, pastki kuchlanishi $U_{2nom}=0{,}4\,kV$, salt ishlaganda quvvat isrofi (nominal kuchlanishda) $P_p=365Vt$, qisqa tutashuvdagi quvvat isrofi $P_{q.t.}=1970Vt$, qisqa tutashuv kuchlanishi $U_{q.t.}=4{,}5\%$ (nominal kuchlanishga nisbatan), chulg’amlarni birlashtirish usuli $Y/Y_0=12$.

Quyidagilar aniqlansin:

1. Transformatsiya koeffitsiyenti;
2. Birlamchi va ikkilamchi chulg’amlardagi nominal toklar;
3. Transformator salt ishlaganda faza chulg’amlarining qismlaridagi kuchlanish;
4. Transformator chulg’amlarining nominal tokiga to’g’ri keladigan aktiv qarshiliklari;
5. Transformatorning quvvat koeffitsiyenti $\cos\varphi_2=0{,}8$ bo’lib (yuklanish aktiv-induktiv xarakterga ega), yuklanish koeffitsiyenti $\beta=0{,}25;0{,}5;0{,}75;1$ bo’lgandagi foydali ish koeffitsiyentlari;
6. Quvvat koeffitsiyenti $\cos\varphi_2=0{,}8$ bo’lib, yuklanish nominal bo’lganda ($\beta=1$) kuchlanish ΔU ning o’zgarishi.

Yechilishi:

1. Transformatsiya koeffitsiyenti:

$$K=\frac{U_{1nom}}{U_{2nom}}=\frac{10}{0{,}4}25$$

2. Chulg’amlardagi toklar:

$$I_{1nom} = \frac{S_{nom}}{\sqrt{3} \cdot U_{1nom}} = \frac{100}{\sqrt{3} \cdot 10} = 5{,}78\,A;$$

$$I_{2nom} = \frac{S_{nom}}{\sqrt{3} \cdot U_{2nom}} = \frac{100}{\sqrt{3} \cdot 0{,}4} = 144{,}5\,A.$$

3. Transformator salt ishlaganda faza chulg'amlarining qismlaridagi kuchlanish:

$$U_{10f} = \frac{U_{1nom}}{\sqrt{3}} = \frac{10000}{\sqrt{3}} = 5788\,V;$$

$$U_{20f} = \frac{U_{2nom}}{\sqrt{3}} = \frac{400}{\sqrt{3}} = 231V.$$

4. Chulg'amlarning aktiv qarshiliklari.

Transformatorning qisqa tutashuv paytidagi quvvat isrofi ikkala chulg'amlarning quvvat isroflari yig'indisiga teng:

$$P_{q.t.} = 3 \cdot r_1 \cdot I_{1nom}^2 + 3 \cdot r_2 \cdot I_{2nom}^2$$

Qisqa tutashuv tajribasi vaqtida chulg'amlardan nominal tok oqib o'tadi. Shuning uchun

$$3 \cdot r_1 \cdot I_{1nom}^2 = 3 \cdot r_2 \cdot I_{2nom}^2$$

U holda birlamchi chulg'am uchun

$$3 \cdot r_1 \cdot I_{1nom}^2 = \frac{P_{q.t.}}{2}, \qquad \text{bundan} \quad r_1 = \frac{P_{q.t.}}{2 \cdot 3 \cdot I_{1nom}^2}$$

Demak,

$$r_1 = \frac{1970}{2 \cdot 3 \cdot 5{,}78^2} = \frac{1970}{200{,}4} = 9{,}83\,Om$$

Ikkilamchi chulg'am uchun esa

$$3 \cdot r_2 \cdot I_{2nom}^2 = \frac{P_{q.t.}}{2}, \qquad \text{bundan} \quad r_2 = \frac{P_{q.t.}}{2 \cdot 3 \cdot I_{2nom}^2}$$

Demak,

$$r_2 = \frac{1970}{2 \cdot 3 \cdot 144{,}5^2} = \frac{1970}{125280} = 0{,}0157\,Om$$

Chulg'amlarning elektr qarshiligi temperaturaga bog'liq bo'lib, transformator salt ishlashdan nominal yuklanishga o'tganda o'zgaradi.

5. Transformatorning yuqorida ko'rsatilgan quvvat koeffitsiyenti va yuklanish koeffitsiyentlariga mos foydali ish koeffitsiyentlari quiydagicha aniqlanadi:

$$\eta \quad \frac{\beta \cdot S_{nom} \cdot \cos\varphi_2}{\beta \cdot S_{nom} \cdot \cos\varphi_2 + P_p + \beta^2 P_{q.t.}};$$

$$\eta_{0,25} = \frac{0,25 \cdot 100 \cdot 10^3 \cdot 0,8}{0,25 \cdot 100 \cdot 10^{10} \cdot 0,8 + 365 + 0,25^2 \cdot 1970} = 0,9790;$$

$$\eta_{0,50} = \frac{0,50 \cdot 100 \cdot 10^3 \cdot 0,8}{0,50 \cdot 100 \cdot 10^{10} \cdot 0,8 + 365 + 0,50^2 \cdot 1970} = 0,9790;$$

$$\eta_{0,75} = \frac{0,75 \cdot 100 \cdot 10^3 \cdot 0,8}{0,75 \cdot 100 \cdot 10^{10} \cdot 0,8 + 365 + 0,75^2 \cdot 1970} = 0,9790;$$

$$\eta_{1,0} = \frac{1 \cdot 100 \cdot 10^3 \cdot 0,8}{1 \cdot 100 \cdot 10^{10} \cdot 0,8 + 365 + 1^2 \cdot 1970} = 0,9716.$$

Odatda, transforomator chulg'amlaridagi quvvat isrofi bilan po'lat o'zakdagi quvvat isrofi tenglashgandagi yuklanish koeffitsiyentida transformatorning foydali ish koeffitsiyenti maksimal bo'ladi:

$$\beta^2 \cdot P_{q.t.} = P_p$$

U holda izlanayotgan optimal yuklanish koeffitsiyenti:

$$\beta = \sqrt{\frac{P_p}{P_{q.t.}}} = \sqrt{\frac{365}{1970}} = \sqrt{0,1852} \approx 0,43$$

6. Yuklanish nominal bo'lganda ($\beta = 1$ va $I = I_{nom}$) kuchlanish ΔU ning o'zgarishi quyidagi formula bilan aniqlanadi:

$$\Delta U\% \approx \beta(U_a \cos\varphi_2 + U_p \cdot \sin\varphi_2)$$

Bu yerda U_a va U_p qisqa tutashuv kuchlanishining aktiv va reaktiv tashkil etuvchilari hisoblanadi. Ular quyidagicha aniqlanadi:

$$U_a = \frac{P_{q.t.}}{S_{nom}} \cdot 100 = \frac{1970}{100000} \cdot 100 = 1,97\%;$$

$$U_p = \sqrt{U_{q.t.}^2 + U_a^2} = \sqrt{4,5^2 + 1,97^2} = 4,91\%;$$

$$\Delta U\% = U_a \cdot \cos\varphi_2 + U_p \cdot \sin\varphi_2 = 1,97 \cdot 0,8 + 4,91 \cdot 0,6 = 4,52\%.$$

5. O’ZGARMAS TOK GENERATOR

5.1 – masala. Mustaqil uyg’otishli generatorning (5.1-rasm) texnik ma’lumotlari quyidagicha:

Nominal quvvati $P_{nom} = 16\,kVt$, nominal kuchlanish $U_{nom} = 230V$, yakor chulg’amining qarshiligi $r_y = 0{,}12\,Om$, uyg’otish zanjirining qarshiligi $r_u = 18\,Om$, uyg’otish zanjirining kuchlanishi $U_u = 110V$.

Mexanik va magnit isrofgarchiliklari generator nominal quvvatining 4,5% ini tashkil etadi.

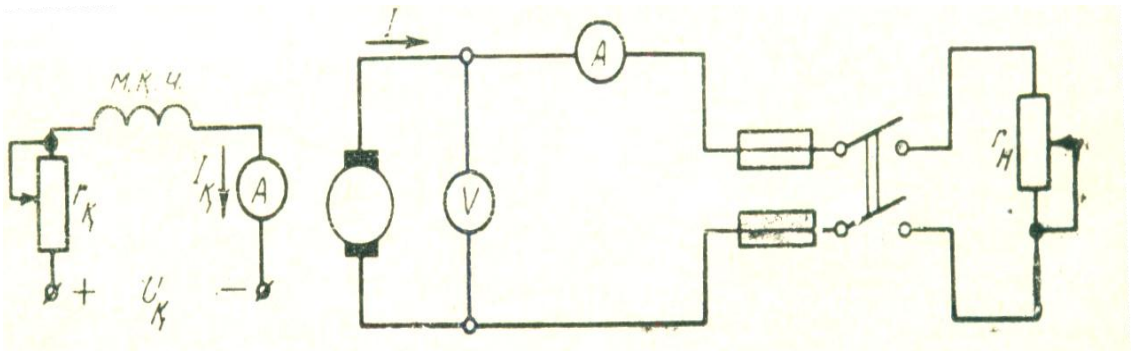
Quyidagilar aniqlansin:

1. Generatorning EYuK i (E);
2. Generatorning nagruzkasi nominal qiymatga teng bo’lgandagi foydali ish koeffitsiyenti (η).

Yechilishi:

1. Generatorning EYuK i

$$E = U + I_y \cdot r_y$$



5.1-rasm

Mustaqil qo’zg’otishli generatorda:

$$I_y = I$$

Generatorning nominal toki

$$I_{nom} = \frac{P_{nom}}{U_{nom}} = \frac{16 \cdot 10^3}{230} = 69{,}57\,A$$

U holda

$$E = 230 + 69{,}57 \cdot 0{,}12 = 238{,}35V$$

2. Nominal rejimda generatorning FIK i

$$\eta = \frac{P_{nom}}{P_{nom} + \sum P}$$

bu yerda: $\sum P$ - generatordagi quvvat isrofgarchiliklarining yig'indisi:

$$\sum P = P_u + P_y + P_{mex} + P_{mag}$$

Ana shu paytda uyg'otish zanjiridagi quvvat isrofgarchiligi

$$P_y = \frac{U_u^2}{R_u} = \frac{110^2}{18} = 672Vt = 0{,}672\,kVt$$

Yakor chulg'amidagi quvvat isrofgarchiligi:

$$P_y = I_{ynom}^2 \cdot r_y = 69{,}57^2 \cdot 0{,}12 = 581Vt = 0{,}581kVt$$

Shart bo'yicha:

$$P_{mex} + P_{mag} = 0{,}045P_{nom} = 0{,}045 \cdot 16 \cdot 10^3 = 720Vt = 0{,}72\,kVt$$

Demak,

$$\eta = \frac{P_{nom}}{P_{nom} + P_u + P_y + P_{mex} + P_{mag}} = \frac{16}{16 + 0{,}672 + 0{,}581 + 0{,}72} = 0{,}89.$$

5.2 – masala. Mustaqil uyg'otishli generotor (5.1 - rasm) salt ishlaganda uning uchlaridagi kuchlanish U_0= 248 V. Yakorning aylanish tezligi n = 1000 ayl/min, yakor zanjirining qarshiligi r_{ya} = 0,19 Om. Hagruzka ulangandan so'ng ampermetr I = 53 A tokni, voltmetr U = 220 V kuchlanishni ko'rsatadi. Nagruzka ulangandan keyingi yakorning aylanish tezligi aniqlansin. Magnit oqimlarining o'zgarishiga e'tibor berilmasin.

Yechilishi:

Generator salt ishlagandagi EYuK

$$E_0 = U_0 = 248 \text{ V}.$$

Nagruzka bilan ishlaganda EYuK

$$E = U + I_я r_я = 220 + 53 \cdot 0{,}19 = 230 \text{ V}.$$

Ammo salt ishlaganda:

$$E_0 = c \cdot n_0 \cdot \Phi.$$

Nagruzka bilan ishlaganda esa:

$$E = c \cdot n \cdot \Phi,$$

chunki shart bo'yicha:

$$\Phi \approx const,$$

Bu vaqtda:

$$\frac{E_0}{E} = \frac{n_0}{n},$$

bundan

$$n = n_0 \cdot \frac{E}{E_0} = 1000 \cdot \frac{230}{248} = 927 \text{ ayl/min}.$$

6. ASINXRON GENERATOR

6.1 – masala. 4A180S4У3 tipdagi uch fazali qisqa tutashgan rotorli asinxron dvigatelning stator chulg'amlari yulduz sxemada biriktirilib, chastotasi $f = 50Gts$, liniya kuchlanishi $U_l = 380V$ bo'lgan uch fazali tok tarmog'iga ulangan. Dvigatelning pospartida quyidagi nominal ma'lumotlar berilgan:

1. Dvigatelning o'qidagi foydali quvvat $P_{nom} = 22kVt$;
2. Rotorning aylanish tezligi $n_2 = 1470ayl/\min$;
3. Foydali ish koeffitsiyenti $\eta_{nom} = 0{,}9$;
4. Stator zanjiridagi quvvat koeffitsiyenti $\cos\varphi_1 = 0{,}9$;
5. Qutblar soni – 4;
6. Maksimal va yurgizish momentining nominal momentga nisbatlari 2,3; 1,4;
7. Yurgizish tokining nominal tokka nisbati 6,5.

Quyidagilar aniqlansin:

1. Rotorning nominal sirpanishi;
2. Dvigatelning nominal, yurgizish va maksimal aylantiruvchi momentlari;
3. Dvigatelning tarmoqdan iste'mol qiladigan quvvati;
4. Dvigatelning nominal va yurgizish toklari;
5. Tarmoq kuchlanishi 10 va 20% ga pasayganda yurgizish momenti va tokining qiymatlarini aniqlab dvigatelning ishiga xulosa bering.

Yechilishi:

Dvigatelning qutblar soni 4 ta bo'lganda, juft qutblar soni $p = 2$ bo'ladi. U holda statordagi aylanuvchan magnit maydonining sinxron tezligi:

$$n_1 = \frac{60 \cdot f}{p} = \frac{60 \cdot 50}{2} = 1500\,ayl/\min.$$

Rotorning sirpanishi:

$$S = \frac{n_1 - n_2}{n_1} = \frac{1500 - 1470}{1500} = 0{,}02$$

Nominal aylantiruvchi momenti

$$M_{nom} = 9550 \cdot \frac{P_{nom}}{n_2} = 9550 \cdot \frac{22}{1470} = 143\,N \cdot m$$

Yurgizish momenti

$$M_{yu} = 1{,}4 \cdot M_{nom} = 1{,}4 \cdot 143 = 200{,}2\,N \cdot m$$

Maksimal aylantiruvchi moment

$$M_{\max} = 2{,}3 \cdot M_{nom} = 2{,}3 \cdot 143 = 328{,}9\,N \cdot m$$

Dvigatelning elektr tarmog'idan iste'mol qiladigan quvvati

$$P_1 = \frac{P_{nom}}{\eta_{nom}} = \frac{22}{0{,}9} = 24{,}44\,kVt$$

Elektr tarmog'idan qabul qiladigan nominal tok

$$I_{nom} = \frac{P_{nom}}{\sqrt{3} \cdot U_{1nom} \cdot \eta_{nom} \cdot \cos\varphi_{1nom}} = \frac{22}{\sqrt{3} \cdot 0{,}02 \cdot 0{,}9 \cdot 0{,}9} = 71{,}43\,A$$

Dvigatelni yurgizish paytida tarmoqdan qabul qilinadigan toki

$$I_{yu} = 6{,}5 \cdot I_{nom} = 6{,}5 \cdot 71{,}43 = 464{,}3\,A$$

Tarmoq kuchlanishi 10% ga pasaygandagi dvigatelning yurgizish momenti va toki. Asinxron dvigatelning aylantiruvchi momenti tarmoq kuchlanishining kvadratiga proporsional. Agar tarmoq kuchlanishi 10% ga pasaysa, u $0{,}9U_{1nom}$ ga teng bo'ladi. U holda aylantiruvchi moment nominalga nisbatan $(0{,}9)^2 = 0{,}81$ ni tashkil etadi. Shu kuchlanishdagi yurgizish momenti

$$M'_{yu} = 0{,}81 \cdot M_{yu} = 0{,}81 \cdot 200{,}2 = 162{,}1 N \cdot m$$

Yurgizish tokini kuchlanishning birinchi darajasiga proporsional deb taxminan quyidagicha hisoblash mumkin

$$I'_{yu} = 0{,}9 \cdot I_{yu} = 0{,}9 \cdot 464{,}3 = 418\,A$$

Tarmoq kuchlanishi 20% ga pasaygandagi dvigatelning yurgizish momenti va toki. Bunda tarmoq kuchlanishi $0{,}8U_{1nom}$ ga teng bo'lib, aylantiruvchi moment nominal momentning $(0{,}8)^2 = 0{,}64$ qismini tashkil etadi. Shu kuchlanishdagi yurgizish momenti

$$M''_{yu} = 0{,}64 \cdot M_{yu} = 0{,}64 \cdot 200{,}2 = 128\,N \cdot m$$

Shu kuchlanishdagi dvigatelning yurgizish toki

$$I_{yu}^{''} = 0{,}8 \cdot 464{,}3 = 371{,}5\,A$$

Xulosa. Tarmoq kuchlanishi 10% ga pasayganda $M_{yu}^{'} > M_{nom}$ bo'lganidan dvigatelni nominal nagruzkada yurgizish mumkin. Ammo tarmoq kuchlanishi 20% ga pasayganda $M_{yu}^{'} < M_{nom}$ bo'lib, dvigatelni nominal nagruzkada yurgizish bo'lmaydi.

6.2 - masala. Sexga o'rnatilgan uch fazali asinxron dvigatellarning iste'mol qiladigan umumiy aktiv quvvati P_{dv}= 300 kVt, kuchlanishi U_{nom} = 380 B va quvvat koeffitsiyentlarining o'rtacha qiymati $\cos\varphi_{o'r}$ =0,7. Yoritgich lampalarining iste'mol qiladigan umumiy quvvati P_{yor} = 20 kVt. Sexning quvvat koeffitsiyentlarini 0,95 gacha oshirish uchun kondensatorlar batareyasidan fodalanish tafsiya etiladi.

Quyidagilar aniqlansin.

1. Kondensatorlar o'rnatilmasdan avvalgi sex nagruzkalarining umumiy quvvati – P_1.
2. Kondensatorlar batareyasining sig'imi – C.
3. Kondensatorlar batareyasi o'rnatilmasdan avval va o'rnatilgandan so'ng liniya simlaridagi I_1 va I_2 toklar.

Yechilishi:

Kondensatorlar batareyasi o'rnatilmasdan avvalgi umumiy aktiv quvvat:

$$P_1 = P_{dv} + P_{yor} = 300 + 20 = 320 \text{ kVt}.$$

Reaktiv quvvat:

$$Q_1 = P_{dv} \bullet \operatorname{tg}\varphi_{o'r} = 300 \bullet 1 = 300 \text{ kVAr } (\operatorname{tg}\varphi_{o'r} = 1).$$

1. $\cos\varphi_1$ ni aniqlash uchun, $\operatorname{tg}\varphi_1$ ni topamiz:

$$\operatorname{tg}\varphi_1 = \frac{Q_1}{P_1} = \frac{300}{320} = 0{,}938, \text{ u vaqtda } \cos\varphi_1 = 0{,}734;$$

$$\cos\varphi_2 = 0{,}95 \text{ bo'lganda } \operatorname{tg}\varphi_2 = 0{,}328.$$

2. Kerakli кondensatorlar batareyasining sig'imi:

$$C = \frac{P(\operatorname{tg}\varphi_1 - \operatorname{tg}\varphi_2)}{\omega \cdot U^2} = \frac{300 \cdot (0{,}938 - 0{,}328) \cdot 10^3}{314 \cdot 380^2} = 4 \cdot 10^{-3} \text{ Ф}.$$

3. Liniya simlaridagi toklar.

$$I_1 = \frac{P_1}{\sqrt{3} \cdot U_{НОМ} \cdot \cos\varphi_1} = \frac{320 \cdot 10^3}{\sqrt{3} \cdot 380 \cdot 0{,}734} = 663{,}17 \text{ A},$$

$$I_2 = \frac{P_1}{\sqrt{3} \cdot U_{НОМ} \cdot \cos\varphi_2} = \frac{320 \cdot 10^3}{\sqrt{3} \cdot 380 \cdot 0{,}95} = 512{,}4 \text{ A}.$$

7. SINXRON GENERATOR

7.1 – masala. СД2 – 85/29 – 10 tipdagi sinxron dvigatelь quyidagi nominal qiymatlarga ega: quvvati P_{nom} = 250 kVt, kuchlanishi U_{nom} =0,38 kV, chastotasi f = 50 Gs, foydali ish koeffitsiyenti η_{nom} = 93,2%, quvvat koeffitsiyenti $\cos\varphi_{\text{nom}}$ = 0,9, rotorining aylanish tezligi n_{nom} = 1000 ayl/min, maksimal yurgizish momentlarining nominal momentga nisbatlari 1,7 va 1,2, yurgazish tokning nominal tokka nisbati 5,5.

Quyidagilar aniqlansin.

1) dvigatelning juft qutblar soni – *p,*
2) dvigatelning tarmoqdan iste'mol qilayotgan quvvati-P_1,
3) dvigatelning yurgizish toki – I_{yu} ,
4) dvigatelning nominal, yurgizish va maksimal aylantiruvchi momentlari,
5) nominal nagruzkadagi quvvat isrofgarchiligi.

Yechilishi:

Dvigatelning juft qutblari soni

$$p = \frac{60 \cdot f}{n_{nom}} = \frac{60 \cdot 50}{1000} = 3.$$

Dvigatelning tarmoqdan iste'mol qilayotgan quvvati

$$P_1 = \frac{P_{nom}}{\eta_{nom}} = \frac{250}{0{,}932} = 268{,}2 \text{ kVt.}$$

Dvigatelning nominal toki

$$I_{nom} = \frac{P_{nom}}{\sqrt{3} \cdot U_{nom} \cdot \eta_{nom} \cdot \cos\varphi_{nom}} = \frac{250}{\sqrt{3}.0{,}38 \cdot 0{,}932 \cdot 0{,}9} = 454{,}5 \text{ A.}$$

Dvigatelning yurgizish toki

$$I_{yu} = 5{,}5 \cdot I_{nom} = 5{,}5 \cdot 454{,}5 \approx 2500 \text{ A.}$$

Nominal moment

$$M_{nom} = 9550 \cdot \frac{P_{nom}}{n_{nom}} = 9550 \cdot \frac{250}{1000} = 2388{,}5 \cdot \quad N \cdot m$$

Yurgizish momenti

$$M_{yu} = 1{,}2 \cdot M_{nom} = 1{,}2 \cdot 2388{,}5 = 2866{,}2\, N \cdot m$$

Maksimal momenti

$$M_{\max} = 1{,}7 M_{nom} = 1{,}7 \cdot 2388{,}5 = 4060{,}5\ N \cdot m$$

Nominal nagruzkadagi quvvat isrofgarchiligi

$$\Delta P = P_1 - P_{nom} = 268{,}2 - 25 = 18{,}2\ \text{kVt.}$$

7.2 - masala. Korxonada o'rnatilgan uch fazali asinxron dvigatellar, kuchlanish U = 380 V va quvvat koeffitsiyenti $\cos\varphi_{o'r}$ =0,8 bo'lganda, iste'mol qilayotgan aktiv quvvatlarning yig'indisi P_{dv} = 350 kVt. Yoritgich nagruzkaning quvvati P_{yor} = 30 kVt. Bundan tashqari umumiy quvvati P_p = 50 kVt bo'lgan qizdirgich pechlar o'rnatilib, korxonaning iste'mol qilayotgan umumiy quvvati o'zgarmay qolishi kerak. Korxonaning quvvat koeffitsiyentini oshirib pechlarni elektr energiya bilan ta'minlash maqsadida, qo'shimcha quvvat olish uchun sinxron kompensator o'rnatish taklif etiladi.

Quyidagilar aniqlansin.

1) qizdirgich pechlar va sinxron kompensator o'rnatilgunga qadar, shuningdek, o'rnatilgandan keyin korxananing quvvat koeffitsiyentini.
2) agar sinxron kompensatordagi aktiv quvvat isrofgarchiligi uning reaktiv quvvatning 5% ini tashkil etsa, kompensatorning to'la quvvatini,
3) quvvatlar uchburchagi qurilsin.

Yechilishi:

Sinxron kompensator va qizdirgich pechlar o'rnatilgunga qadar:

$$P_1 = P_{dv} + P_{yor} = 350 + 30 = 380 \text{ kVt};$$

$$Q_1 = P_{dv} \cdot tg\varphi_{o'r} = 350 \cdot 0{,}748 = 262 \text{ kVAr } (\varphi_{o'r} = 36°50');$$

$$S = \sqrt{P_1^2 + Q_1^2} = \sqrt{380^2 + 262^2} = 462 \text{ kVa}.$$

$$\cos\varphi_1 = \frac{P_1}{S} = \frac{380}{462} = 0{,}823 \qquad (\varphi_1 = 34°35')$$

o'rnatilgandan so'ng

$$P_2 = P_1 + P_{\text{П}} = 380 + 50 = 430 \text{ kVt}$$

$$\cos\varphi_2 = \frac{P_2}{S} = \frac{430}{462} = 0{,}93 \qquad (\varphi_2 = 21°24').$$

Kompensatsiyalanishi kerak bo’lgan reaktiv quvvat

$$Q_к = P_1 tg\varphi_1 - P_2 tg\varphi_2 = 380 \cdot 0{,}69 - 430 \cdot 0{,}392 = 93{,}6 \text{ kVAr.}$$

Kompensatordagi quvvat isrofgarchiligi

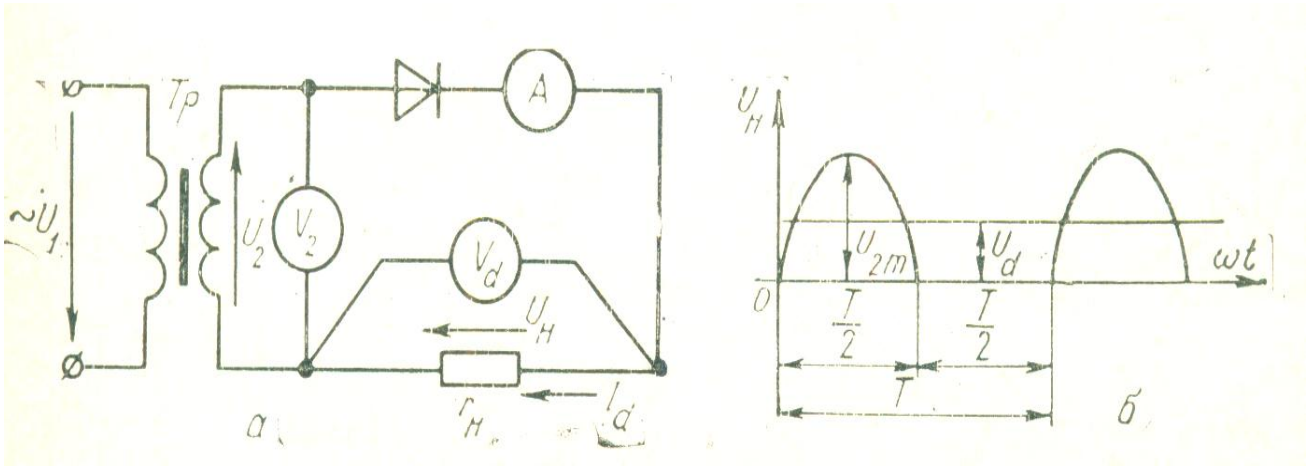
$$P_K = 0{,}05 \cdot Q_K = 0{,}05 \cdot 93{,}6 = 4{,}68 \text{ kVt.}$$

Kompensatorning to’la quvvati

$$S_к = \sqrt{P_к^2 + Q_к} = \sqrt{4{,}68^2 + 93{,}6^2} = 93{,}7 \text{ кВА.}$$

8. O’ZGARUVCHAN TOKNI O’ZGARMAS TOKKA TO’G’RILASH

8.1 – masala. Qarshiligi r_n = 60 Om bo’lgan nagruzka bitta yarim davrli to’g’rilagich va transformator orqali sinusoidal o’zgaruvchan kuchga ulangan (8.1- rasm). Agar U_2 = 120 V bo’lsa, to’g’rilangan tokning o’rtacha qiymati hisoblansin. (ventilning ichki qarshiligi va transformator chulg’amlari qarshiligi xisobga olinmasin.)



8.1-rasm

Yechilishi:

Tokning o’rtacha qiymatini quyidagi formula yordamida aniqlaymiz:

$$I_{o'r} = I_d = \frac{U_d}{r_n},$$

Bu yerda U_d – то’g’rilangan kuchlanishning o’rtacha qiymati. Transformator ikkilamchi kuchlanish sinusoidal bo’lgani uchun $u_2 = U_{2m} \cdot \sin \omega t$, bu yerda ($\psi_{u2} = 0$).

To’la davr uchun to’g’rilangan kuchlanishning o’rtacha qiymati quyidagi formula yordamida aniqlanadi:

$$U_d = U_{o'r} \ \frac{1}{\pi} U_{2m} = \frac{\sqrt{2}}{\pi} U_2 = 0{,}45 U_{2.}$$

Demak ,

$$I_{o'r} = \frac{U_{o'r}}{r_n} = \frac{0{,}45 \cdot 120}{60} = 0{,}9 \text{ A.}$$

8.2 – masala. Ikkita va bitta yarim davrli to'g'rilash sxemasi uchun kuchlanishning pulьsatsiya aniqlansin.

Yechilishi:

O'zgaruvchan kuchlanish effektiv qiymatini pulьsatsiyalanuvchi to'g'rilangan kuchlanish o'rtacha qiymatiga bo'lgan nisbati pulьsatsiyalanish koeffitsiyenti deb ataladi.

To'g'rilangan kuchlanishning effektiv qiymati:

$$U = \sqrt{U_d^2 + U_1^2 + U_2^2 + \cdots\cdots + U_{П}^2},$$

bu yerda $U_1^{\,2} + U_2^{\,2} + \cdots\cdots + U_{П}^{\,2} = U_{П}^2$ - pulьsatsiyalanuvchi kuchlanish effektiv qiymatning kvadrati yoki $U_{\text{П}} = \sqrt{U^2 - U_d^2}$,

Ikkita yarim davrli to'g'rlagich sxemasi uchun kuchlanish effektiv qiymatining kvadrati:

$$U^2 = \left(\frac{U_m}{\sqrt{2}}\right)^2 = \frac{U_m^{\,2}}{2} \ .$$

To'g'rilangan kuchlanish o'rtacha qiymatining kvadrati:

$$U_d^2 = \left(\frac{2 \cdot U_m}{\pi}\right)^2 = \frac{4 \cdot U_m^2}{\pi^2}$$

Pulьsatsiyalanuvchi kuchlanishning effektiv qiymati:

$$U_{\text{П}} = \sqrt{\frac{U_m^2}{2} - \frac{4U_m^2}{\pi^2}} = \frac{U_m}{\pi}\sqrt{\frac{\pi^2 - 8}{2}}$$

Pulьsatsiyalanish koeffitsiyenti:

$$K_{\text{П}} = \frac{U_{\text{П}}}{U_d} = \frac{U_m\sqrt{\pi^2 - 8}}{\sqrt{2} \cdot \pi} \cdot \frac{\pi}{2 \cdot U_m} = \frac{\sqrt{\pi^2 - 8}}{2\sqrt{2}} = 0{,}48$$

yoki $K_{\text{П}}$= 48 % .

Bitta yarim davrli to’g’rilagich sxemasi uchun kuchlanish effektiv qiymatining kvadrati:

$$U^2 = \left(\frac{U_m}{2}\right)^2 = \frac{U_m{}^2}{4}\cdot$$

To’g’rilangan kuchlanish o’rtacha qiymatining kvadrati:

$$U_d^2 = \left(\frac{1}{\pi}U_m\right)^2 = \frac{U_m^2}{\pi^2},$$

Pulsatsiyalanuvchi kuchlanishning effektiv qiymati:

$$U_n = \sqrt{\frac{U_m^2}{2} = \frac{U_m^2}{\pi^2}} = \frac{U_m}{2\pi}\sqrt{\pi^2 - 4},$$

Pulsatsiyalanish koeffitsiyenti:

$$K_{\Pi} = \frac{U_{\Pi}}{U_d} = \frac{U_m\sqrt{\pi^2 - 4}}{2\pi}\cdot\frac{\pi}{U_m} = \frac{\sqrt{\pi^2 - 4}}{2} = 1{,}21 \quad \text{yoki} \quad K_{\Pi} = 121\%.$$

Bitta yarim davrli sxemada pulsatsiyalanish koeffitsiyenti ikkita yarim davrli sxemadagiga nisbatan 2,5 marta kattadir.

9. ELEKTR YURITMALAR

9.1 – masala. 4AH160S4 rusumli asinxron motorning quyidagi ko'rsatkichlari berilgan:

$P_{2H}=18{,}5kVt;\ n_H=1450\,ayl/\min;\ I_{1H}=36{,}5A;\ \eta_H=88\%;\ \cos\varphi_{\text{H}}=0{,}87;\ M_{i.t.}/M_H=2{,}1;$

Elektr yuritmaning sirpanish koeffitsiyenti, o'zgarmas quvvat isrofi aniqlansin.

Yechilishi:

Asinxron motorning nominal va salt yurish rejimi burchak tezliklarini aniqlaymiz:

$$\omega_H=\frac{2\pi n_H}{60}=\frac{2\cdot 3{,}14\cdot 1450}{60}=152\,rad/sek$$

$$\omega_0=\frac{2\pi f_1}{P}=\frac{2\cdot 3{,}14\cdot 50}{2}=157\,rad/sek$$

Asinxron motorning nominal sirpanishi va momenti qiymatlarini aniqlaymi:

$$S_H=\frac{\omega_0-\omega_H}{\omega_0}=\frac{157-152}{157}=0{,}033$$

$$M_H=\frac{P_H}{\omega_H}=\frac{18500}{152}=122\,Nm$$

Asinxron motor mexanik tavsifining ushbu uchastkasini chiziqli deb (9.1.-rasm)

$$M=2M_K\frac{S}{S_K}$$

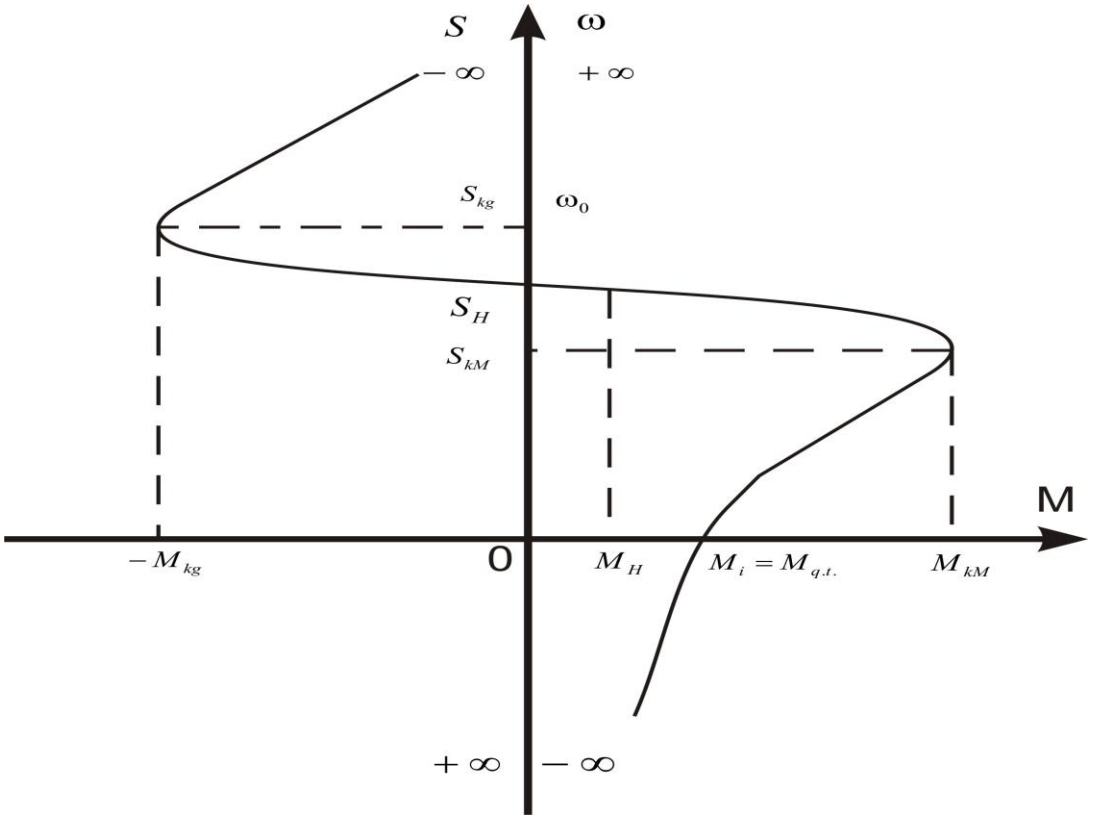
ifodadan

$$M_s=0{,}9M_n=0{,}9\cdot 122=110\,N\cdot m$$

ni aniqlab

$$S_s=\frac{S_n\cdot M_{sun}}{M_n}=0{,}033\cdot 0{,}9=0{,}3$$

ni hisoblab topamiz.



9.1 - rasm. Asinxron motorning mexani tavsifi

Asinxron motorning to'liq o'zgaruvchi quvvat isrofi:

$$\Delta P = M_{sun} \cdot \omega_0 \cdot S_s (1 + \frac{R_1}{R_2}) = 110 \cdot 157 \cdot 0{,}03 \cdot (1 + 0{,}6) = 829\, Vt$$

Asinxron motorning nominal quvvat isrofi:

$$\Delta P = P_H \cdot \frac{1 - \eta_H}{\eta_H} = 18500 \cdot \frac{1 - 0{,}88}{0{,}88} = 2523 Vt$$

$$V_H = M_H \cdot \omega_0 \cdot S_H \cdot (1 + \frac{R_1}{R_2}) = 122 \cdot 157 \cdot 0{,}033 \cdot (1 + 0{,}6) = 1011 Vt$$

Asinxron motorning o'zgarmas quvvat isrofi:

$$K = \Delta P_H - V_H = 2523 - 1011 = 1512 Vt.$$

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