O‘zbekiston Respublikasi oliy va o‘rta maxsus ta'lim vazirligi

O‘zbekiston respublikasi transport vazirligi

Toshkent davlat transport universiteti

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ELEKTR MASHINALAR VA ELEKTR YURITMA ASOSLARI

5310600-Yer usti transporti tizimlari va ularning ekspluatatsiyasi (elektr transporti) ta’lim yo‘nalishi 3-bosqich bakalavriat talabalari va professor-o‘qituvchilar uchun amaliy mashg‘ulotlarni bajarishga doir
uslubiy qo‘llanma

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Elektr mashinalar va elektr yuritma asoslari. Uslubiy qo‘llanma. **U.T.Berdiev, A.M.Kurbanov, F.F.Xasanov.** TDTU, T.: 2021 y., 60 bet.

“Elektr mashinalar va elektr yuritma asoslari” fani bo‘yicha tuzilgan ushbu uslubiy qo‘llanma 5310600 - Yer usti transporti tizimlari va ularning ekspluatatsiyasi (elektr transporti) ta’lim yo‘nalishida tahsil olayotgan 3-bosqich bakalavriat talabalari va professor-o‘qituvchilar uchun amaliy mashg‘ulotlarda masalalar yechishga mo‘ljallangan.

Universitetning Ilmiy-uslubiy kengashi tomonidan nashrga tavsiya etilgan.

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Kirish

Hozirgi kunda elektromexanik qurilmalardan elektr mashinalari bir necha kVt quvvatga mo‘ljallab tayyorlanishi hamda ularni osongina avtomatik boshqarish imkoni borligi sababli sanoat, transporti va qishloq xo‘jaligini elektrlashtirishda asosiy ish mashinasi sifatida ishlatiladi. Elektr mashinalarining asosiy afzalliklaridan biri ularning generator, motor hamda elektromagnit tormoz sifatida ishlash imkonining mavjudligi hisoblanadi. Bunday mashinalar o‘zgaruvchan tokni o‘zgarmas tokka, yoki past kuchlanishli o‘zgaruvchan tokni yuqori kuchlanishli o‘zgaruvchan tokka o‘zgartirib beruvchi o‘zgartgichlar, ya’ni transformatorlar sifatida ham qo‘llanadi.

Amaliy hisoblarni bajarishdan maqsad, elektr mashinalarining tavsiflarini amaliy yo‘l bilan hisoblab, nazariy bilimlarni mustahkamlash, ular orqali olingan tavsiflar bilan taqqoslash va xulosa chiqarishdan iborat. Respublikamizda sanoat va transport tizimlarida elektromexanik qurilmalardan to‘g‘ri foydalanish dolzarb muammolardan hisoblanadi. Buning uchun elektromexanik qurilmalarni to’g‘ri hisoblash va tanlash lozim bo‘ladi. Ushbu qo‘llanma talabalarga yuqoridagi masalalarni hal qilishda muhim dastur hisoblanadi.

Uslubiy qo‘llanma 5521300-Elektrotexnika, elektr mashinalar va elektr yuritma asoslari va elektrotexnologiya (Elektr transporti), 5521100-Yer usti transport tizimlari (Elektr harakat tarkibi) va 5520200-Elektr energetika (Temir yo‘l transporti) ta’lim yo‘nalishlari talabalari uchun mo‘ljallangan.

Transformatorlar

(Asosiy kattaliklar va ularni aniqlash tenglamalari)

1.1. Transformatorni ekspluatatsiyalash rejimlari

Transformatorning to‘la quvvati quyidagicha topiladi

$$S = m \cdot U \cdot I, \tag{1.1}$$

bu yerda: m-fazalar soni; U-kuchlanish, I- tok.

To‘la quvvatning reaktiv tashkil etuvchisi

$$Q = m \cdot U \cdot I \cdot \sin\varphi, \tag{1.2}$$

bu yerda: φ-tok va kuchlanish orasidagi burchak.

To‘la quvvatning aktiv tashkil etuvchisi

$$P = m \cdot U \cdot I \cdot \cos\varphi. \tag{1.3}$$

Malumki magnit oqimi F birlamchi va ikkilamchi chulg‘amlarda EYUK E_1 va E_2 larni hosil qiladi:

$$E_1 = 4{,}44 \cdot f \cdot \omega_1 \cdot \Phi$$

$$E_2 = 4{,}44 \cdot f \cdot \omega_2 \cdot \Phi, \tag{1.4}$$

bu yerda: f-tarmoq chastotasi; ω_1, ω_2-tegishlicha birlamchi va ikkilamchi cho‘lg‘amlarning o‘ramlar soni; F-magnit oqimning maksimal qiymati.

Transformatorning transformatsiyalash koeffitsiyenti

$$k_T = \frac{E_1}{E_2} = \frac{\omega_1}{\omega_2} = \frac{U_1}{U_2} = \frac{I_1}{I_2}. \tag{1.5}$$

Birlamchi va ikkilamchi chulg‘amdagi MYUK lar

$$F_2 = I_1\omega_1;\ F_2 = I_2\omega_2 \tag{1.6}$$

Ikkilamchi chulg‘am parametlarini birlamchi chulg‘am parametlariga keltirilgan qiymatlari:

Keltirilgan tok

$$I' = I_2 / k_T \tag{1.7}$$

Keltirilgan kuchlanish

$$U'_2 = k_T \cdot U_2; \tag{1.8}$$

Keltirilgan aktiv va induktiv qarshiliklar

$$R'_2 = k^2_T \cdot R_2;\ x'_2 = k^2_T \cdot x_2. \tag{1.9}$$

1.2. Transformator kuchlanishlarning muvozanat tenglamasi

Salt ishlayotgan transformator kuchlanishlarining muvozanat tenglamasi:

$$\dot{U} = -\dot{E} + \dot{I}_x R_1 + j\dot{I}_1 x = -\dot{E} + \dot{I}_1(R_1 + j x_1)$$

$$-\dot{E} = \dot{U}_2 - \dot{I}_2 R'_2 - j\dot{I}_2 x'_2 = \dot{U}_2 - \dot{I}_2(R'_2 + j x_2) \qquad (1.10)$$

$$\dot{I}_1 + \dot{I}'_2 = \dot{I}_x$$

Transformatorning quvvat koeffitsiyenti

$$\cos\varphi = P/\sqrt{3}UI\,. \qquad (1.11)$$

Qisqa tutashuv kuchlanishi

$$U_{KT} = \frac{U_{KTH}}{U_{1H}} \cdot 100\,. \qquad (1.12)$$

Qisqa tutashuv kuchlanishining absolyut qiymati

$$U_{KT} = \sqrt{U^2{}_a + U^2{}_p}\,. \qquad (1.13)$$

Qisqa tutashuv rejimidagi quvvat koeffitsiyenti

$$\cos\varphi_{KT} = \frac{R}{z} = \frac{R}{\sqrt{R^2 + x^2}} = \frac{U_a}{U_p} = \frac{U_a}{\sqrt{U^2{}_a + U^2{}_p}}\,. \qquad (1.14)$$

1.3. Transformatorning FIK va quvvat isroflari

Transformatorlarda asosan chulg‘amlardagi quvvat isrofi $P_{÷}$ va po‘latdagi isrof $P_{ï}$ lar bo‘ladi.

Po‘latdagi isrof

$$P_n \approx k_{tr} P_{1.0} (B_m)^2 m_n\,, \qquad (1.15)$$

bu yerda: $P_{1.0}$-induksiya 1Tl bo‘lgan 1 kg po‘latdagi solishtirma quvvat isrofi; m_n-magnit o‘tkazgichning konstruksiyasiga va unga ishlov berishga bog‘liq bo‘lgan doimiy. Bu doimiyning o‘rtacha qiymati $k_{tr} = 1{,}2$ ga teng.

Cho‘lg’amlardagi elektr isroflar

$$P_ч = m_1 I^2{}_{1ф} R_1 + m_2 I^2{}_{2ф} R_2\,, \qquad (1.16)$$

bu yerda: m_1, m_2- birlamchi va ikkilamchi chulg‘amlarining fazalar soni; $I_{1ô}, I_{2ô}$-tegishlicha chulg‘amlarning faza toklari; R_1, R_2-tegishlicha chulg‘amlarning aktiv qarshiligi.

$$\eta = \frac{P_2}{P_2 + P_n + P_r} \cdot 100 = \frac{P_1 - P_n - P_r}{P_1} \cdot 100\,, \qquad (1.17)$$

yoki to‘la quvvat orqali FIK ni yozsak, u holda

$$\eta = \frac{S_2 \cos\varphi_2}{S_2 \cos\varphi_2 + P_n + P_r} \cdot 100 \qquad (1.18)$$

Yuqoridagi tenglamaning surati va maxrajini $S_2 \cos\varphi_2$ ga bo‘lib, hamda

$P_ч = P_{чн}\left(\frac{S_2}{S_H}\right) = P_{чн}x^2$ ni kiritib

$$\eta = \frac{1}{1+\frac{P_n + P_ч}{S_2\cos\varphi_2}}\cdot 100 = \frac{1}{1+\frac{P_n + x^2 P_{ч.н}}{S_2\cos\varphi_2}}\cdot 100 \qquad (1.19)$$

1.4. Transformatorning ikkilamchi chulg‘amdagi kuchlanishini o‘zgartirish

Agarda transformatorning birlamchi chulg‘amidagi kuchlanish $U_1 = const$ deb hisoblasak, u holda ikkilamchi chulg‘amning kuchlanish U_2 yuklama xarakteriga qarab o‘zgaradi.

Kuchlanish pasayishi

$$\Delta U = U_1 - U'_2 = IR\cos\varphi_2 + Ix\sin\varphi_2 = I(R\cos\varphi_2 + x\sin\varphi). \qquad (1.20)$$

(23) dan U'_2 ni topsak

$$U'_2 = U_1 - I(R\cos\varphi_2 + x\sin\varphi_2). \qquad (1.21)$$

(24) dan ikkinchi tashkil etuvchi U_{1H} ga bo‘lib, quyidagiga ega bo‘lamiz

$$U_{KT} = U_a\cos\varphi_2 + U_p\sin\varphi_2. \qquad (1.22)$$

(25) tenglama $\cos\varphi_2 \le 0{,}04$ da juda yaxshi natija beradi, agarda $\cos\varphi_2 > 0{,}05$ bo‘lsa, u holda quyidagi formulani qo‘llash lozim

$$U_{KT} = (U_a\cos\varphi_2 + U_p\sin\varphi_2) + \frac{1}{200}(U_p\cos\varphi_2 - U_a\sin\varphi_2). \qquad (1.23)$$

1.5. Namunaviy masalalar yechish

1.5.1. Quvvati $S_H = 100$ kVt va kuchlanishlari $U_1/U_2 = 5000/400$ V bo‘lgan bir fazali magnit o‘tkazgichi bronli bo‘lgan transformator berilgan. Bitta o‘ramga tasir etuvchi kuchlanish $U_{ў} = 4{,}26$ V, chastota f =50 Gs bo‘lsa, transformatorning ikkala chulg‘amlarining o‘ramlari soni ω_1 va ω_2 lar aniqlansin; tok zichligi $j = 3{,}2\ A/мм^2$ bo‘lganda chulg‘am simlarining kesim yuzalari A_1 va A_2 lar aniqlansin, induksiya $B_m = 1{,}4$ Tl bo‘lgan magnit o‘tkazgichning ko‘ndalang kesim yuzasi aniqlansin.

Yechish:

$$\omega_1 = \frac{U_1}{U_y} = \frac{5000}{4{,}26} = 1173$$

$$\omega_2 = \frac{U_2}{U_y} = \frac{400}{4{,}26} = 94$$

Nominal toklar

$$I_{1H} = \frac{S_H}{U_1} = \frac{100 \cdot 10^3}{5 \cdot 10^3} = 20\,A$$

$$I_{2H} = \frac{S_H}{U_2} = \frac{100 \cdot 10^3}{0{,}4 \cdot 10^3} = 250\,A$$

Chulg‘am simlarining kesim yuzasi

$$A_1 = \frac{I_{1H}}{j} = \frac{20}{3{,}2} = 6{,}25\,мм^2$$

$$A_1 = \frac{I_{1H}}{j} = \frac{250}{3{,}2} = 78{,}12\,мм^2$$

Magnit oqim

$$\Phi = \frac{U_y}{B_m} = \frac{0{,}01918}{1{,}4} = 0{,}0137 \quad \text{Vb}$$

1.5.2. 1.5.1.-masalada keltirilgan transformatorning salt ishlash va qisqa tutashuv tajribasi o‘tkazilgan. Tajribadan olingan natijalar:

Salt ishlash quvvat isrofi $P_0 = 900$ Vb

Salt ishlash kuchlanishi $U_0 = 320$ V

Salt ishlash toki $I_0 = 16{,}5$ A

Qisqa tutashuv quvvat isrofi $P_{KT} = 1250$ Vt

Qisqa tutashuv kuchlanishi $U_{KT} = 240$ V

Qisqa tutashuv toki $I_{KT} = 13$ A.

Transformatorning po‘latidagi quvvat isrofi P_n, chulg‘amdagi quvvat isrofi $P_ч$, salt ishlashdagi quvvat isrofi $\cos\varphi_0$, qisqa tutashuvdagi quvvat koeffitsiyenti $\cos\varphi_{KT}$ va qisqa tutashuv kuchlanishining foizdagi qiymati topilsin.

Yechish. Po‘latdagi isrof

$$P_n = \left(\frac{U_H}{U_0}\right)^2 P_0 = \left(\frac{400}{320}\right)^2 \cdot 900 = 1406 \text{ Vt.}$$

Chulg‘amdagi quvvat isrofi

$$P = \left(\frac{I_H}{I_{KT}}\right)^2 P_{KT} = \left(\frac{20}{13}\right)^2 \cdot 1250 = 2956 \text{ Vt.}$$

Quvvat koeffitsiyentlari

$$\cos\varphi_0 = \frac{P_0}{U_0 I_0} = \frac{900}{320 \cdot 16{,}5} = 0{,}1704$$

$$\cos\varphi_{K/T} = \frac{P_{KT}}{U_{KT} I_{KT0}} = \frac{1250}{240 \cdot 13} 0{,}4006$$

Nominal tokdagi qisqa tutashuv kuchlanishi

$$U_{K.T.H} = U_H \frac{I_H}{I_{KT}} = 240 \cdot \frac{20}{13} = 369{,}2B$$

$$U_{K.T} = \frac{U_H}{U_1} \cdot 100 = \frac{369{,}2}{5000} \cdot 100 = 7{,}38\%$$

bu yerda: $U_1 = 5000$ V (2.5.1-masalaga qarang).

1.5.3. 1.5.1-masalada keltirilgan transformatorning past ku chlanish chulg‘ami to‘la qarshilik $z_{юк} = 1{,}2 + j1{,}5$ Om yuklama bilan yuklangan.

a) Transformatorning FIK o‘sha yuklama uchun aniqlansin.
b) Qarshilik $R_{.юк} = 1{,}2$ Om transformatorni naminal tok bilan yuklagan vaqtdagi induktiv qarshilik $x_{юк1\min}$ va quvvat koeffitsiyenti $\cos\varphi_{\max}$ topilsin.
c) b) punktdagi asosan FIK η , aniqlansin.
d) Ikkala yuklama uchun transformatorning ikkilamchi chulg‘amidagi kuchlanish topilsin.

Yechish. a) Berilgan yuklama uchun transformatorning toki:

$$\dot{I}_{юк} = \frac{\dot{U}_2}{z_{юк}} = \frac{400}{1{,}2 + j1{,}5} = 130 - j162{,}6A$$

$$I_{юк} = \sqrt{130^2 + 162{,}6^2} = 208A$$

$$\cos\varphi = \frac{R_{юк}}{z_{юк}} = \frac{1{,}2}{\sqrt{1{,}2^2 + 1{,}5^2}} = 0{,}625$$

Iste`mol qilinayotgan va chulg‘amlardagi quvvat isrofi

$P_2 = I^2{}_{юк} R_{юк} = 208^2 \cdot 1{,}2 = 51920Bt = 51{,}92kBt.$

$$P'_2 = P_H \left(\frac{I_{юк}}{I_{2H}} \right) = 2056 \left(\frac{208}{250} \right)^2 = 2046Bt = 2{,}046kBt.$$

bu yerda: $P_{чH} = 2956B; I_{2H} = 250A$ (2.5.1. va 2.5.2-qaralsin).

Berilgan yuklamadagi FIK

$$\eta = \frac{P_2}{P_2 + P_n + P_r} \cdot 100 = \frac{51{,}92}{51{,}92 + 1{,}406 + 2{,}046} \cdot 100 = 93{,}72\%$$

b) Yuklamaning minumum reaktiv qarshiligi

$I_{2H} = \frac{U_2}{z^*_{юк}}$, bundan $z_{юк}^* = \frac{U_2}{I_{2H}} = \frac{400}{250} = 1{,}6$ Om

$x_{юк.max} = \sqrt{z'^2_{юк} - R^2_{юк}} = \sqrt{2{,}56 - 1{,}44} = 1{,}061$ Om

Naminal tokdagi quvvat koeffitsiyenti

$$\cos\varphi_{\max} = \frac{R_{юк}}{z^*_{юк}} = \frac{1{,}2}{1{,}6} = 0{,}75.$$

c) Nominal tokdagi FIK

$$\eta_1 = \frac{P^*_2}{P^*_2 + P_n + P_r} \cdot 100 = 94{,}5\%,$$

bu yerda: $P^*_2 = I^2_{2H}\ R = 250^2 \cdot 1{,}2 = 75000Bt = 75kBt.$

d) Ikkilamchi chulg‘amdagi kuchlanishni xisoblashda ulchovchi shaxobchalarni xisobga olmaymiz

$U'_2 = U_1 - I'_{юк}(R\cos\varphi + x\sin\varphi)$.

Elektr zanjirning qisqa tutashuv rejimdagi to‘la qarshiligi

$$z = \frac{U_{KT}}{I_{1H}} = \frac{369{,}2}{20} = 18{,}46Om$$

$$R = z\cos\varphi_{KT} = 18{,}46 \cdot 0{,}4006 = 7{,}395Om;$$

$$x = z\sin\varphi_{KT} = 18{,}46 \cdot 0{,}9164 = 16{,}92Om;$$

$$U'_2 = 5000 - \frac{208}{12{,}5}(7{,}395 \cdot 0{,}625 + 16{,}92 \cdot 0{,}7804) = 4704B$$

$$U_{21} = \frac{U_{K.T.1}}{n} = \frac{4704}{12{,}5} = 376{,}3B;$$

$$U'_{22} = 5000 - \frac{250}{12{,}5}(7{,}395 \cdot 0{,}74 + 16{,}92 \cdot 0{,}6613) = 4665B.$$

$$U_{22} = \frac{U'_{KT2}}{n} = \frac{4665}{12{,}5} = 373{,}2B$$

1.5.4. Bir fazali transformatorning quvvati $S_H = 16$ kVA, kuchlanishlari $U = 380/110$ V, qisqa tutashuv kuchlanishi 8,5%. Naminal tok va nominal kuchlanishda chulg‘amdagi quvvat isrofi $P_{чш} = 0{,}048 \cdot S_н$, po‘latdagi quvvat isrofi $P_n = 0{,}036 \cdot S_н$. Transformatorning magnit o‘tkazgichi qalinligi 0,5 mm bo‘lgan plastinkalardan yig‘ilib, solishtirma quvvat isrofi $P_{1.0} = 2{,}3$ Vt/kg.

Quyidagilar aniqlansin:

a) Agar sterjin va yarmoda induksiyaning maksimal qiymati 1,4 Tl bo‘lsa magnit o‘tkazgichning massasi m_n;

b) Agar po‘lat to‘ldirish koeffitsiyenti $\kappa_з = 0{,}94$ va past kuchlanish

chulg‘amining o‘ramlar soni $\omega_2 = 31$ bo‘lsa, sterjenning ko‘ndalang kesim yuzasi;

c) Quvvat koeffitsentlari $\cos\varphi_2 = 1 : 0{,}8$ va0,6 uchun aktiv induktiv yuklamada maksimal FIK lari $\eta_{\max_{1,0}}$;$\eta_{\max 0{,}8}$ va $\eta_{\max_{0,6}}$;

d) Qisqa tutashuv quvvat koeffitsiyenti $\cos\varphi_{KT}$, aktivv R va induktiv x qarshiliklar;

e) Qisqa tutashuv rejimida 75% nominal tok bilan yuklangan vaqtdagi sig‘im xarakteriga ega bo‘lgan to‘la qarshilik $z_{юк}$ va uning siljish burchagi $\varphi_{юк}$ lar aniqlansin.

Yechish. a) Magnit o‘tkazgichning massasini hisoblash mumkin, agarda po‘latdagi to‘la va solishtirma isroflar aniq bo‘lsa.

Berilgan induksiyada solishtirma isrof

$P = P_{1,0} B^2{}_m = 2{,}3 \cdot 1{,}48^2 = 5{,}037$ Vt/kg

Po‘latdagi to‘la isrof

$P_n = 0{,}036 \cdot S_H = 0{,}036 \cdot 16000 = 576$ Vt

$$T_n = \frac{P_n}{P} = \frac{576}{5{,}037} = 114 \text{ kg.}$$

b) sterjenning ko‘ndalang kesim yuzasini hisoblash uchun, magnit oqimini bitta o‘ramdagi kuchlanishi orqali topish mumkin:

$$U_y = \frac{U_2}{\omega_2} = \frac{110}{31} = 3{,}548 B \ / y$$

$U_y = 4{,}44 \phi f, bundan$

$$\phi \quad \frac{U_y}{4{,}44 f} = \frac{3{,}548}{4{,}44 \cdot 50} = 0{,}01589 Вб$$

$$A_n = \frac{\Phi}{B} = \frac{0{,}01589}{1{,}48} = 0{,}0107 м^2 = 107 sm^2.$$

$$A_{on} = \frac{A_n}{K_з} = \frac{107}{0{,}94} = 113{,}8 sm^2.$$

c) Transformatorning aktiv qarshiligini nominal elektr isroflari orqali topish mumkin:

$$R = \frac{P_{r.н}}{I^2{}_{1н}} = \frac{0{,}048 \cdot S_H}{\left(\frac{S_H}{U_1}\right)^2} = \frac{0{,}048 \cdot 16000}{\left(\frac{16000}{380}\right)^2} = 0{,}4334 \text{ Om.}$$

$P_n = P_r = I^2 R$, bundan

$$I = \sqrt{\frac{P_n}{R}} = \sqrt{\frac{576}{0{,}4334}} = 36{,}4A.$$

$$n = \frac{U_1}{U_2} = \frac{380}{110} = 3{,}454;$$

$$\eta_{\max 1,0} = \frac{U_2 nI\cos\varphi}{U_2 nI\cos\varphi + 2P_n}\cdot 100 = \frac{110\cdot 3{,}454\cdot 36{,}4\cdot 1}{110\cdot 3{,}454\cdot 36{,}4\cdot 1 + 2\cdot 576}\cdot 100 = 92{,}31\%;$$

$$\eta_{\max 0,8} = \frac{U_2 nI\cos\varphi}{U_2 nI\cos\varphi + 2P_n}\cdot 100 = \frac{110\cdot 3{,}454\cdot 36{,}4\cdot 0{,}8}{110\cdot 3{,}454\cdot 36{,}4\cdot 0{,}8 + 2\cdot 576}\cdot 100 = 90{,}56\%;$$

$$\eta_{\max 1,0} = \frac{U_2 nI\cos\varphi}{U_2 nI\cos\varphi + 2P_n}\cdot 100 = \frac{110\cdot 3{,}454\cdot 36{,}4\cdot 0{,}6}{110\cdot 3{,}454\cdot 36{,}4\cdot 0{,}6 + 2\cdot 576}\cdot 100 = 87{,}8\%.$$

d) Qisqa tutashuv rejimidagi elektr zanjirining to‘la qarshiligi

$$z = \frac{U_{KT}}{I_{1H}} = \frac{U_{KT}U_1/100}{S_H/U_1} = \frac{8{,}5\cdot 380/100}{16000/380} = 0{,}7672 \text{ Om};$$

$$\cos\varphi_{KT} = R/z = 0{,}4334/0{,}7672 = 0{,}5649.$$

$$x = \sqrt{z^2 - R^2} = \sqrt{0{,}7672^2 - 0{,}4334^2} = 0{,}632 \text{ Om}.$$

e) Ikkilamchi chulg‘amdagi kuchlanish

$U'_2 = U_1 - I_1(R\cos\varphi_{юк} + x\sin\varphi_{юк})$.

$U'_2 = U_1$ shartning bajarish uchun $I_1(R\cos\varphi_{юк} + x\sin\varphi_{юк}) = 0$ bo‘lishi kerak.

Yuklama sig‘im xarakterida, yani $\varphi_{юк} < 0$ bo‘lganligi sababli $I_1(R\cos\varphi_{юк} - x\sin\varphi_{юк}) = 0$, bundan $R\cos\varphi_{юк} = x\sin\varphi_{юк}$;

$$\frac{R}{x} = \frac{\sin\varphi_{юк}}{\cos\varphi_{юк}} = tg\varphi_{юк} = \frac{0{,}4334}{0{,}632} = 0{,}6857.$$

$$\varphi_{юк} = arctg\,0{,}6857 = 34{,}35^0.$$

To‘la yuklama qarshilik moduli

$$z_{юк} = \frac{U_2}{0{,}75I_{2H}} = \frac{110}{0{,}75\cdot 16000/110} = 1{,}01 \text{ Om}$$

$$R_{юк} = z_{юк}\cos\varphi_{юк} = 1{,}01\cdot 0{,}834 \text{ Om}$$

$$x_{юк} = z_{юк}\sin\varphi_{юк} = 1{,}01\cdot 0{,}5642 = 0{,}5698 \text{ Om}$$

$$z_{юк} = R_{юк} - jx_{юк} = 0{,}834 - j0{,}5698 \text{ Om}.$$

1.5.5. Ulanish sxemasi va guruhi $\Delta/Y-11$ bo‘lgan uch fazali transformatorning nominal quvvati $S_н = 40$ kVt, nominal kuchlanishi $U_1/U_2 = 10/0{,}4$ kV, salt ishlash toki $I_0 = 0{,}04\cdot I_i$ qisqa tutashuv quvvati isrofi $P_{KT} = 1{,}1$ kVt, qisqa tutashuv kuchlanishi $U_{KT} = 4{,}5\%$, sterjendagi induksiya $B_m = 1{,}67$ Tl.

Quyidagi topilsin:

a) salt ishlash va qisqa tutashuv rejimidagi quvvat koeffitsiyentlari, yani $\cos\varphi_0$ va $\cos\varphi_{KT}$;
b) chulg‘amning aktev R va induktiv x qarshiliklari;
c) agarda po‘lat sterjenning kesim yuzasi $A_n = 654 sm^2$ bo‘lsa, bitta o‘ramdagi kuchlanish $U_{ў}$;
d) chulg‘amdagi o‘ramlar soni ω_1 va ω_2;
e) agarda o‘ramnmng o‘rtacha uzunligi $l_1 = 0{,}576$ m, o‘tkazgichning (simning) kesim yuzasi $A_1 = 0{,}503 мм^2$, solishtirma qarshilik $\rho = 0{,}024$ mkOmm bo‘lsa, birlamchi chulg‘amning aktiv qarshiligi R_1;
f) transformatorning ikkala chulg‘amlarining tok zichliklari bir xil bo‘lsa, ikkilamchi chulg‘amning simini kesim yuzasi A_2 aniqlansin.

Yechish. Nominal toklar

$$I_{1H} = S_H / \sqrt{3} U_1 = 40 \cdot 10^3 / \sqrt{3} \cdot 10^4 = 2{,}312 A$$

$$I_{1H.Ф} = I_{1H} / \sqrt{3} = 2{,}312 / \sqrt{3} = 1{,}336 A$$

$$I_{2H} = S_H / \sqrt{3} U_2 = 40 \cdot 10^3 / \sqrt{3} \cdot 400 = 57{,}8 A.$$

Quvvat koeffitsiyentlari

$$\cos\varphi_0 = \frac{P_0}{\sqrt{3} I_0 U_0} = \frac{195}{\sqrt{3} \cdot 0{,}04 \cdot 57{,}8 \cdot 400} = 0{,}1218.$$

$$U_{KTH} = \frac{U_H U_1}{100} = \frac{4{,}5 \cdot 10^4}{100} 450 B$$

$$\cos\varphi_{KT} = \frac{P_{KT}}{\sqrt{3} I_{KT} U_{KT}} = \frac{1100}{\sqrt{3} \cdot 450 \cdot 2{,}312} = 0{,}6111.$$

b) aktiv qarshilikni qisqa tutashuv quvvat isrofi orqali xisoblash mumkin

$$P_{KT} = \frac{P}{3 I^2_{1H.Ф}} = \frac{1100}{3 \cdot 1{,}336^2} = 205{,}4 \text{ Om}$$

$tg\varphi_{KT} = \frac{x}{R}$, bundan

$$x = R tg\varphi_{KT} = 205{,}4 \cdot 1{,}294 = 265{,}8 \text{ Om}$$

$$\varphi_{KT} = \arccos 0{,}6111 = 52{,}3^0$$

c,d) o‘ramdagi kuchlanish va chulg‘amlardagi o‘ramlar soni

$$U_y = 4{,}44 f B_m A_n = 4{,}44 \cdot 50 \cdot 1{,}67 \cdot 65{,}4 \cdot 10^{-4} = 2{,}425 B / y$$

$$\omega_1 = U_1 / U_y = 10 \cdot 10^3 / 2{,}425 = 4124$$

$$\omega_2 = U_2 / \sqrt{3} U_y = 400 / \sqrt{3} \cdot 2{,}425 = 95{,}3 = 95$$

e) birlamchi chulg‘am fazasining aktiv qarshiligi

$$R_1 = \rho_{20} \omega_1 l_1 / A_1 = 0{,}024 \cdot 4124 \cdot 0{,}567 / 0{,}503 = 111{,}6 \text{ Om.}$$

f.j) simning ko‘ndalang kesim yuzasi va past kuchlanish chulg‘amining aktiv qarshiligi

$A_2 = I_{2H} / j = I_{2H} /(I_{2H} / A_1) = A_1 I_{2H} / I_{1H.\phi} = 0{,}503 \cdot 57{,}8 / 1{,}336 = 21{,}76\ мм^2$

$R'_2 = R - R_1 = 205{,}4 - 111{,}6 = 93{,}8\ Ом$

$R'_2 = n^2 R_2$, *бунда*

$$R_2 = R'_2 / n^2 = R'_2(\omega_1 / \omega_2)^2 = \frac{93{,}8}{(4124/95)^2} = 0{,}05009$$

1.5.6. Uch fazali transformatorning nominal quvvati ulanishi va guruhi $\Delta/Y-5$; qisqa tutashuv kuchlanishning qiymati U_{KT} 4,8%, aktiv tashkel etuvchisi $U_a = 1{,}8\%$. Transformatorning ikkilamchi chulg‘ami quvvat koeffitsiyenti $\cos\varphi = 0{,}9$ bo‘lgan induktiv yuklama bilan $1{,}2 I_{2H}$ yuklangan.

Quyidagilar topilsin:

a) o‘ramdagi kuchlanish $U_y = 6{,}8\ B/y$ bo‘lgan birlamchi va ikkilamchi chulg‘amlarning o‘ramlar soni ω_1 va ω_2 lar;

b) $f = 50$ Gs da magnit oqimining maksimal qiymati F;

c) nominal toklar I_{1H}, I_{2H} va tansformatsiyalash koeffitsiyenti;

d) po‘latdagi isrof $P_n = 0{,}026 \cdot S_H$ va R_1, R_2 (bunda R_1, R'_2);

e) qisqa tutashuv rejimida chulg‘amlardagi nominal quvvat isrofi P_r va quvvat koeffitsiyenti $\cos\varphi_{KT}$.

Yechish. a.b) o‘ramlar soni va maksimal magnit oqimi

$\omega_1 = U_1 / U_y = 5000 / 6{,}8 = 735;$

$\omega_2 = U_2 / \sqrt{3} U_y = 1000 / \sqrt{3} \cdot 6{,}8 = 85;$

$\Phi = U_y / 4{,}44 f = 6{,}8 / 4{,}44 \cdot 50 = 0{,}03063$ Vb.

c) nominal toklar va transformatsiyalash koeffitsiyenti

$I_{1H} = S_H / \sqrt{3} U_1 = 300 \cdot 10^3 / \sqrt{3} \cdot 5 \cdot 10^3 = 34{,}68 A$

$I_{1H.\Phi} = I_{1H} / \sqrt{3} = 34{,}68 / \sqrt{3} = 20{,}04 A$

$I_{2H} = S_H / \sqrt{3} U_2 = 300 \cdot 10^3 / \sqrt{3} \cdot 10^3 = 173{,}4 A$

$n = \omega_1 / \omega_2 = 735 / 85 = 8{,}65.$

d) qisqa tutashuv kuchlanishining aktiv tashkel etuvchisi U_a orqali yig‘indi aktiv qarshilikni topamiz

$U_a = I_{1H.\Phi} R / U_1 \cdot 100, bundan$

$R = U_1 U_a / I_{1H.\Phi} \cdot 100 = 5000 \cdot 1{,}8 / 20{,}04 \cdot 100 = 4{,}491\ Омю$

$1{,}2 \cdot I_{1H.\Phi}$

yuklama uchun chulg‘amdagi quvvat isrofi va FIK.

$P_1 = 3(1{,}2 \cdot I_{1H.\Phi})^2 R_1 = 3(1{,}2 \cdot 20{,}04)^2 \cdot 4{,}491 = 7{,}791$ kVt;

$$\eta = \frac{\sqrt{3}U_2 1{,}2 I_{2H}\cos\varphi}{\sqrt{3}U_2 \cdot 1{,}2 I_{2H}\cos\varphi + P_r + P_n}\cdot 100 = \frac{\sqrt{3}\cdot 1000\cdot 1{,}2\cdot 173{,}4\cdot 0{,}9}{\sqrt{3}\cdot 1000\cdot 1{,}2\cdot 173{,}4\cdot 0{,}9 + 7{,}791 + 0{,}026\cdot 300\cdot 10^3}\cdot 100 = 95{,}4\%$$

$R_1 = R'_2$, bo‘lgani uchun

$R'_2 = R_1 = R/2 = 4{,}491/2 = 2{,}25$ Om

$R_2 = R'_2/n^2 = 2{,}25/8{,}65^2 = 0{,}03$ Om.

e) nominal yuklama uchun chulg‘amdagi quvvat isrofi va qisqa tutashuv rejimidagi quvvat koeffitsiyenti $\cos\varphi_{KT}$

$R_{r.H} = 3I^2_{1H.\Phi}R = 3\cdot 20{,}04^2\cdot 4{,}491 = 5410Bt = 5{,}49kBt.$

$$\cos\varphi_{KT} = \frac{R}{z} = \frac{R}{U_{K.TH}/I_{KT}} = \frac{RI_{1H.\Phi}}{U_{KT}U_1/100} = \frac{4{,}491\cdot 20{,}04}{4{,}8\cdot 5000/100} = 0{,}375.$$

$x = \sqrt{z^2 - R^2} = \sqrt{11{,}47^2 - 4{,}491^2} = 11{,}1$

bu yerda:

$$z = U_{KT}/I_{1H.\Phi} = \frac{(4{,}8\cdot 5000/100)}{20{,}04} = 11{,}47 \text{ Om.}$$

1.5.7. Uch fazali transformatorning to‘la quvvati $S_н = 63$ kVt, kuchlanishlari $U_1/U_2 = 21/0{,}4$ kV; salt ishlash toki $I_0 = 0{,}035\cdot I_í$, salt ishlash quvvat isrofi $P_0 = 0{,}29$ kVt, qisqa tutashuv rejimidagi isrof $P_{r.н} = 1{,}65$ kVt, qisqa tutashuv kuchlanishi $U_{KT}4{,}5\%$, ulanish va guruhi $Y/Z-11$.

Quyidagilar topilsin.

a) salt ishlash va qisqa tutashuv rejimlaridagi quvvat koeffitsiyentlari $\cos\varphi_0$, $\cos\varphi_{KT}$;

b) yig‘indi aktiv R va induktiv x qarshiliklar;

c) v) nominal yuklamada FIK lar η_1 va $\eta_{0,8}$, $\cos\varphi = 1$ va $\cos\varphi = 0{,}8$ uchun;

d) ikkilamchi chulg‘am uchun aktiv quvvat (FIK η, $\cos\varphi = 0{,}8$ da maksimum bo‘lgan hol uchun);

e) $\cos\varphi = 1$ va $\cos\varphi = 0{,}8$ da aktiv- induktiv xarakterdagi nominal yuklama uchun ikkilamchi chulg‘amdagi kuchlanish $U_{2(1)}$, $U_{2(0,8)}$.

Yechish.

a) nominal tok va quvvat koeffitsiyentlari

$$I_{1H} = \frac{S_H}{\sqrt{3}U_1} = \frac{63\cdot 10^3}{\sqrt{3}\cdot 21\cdot 10^3} = 1{,}734A;$$

$$I_{2H} = \frac{U_1}{U_2}\cdot I_{1H} = \frac{21\cdot 10^3}{400}\cdot 1{,}734 = 91{,}03A;$$

$$\cos\varphi_0 = \frac{P_0}{\sqrt{3}I_0U_0} = \frac{290}{\sqrt{3}\cdot 0{,}035\cdot 1{,}734\cdot 21\cdot 10^3} = 0{,}1315;$$

$$\cos\varphi_{KT} = \frac{P_{r.н}}{\sqrt{3}U_{KT}I_{r.н}} = \frac{P_{r.н}}{\sqrt{3}\frac{U_{KT}U_1}{100}I_{r.н}} = \frac{1650}{\sqrt{3}\frac{4{,}5\cdot 21\cdot 10^3}{100}\cdot 1{,}734} = 0{,}592.$$

b) yig‘indi aktiv va induktiv qarshiliklar

$P_{r.í} = 3I^2_{r.í}R,$ bundan

$$R = \frac{P_{r.í}}{I^2_{r.í}} = \frac{1650}{3 \cdot 1{,}734^2} = 183 \text{ Om.}$$

$$x = \frac{U_{P\Phi}}{I_{1H}} = \frac{U_p U_{1H}}{\sqrt{3} \cdot 100 I_{1H}} = \frac{\sqrt{U^2{}_k - U^2{}_a} \cdot U_{1H}}{\sqrt{3} \cdot 100 I_{1H}} = \frac{\sqrt{4{,}5^2 - 2{,}54^2} \cdot 21 \cdot 10^3}{\sqrt{3} \cdot 100 \cdot 1{,}734} = 260 \text{ Om}$$

c) nominal yuklamadagi FIK

$$\eta_1 = \frac{S_H \cos\varphi}{S_H \cos\varphi + P_0 + P_{KT}} \cdot 100 = \frac{63 \cdot 1}{63 \cdot 1 + 0{,}29 + 1{,}65} \cdot 100 = 97{,}01\%$$

$$\eta_{0,8} = \frac{63 \cdot 0{,}8}{63 \cdot 0{,}8 + 0{,}29 + 1{,}65} \cdot 100 = 96{,}29\%$$

d) tok maksimum η uchun tok

$3I^2{}_1R = P_0$, bundan

$$I_1 = \sqrt{\frac{P_0}{3R}} = \sqrt{\frac{290}{3 \cdot 183}} = 0{,}727A$$

$$I_2 = nI_1 = \frac{21}{0{,}4} \cdot 0{,}727 = 38{,}17A$$

$$P = \sqrt{3}U_2 I_2 \cos\varphi = \sqrt{3} \cdot 400 \cdot 38{,}17 = 21{,}1 \text{ kVt.}$$

e) nominal yuklama uchun ikkilamchi chulg‘amdagi kuchlanish

$U'_{2\phi} = U_{1\phi} - I(R\cos\varphi \pm x\sin\varphi)$, $\cos\varphi = 1$ uchun $(\sin\varphi = 0)$

$$U'_{1\phi(1)} = \frac{21 \cdot 10^3}{\sqrt{3}} - 1{,}734 \cdot 183 = 11{,}82 \cdot 10^3 \text{ B}$$

$$U_{2(1)} = \frac{\sqrt{3}U'_{2\phi(1)}}{U_1 / U_2} = \frac{\sqrt{3} \cdot 11{,}82 \cdot 10^3}{21/0{,}4} = 389{,}5 \text{ V}$$

$\cos\varphi = 0{,}8$ uchun $(\sin\varphi) = 0{,}6$

$$U'_{2\phi(0,8)} = \frac{21 \cdot 10^3}{\sqrt{3}} - 1{,}734 \cdot (183 \cdot 0{,}8 + 260 \cdot 0{,}6) = 11{,}63 \cdot 10^3 \text{ V}$$

$$U_{2(0,8)} = \frac{\sqrt{3}U'_{2\phi(0,8)}}{U_1 / U_2} = \frac{\sqrt{3} \cdot 11{,}63 \cdot 10^3}{21/0{,}4} = 383{,}2 \text{ V}$$

1.5.8. Aktiv-induktiv yuklama xarakteridagi quvvati $P = 50$ kVt bo‘lgan istemolchi uch fazali elektr tarmog‘iga transformator orqali uzatish kerak. Quyidagi uchta transformatordan bittasi (tejamlisi) tanlansin:

	I	II	III
Nominal quvvat, kVt	63	100	160
Chulg‘amdagi isrof, kVt	1,65	2,b	3,9
Salt ishlash quvvat isrofi, kVt	0,29	0,375	0,55

Topish kerak:

a) Uchta transformatorning ham maksimum FIK η uchun to‘la quvvatlari;
b) $\cos\varphi = 1$ va $\cos\varphi = 0{,}8$ uchun maksimum FIK η;
c) Berilgan yuklama uchun FIK η;
d) bir yillik (8760 soat) quvvat isroflari uchun xarajatlar $\kappa_{63}, \kappa_{100}, \kappa_{160}$, agarda elektr energiyasi narxi $e = 16{,}5$ so‘m/ (kVts) bo‘lsa;
e) Eng tejamli transformatorni ishlatish jarayonidagi elektr energiyasi isrofi uchun tejalgan yillik xarajatlar.

Yechish.

a) Transformatorning nisbiy yuklamasini $x = S_2 / S_H$ bilan belgilaymiz, u holda chulg‘amdagi quvvat isrofi $P_r = x^2 P_{r.н}$ bo‘ladi. Eng katta FIK $P_{0,x} = P_r = x^2 P_{r.н}$. Bundan $x = \sqrt{P_0 / P_{r.н}}$.

To‘la quvvatni topamiz:

$$x_1 = \sqrt{\frac{P_{01}}{P_{r.y1}}} = \sqrt{\frac{0{,}29}{1{,}65}} = 0{,}417$$

$$S_1 = x_1 S_{H1} = 0{,}417 \cdot 63 = 26{,}3 kBa;$$

$$x_{11} = \sqrt{\frac{P_{011}}{P_{r.н11}}} = \sqrt{\frac{0{,}375}{2{,}6}} = 0{,}378$$

$$S_{11} = x_{11} S_{H11} = 0{,}378 \cdot 100 = 37{,}8 kBa;$$

$$x_{111} = \sqrt{\frac{P_{0111}}{P_{r.но111}}} = \sqrt{\frac{0{,}55}{3{,}9}} = 0{,}375;$$

$$S_{111} = x_{111} S_{H111} = 0{,}375 \cdot 160 = 60 kBa.$$

b) maksimum FIK η

$$\eta_{1\max(1)} = \frac{S_1 \cos\varphi}{S_1 \cos\varphi + 2P_{01}} \cdot 100 = \frac{26{,}3 \cdot 1}{26{,}3 \cdot 1 + 2 \cdot 0{,}29} = 97{,}58\%;$$

$$\eta_{1\max(0{,}8)} = \frac{S_1 \cos\varphi}{S_1 \cos\varphi + 2P_{01}} \cdot 100 = \frac{26{,}3 \cdot 0{,}8}{26{,}3 \cdot 0{,}8 + 2 \cdot 0{,}29} \cdot 100 = 97{,}4\%;$$

$$\eta_{11\max(1)} = \frac{S_{11} \cos\varphi}{S_{11} \cos\varphi + 2P_{011}} \cdot 100 = \frac{37{,}8 \cdot 1}{37{,}8 \cdot 1 + 2 \cdot 0{,}375} \cdot 100 = 98\%;$$

$$\eta_{11\max(0{,}8)} = \frac{37{,}8 \cdot 0{,}8}{37{,}8 \cdot 0{,}8 + 2 \cdot 0{,}375} \cdot 100 = 97{,}5\%;$$

$$\eta_{111(1)} = \frac{60 \cdot 1}{60 \cdot 1 + 2 \cdot 0{,}55} \cdot 100 = 98{,}1\%;$$

$$\eta_{111(0{,}8)} = \frac{60 \cdot 0{,}8}{60 \cdot 0{,}8 + 2 \cdot 0{,}55} \cdot 100 = 97{,}75\%.$$

c) berilgan yuklamada FIK ni topish uchun to‘la quvvat topiladi

$S = \frac{P}{\cos\varphi} = \frac{50}{0{,}8} = 62{,}5$ kVt, bundan

$$\eta_{63} = \frac{P}{P + P_{01} + P_{гн}\left(\frac{S}{S_{H1}}\right)^2} \cdot 100 = \frac{50}{50 + 0{,}29 + 1{,}65\left(\frac{62{,}5}{63}\right)^2} \cdot 100 = 96{,}32\%;$$

$$\eta_{100} = \frac{50}{50 + 0{,}375 + 2{,}6\left(\frac{62{,}5}{100}\right)^2} \cdot 100 = 97{,}29\%;$$

$$\eta_{160} = \frac{50}{50 + 0{,}55 + 3{,}9\left(\frac{62{,}5}{100}\right)^2} \cdot 100 = 97{,}76\%.$$

d) yillik isrof xarajatlari

$$k_{63} = 8760eP_1 = 8760 \cdot 16{,}5\left[0{,}29 + 1{,}65\left(\frac{62{,}2}{63}\right)^2\right] = 274389 \text{ so‘m}$$

$$k_{100} = 8760eP_{11} = 8760 \cdot 16{,}5\left[0{,}375 + 2{,}6\left(\frac{62{,}5}{100}\right)^2\right] = 201001 \text{ so‘m}$$

$$k_{160} = 8760eP_{111} = 8760 \cdot 16{,}5\left[0{,}55 + 3{,}9\left(\frac{62{,}5}{160}\right)^2\right] = 101552 \text{ so‘m}$$

e) III transformatorni ishlatish tejamli I tansformatorni ishlatish esa tejamsiz ekan. Isroflarga ketadigan xarajatlarning yillik iqtisodi.

$k = k_{63} - k_{160} = 274389 - 101552 = 17284$ so‘m

1.5.9. Podstansiyada quvvat $S_H = 100$ kVa bo‘lgan transformator ishlatilmoqda. Bir yilda (8760 soat) berilgan elektr energiyasi $W_{йил} = 165000$ kVts, aktiv-induktiv yuklamada $(\cos\varphi = 0{,}8)$ eng katta quvvat $P_{\max} = 71{,}5$ Vt. Transformatorning salt ishlash quvvat isrofi $P_0 = 1000$ Vt, nominal yuklamada chulg‘amdagi isrof $P_{г.н} = 3300$ Vt. Quyidagilar topilsin:

a) transformatorning yillik FIK η_{yil};

b) yillik energiya isrofi W_{yil};

c) agarda elektr energiyasi narxi e=12 so‘m/(kVts) bo‘lsa, isrof uchun yillik xarajatlar.

Yechish.

a) yillik FIK $\eta_{йил}$

$$\eta_{йил} = \frac{W_{йил}}{W_{йил} + 876P_c + x^2 \cdot a \cdot 8760P_{г.н}} \cdot 100 = \frac{165000}{165000 + 8760 \cdot 1 + 0{,}8937^2 \cdot 0{,}145 \cdot 8760 \cdot 3{,}3} \cdot 100 = 93{,}16\%$$

bu yerda $x = \frac{S_t}{S_H} = \frac{P_{\max}}{S_H \cos\varphi} = \frac{71{,}5}{100 \cdot 0{,}8} = 0{,}8937;$

$$k = \frac{W_{йил}}{P_{\max} \cdot 8760} = \frac{165000}{71{,}5 \cdot 8760} = 0{,}263$$

(1.10-rasmdagi [2] diagrammadan) foydalanish koeffitsiyenti $\kappa = 0{,}263$ uchun isrof koeffitsiyenti $a = 0{,}145$ to‘g‘ri keladi.

b) Energiya isrofi

$W_{yil} = x^2 P_{r.н} a \cdot 8760 + 8760 P_0 = 0{,}8937^2 \cdot 3{,}3 \cdot 0{,}145 \cdot 8760 + 8760 \cdot 1 = 12108$ kVts.

c) isrof uchun yillik xarajatlar

$k = W_{йил} e = 12108 \cdot 16{,}5 = 199782$ so‘m.

1.5.10. 1.5.9-masaladagi transformator o‘rnida namunaviy transformator ishlatilgan bo‘lib, uning parametirlari quyidagicha:

$S_H = 100$ kVa; $P_0 = 400$ Vt; $P_{r.н} = 2600$ Vt.

Quyidagilar topilsin:

a) transformatorning yillik FIK η_{yil} (2.5.9-masaladagi qiymatlardan foydalanib);

b) yillik energiya isrofi W_{yil};

c) yillik isrof xarajatlari, agarda elektr energiyasi narxi

$e = 16{,}5$ so‘m/(kVts)

d) zamonaviy transformatorni qo‘llagandagi energiya isrofi xarajatlarini tejash;

e) eski transformator narxi 18000000 so‘m, zamonaviy transformator narxi 23000000 so‘m, haqiqiy iqtisodi (foydasi), qo‘shimcha kapital qo‘yilma (investitsiya) hisobiga yillik xarajatlar 20%.

Yechish.

a) yuklama o‘zgarmas bo‘lganda x, k va a parametirlar ham o‘zgarmas holda qoladi. Shularni hisobga olgan holda yillik FIK η_{yil}

$$\eta_{yil} = \frac{W_{йил}}{W_{yil} + 8760 P_0 + x^2 a \cdot 8760 P_{r.н}} \cdot 100 = \frac{165000}{165000 + 8760 \cdot 0{,}4 + 0{,}145 \cdot 0{,}8937^2 \cdot 8760 \cdot 2{,}6} \cdot 100 = 96{,}41\%$$

b) energiya isrofi

$W_{йил} = 8760 P_0 + x^2 a \cdot 8760 P_{r.н} = 8760 \cdot 0{,}4 + 0{,}8937^2 \cdot 0{,}145 \cdot 8760 \cdot 2{,}6 = 6142$ kVts

c) isrof xarajatlari va iqtisod (foyda)

$\kappa = W_{йил} \cdot e = 6142 \cdot 16{,}5 = 101343$ so‘m

$\Delta\kappa = \kappa_0 - \kappa_{10} = 199782 - 101343 = 98439$ so‘m

d) zamonaviy transformatorni qo‘llaganda ortiqcha kapital qo‘yilma (investitsiya) koeffitsiyentini hisobga olganda

$\frac{5000000}{100} \cdot 20 = 1000000$ so‘m

e) haqiqiy iqtisod (foyda)

$\Delta\kappa' = \Delta\kappa - 1000000 = 5000000 - 1000000 = 4000000$ so‘m.

1.6. Mustaqil yechish uchun masalalar

1.6.1. Chulg‘amlarning ulanish sxemasi Y/Y bo‘lgan uch fazali transformator birlamchi chulg‘amining liniya kuchlanishi $U_{2л} = 220$ V, transformator chulg‘amlarining ulanish sxemalari Δ/Δ, Y/Δ va Δ/Y bo‘lganda, ikkilamchi chulg‘amning liniya kuchlanishlari aniqlansin. (**J:** hamma holda 380/220 V bo‘ladi.)

1.6.2. Ko‘p chulg‘amli transformatorning 220 V ga mo‘ljallangan birlamchi chulg‘amining o‘ramlar soni $\omega_1 = 1100$. Ikkilamchi chulg‘amlardan tegishlicha 6 V, 24 V, va 120 V kuchlanishlar olinadi. Shu chulg‘amlarning o‘ramlar soni aniqlansin. (**J:** $\omega_2 = 30;\ \omega_3 = 600$)

1.6.3. Tarmoq kuchlanishi ikkita transformator yordamida 3000 V dan 400 V gacha, so‘ngra 400 V dan 40 V gacha pasaytirildi. Tranformatorlarning FIK lari tegishlicha $\eta_1 = 0{,}85$ va $\eta_2 = 0{,}6$. Ikkinchi transformatordan istemol qilinayotgan aktiv quvvat $P = 5{,}1$ kVt bo‘lsa, birinchi transformatorning kirish tomonidagi aktiv quvvat aniqlansin. (**J:** $P_1 = 10$ kVt.)

1.6.4. Chulg‘amlarining ulanish sxemasi va guruhi $\Delta/Y - 11$ bo‘lgan uch fazali transformatorning kuchlanishlari $U_1/U_2 = 21000/400$ V; bitta o‘ramdagi kuchlanish $U_y = 9{,}62$ V, chulg‘amning o‘rtacha uzunligi va chulg‘am simlarining kesim yuzasi:

yuqori kuchlanish tomonida $l_{y2}0{,}734м, A_2 = 404{,}5мм^2$; nominal quvvat $S_H = 630$ kVa; salt ishlash toki $I_0 = 0{,}021I_H$; salt ishlash quvvat isrofi $P_0 = 1{,}49$ kVt; qisqa tutashuv quvvat isrofi $P_{KT} = 9{,}25$ kVt; qisqa tutashuv kuchlanishi $U_{KT} = 4{,}5\%$.

Quyidagilar topilsin:

a) transformatorning ikkala chulg‘amining aktiv qarshiliklari $R_1,\ R_2(75^0C,\ \rho_{75} = 0{,}0346$ mkOm);
b) cho‘lg‘amdagi isrofni (salt ishlash rejimida) xisobga olgan holda po‘latdagi isrof P_n;
c) birlamchi va ikkilamchi chulg‘amlarning naminal toklari $I_{1н}, I_{2н}$;
d) magnit oqimining maksimal qiymati F;
e) qisqa tutashuv va salt ishlash rejimlaridagi quvvat koeffitsiyentlari $\cos\varphi_0, \cos\varphi_{Kt}$;
f) barcha induktiv sochilma qarshiliklar x_s.

(**J:** a) $R_1 = 15{,}75$ Om, $R_2 = 0{,}0015$ Om, b) $P_{\acute{i}} = 1488$ Vt; v) $I_{1H} = 17{,}34$ A, $I_{2H} = 910$ A;

g) $\phi = 4{,}33 \cdot 10^{-2}$ Vb; d) $\cos\varphi_0 = 0{,}1126$, $\cos\varphi_{KT} = 0{,}3263$; e) $x_S = 89{,}4$ Om.)

1.6.5. Kuchlanishlar $U_1/U_2 = 550/380$ V bo‘lgan uchta parallel transformatordan bir fazali istmolchi kuchlanish olmoqda. Transformatorning quyidagi parametlari berilgan:

$S_{H1} = 15kBA;\ S_{H11} = 20kBA;\ S_{H111} = 18kBA;\ U_{K1} = 4{,}2\%;\ U_{KH} = 4{,}8\%;\ U_{K111} = 5{,}2\%.$

Yuklamaning parametrlari:

$U_{\text{юк}} = U_{\_2} = 380B;\ P_{\text{юк}} = 50kBt;\ \cos\varphi_{\text{юк}} = 0{,}8$ (ind.)

Quyidagilar aniqlansin

a) har bir transformatorning nominal toklari $I_{21H}; I_{211H}; I_{2111H}; I_{1.1H}; I_{1.11H}; I_{1.111H}$.

b) yuklama toki $I_{\text{þê}}$;

c) berilgan yuklama uchun hamma transformatorning toklari $I_1;\ I_{11}\ ; I_{111}$;

d) transformatorlarning yuklanish koeffitsiyentlari

$$\frac{I_1}{I_{21H}} \cdot 100;\ \frac{I_{11}}{I_{211H}} \cdot 100;\ \frac{I_{111}}{I_{2111H}} \cdot 100.$$

e) $U_{KT1} = U_{KT11} = U_{\_KT111} = 6\%$ bo‘lsa transformatorning yuklanish koeffitsiyentlari $\frac{I^*_1}{I_{21H}} \cdot 100;\ \frac{I^*_{11}}{I_{211H}} \cdot 100;\ \frac{I^*_{111}}{I_{2111H}} \cdot 100.$

(**J:** a) $I_{21H} = 39{,}47$ A, $I_{211H} = 52{,}63$ A, $I_{2111H} = 47{,}37$ A; $I_{11H} = 27{,}28$ A, $I_{111H} = 36{,}37$ A, $I_{1.111H} = 32{,}74$

b) $I_{\text{юк}} = 164{,}5$ A; v) $I_1 = 52{,}48$ A; $I_{11} = 61{,}22$ A; $I_{111} = 50{,}88$ A;

c) $(I_1/I_{21H}) \cdot 100 = 133\%; (I_{11}/I_{211H}) \cdot 100 = 116\%; (I_{111}/I_{2111H}) \cdot 100 = 107\%$

d) $(I^*_1/I_{21H}) \cdot 100 = (I^*_{11}/I_{211H}) \cdot 100 = (I^*_{111}/I_{2111H}) \cdot 100 = 118\%.$)

1.6.6. Chulg‘amlari $Y/Y-0$ ulangan transformatorning nominal quvvati $S_H = 63$ kVt, nominal kuchlanishi $U_1/U_2 = 5500/400$ V, $U_{KT} = 6\%,\ U_{KTa} = 2{,}38\%.$

Quyidagilar aniqlansin:

a) nominal yuklama uchun chulg‘amdagi toklar $I_{1H},\ I_{2H}$ va quvvat isrofi $P_{r.\acute{i}}$.

b) aktiv R va induktiv x qarshiliklar;

c) nominal yuklamada ($\cos\varphi = 0{,}85$ va $\eta = 94{,}5\%$) transformatorning po‘latdagi quvvat isrofi P_n.

(**J:** a) $I_{1H} = 6{,}621A;\ I_{2H} = 91{,}04A;\ P_{r.\acute{i}} = 1500$ Vt.

b) $R = 11{,}54$ Om; $x_s = 26{,}7$ Om; $P_n = 1610$ Vt.

1.6.7. Chulg‘amlari $\Delta/Y-11$ ulangan transformatorning nominal quvvati $S_{\_\acute{i}} = 250$ kVt, kuchlanish $U_1/U_2 = 21/0{,}4$ kV. Nominal yuklamada

chulg‘amdagi isrof $P_{r.i} = 4{,}6$ kVt, po‘latdagi isrof $P_n = 0{,}75$ kVt. Bir yillik uzatiladigan elektr energiyasi $W_{yil} = 185000$ kVts. Eng katta quvvat $P_{\max} = 120$ kVt, $\cos\varphi = 0{,}68$ (aktiv-induktiv yuklama).

Quyidagilar topilsin:

a) transformatorning yillik FIK $\eta_é$;
b) agarda elektr energiyasi narxi $e = 0{,}02$ so‘m/(kVts) bo‘lsa transformatordagi isroflarga ketgan yillik xarajatlar k;
c) $U_{KT} = 4{,}5\%$ bo‘lsa, maksimal yuklama uchun U_2.

(**J:** a) $\eta_ü = 95{,}63\%$; b) $\kappa = 43$ so‘m; v) $U_2 = 338$ V.)

1.6.8. Chulg‘amlari $Y/Z-11$ ulangan transformatorning nominal quvvati $S_i = 160$ kVt, kuchlanishlari $U_1/U_2 = 35000/400$ V, bitta o‘ramdagi kuchlanishi $U_y = 8{,}75$ V.

Quyidagilar aniqlansin:

a) nominal toklar $I_{1í}$, $I_{2í}$;
b) ikkala chulg‘amdagi o‘ramlar soni ω_1, $\omega_2 = 2\omega'_2$;
c) $U_{KT} = 6\%$, $U_{KTa} = 2{,}4\%$ bo‘lsa, aktiv R, induktiv x va to‘la qisqa tutashuv qarshiliklari;
d) nomial yuklamada chulg‘amdagi isrof $P_{r.í}$ va qisqa tutashuv xolatidagi quvvat koeffitsiyenti $\cos\varphi_{KT}$;
e) $R_1 = R'_2$ shart uchun ikkilamchi chulg‘amning aktiv qarshiligi R_2;
f) agarda $\rho_{75} = 0{,}216$ mkOmm va tok zichligi $j = 3{,}8A/мм^2$ bo‘lsa, chulg‘am simlarining uzunligi l_1, l_2;
g) induksiyaning maksimal qiymati 1,62 Tl bo‘lsa, magnit o‘tkazgichning (po‘latning) ko‘ndalang kesim yuzasi A_n.

(**J:** a) $I_{1H} = 2{,}664$ A; $I_{2H} = 231$ A; b) $\omega_1 = 2312$; $\omega_2 = 2\omega'_2 = 2\cdot 15 = 30$; v) $R = 184$ Om;

$z_k = 457$ Om; $x_s = 419$ Om; g) $P_{r.í} = 3850$ Vt; $\cos\varphi_{KT} = 0{,}4$;

d) $R_2 = 0{,}0117$ Om; e) $l_1 = 2941$ m; $l_2 = 32{,}75$ m; j) $A_n = 243$ cc^2.)

1.6.9. Chulg‘amlari $Y/Z-11$ ulangan, kuchlanishlari $U_1/U_2 = 21000/400$ V, o‘ramdagi kuchlanish $U_y = 7{,}48$ V, nominal quvvati $S_i = 160$ kVA, qisqa tutashuv isrofi $P_{KT} = 3{,}9$ kVt, salt ishlash toki $i_0 = 3\%$, salt ishlashdagi quvvat isrofi $P_0 = 550$ Vt, $U_{KT} = 4{,}5\%$.

Quyidagilar topilsin:

a) transformatorning ikkala chulg‘amining aktiv R_1, R'_2 va induktiv x_1, x'_2 qarshiliklari (bunda $R_1 = R'_2$ va $x_1 = x'_2$);
b) salt ishlash tokining aktiv $I_{oa}(I_n)$ va reaktiv (I_μ) tashkel etuvchilar;

c) asosiy magnit oqimiga mos keluvchi induktiv qarshilik x_μ va po‘latdagi isroflarga mos keluvchi aktiv qarshilik R_n;

d) induksiya $B = 1{,}5$ Tl bo‘lsa, magnit o‘tkazgichning kesim yuzasi A_n;

e) sterjen atrofida chizilgan aylananing diametri D_0 (kesim yuzasini to‘ldirish koeffitsiyenti $\kappa_{TYJI} = 0{,}86$).

(**J:** a) $R_1 = 33{,}6$ Om; $R'_2 = 33{,}6$ Om; $x_s = 54{,}5$ Om; $x_{s2} = 49{,}5$ Om; b) $I_\mu = 0{,}1304$ A; $I_n = 0{,}01505$ A;

c) $x_\mu = 93$ kOm; $R_n = 806$ Om; g) $A_n = 213{,}2\,см^2$; d) $D_0 = 177$ mm.)

1.6.10. Bir fazali transformatorning parametlari quyidagicha:
$S_H = 6{,}3\,кВт$, $U_1/U_2 = 1000/230\,В$,
$U_{KT} = 5{,}2\%$, $\cos\varphi_{KT} = 0{,}423$;
$P_0 = 132\,Вт$, $i_0 = 8{,}35\%$.
Quyidagilar aniqlansin:
aktiv R va induktiv x qarshiliklar.
(**J:** $R = 3{,}492$ Om; $x_s = 7{,}45$ Om.)

2. Asinxron mashinalar

(Asosiy kattaliklar va ularni aniqlash tenglamalari)

2.1. Asinxron mashinaning tenglamalari va parametrlarini keltirish

Asinxron mashina stator chulg‘amida hosil bo‘lgan EYUK

$$E_1 = 4{,}44\, f \omega_1 k_{r1} \Phi, \qquad (2.1)$$

bu yerda: f – chastota; ω_1 – stator chulg‘amining o‘ramlar soni, κ_{r1} – stator chulg‘amining chulg‘am koeffitsiyenti; F- magnit oqim.

Rotor chulg‘amida hosil bo‘lgan EYUK

$$E_2 = 4{,}44\, f_1 \omega_1 k_{r2} \Phi, \qquad (2.2)$$

bu yerda: $S = \dfrac{n_1 - n}{n_1}$ sirpanish; ω_2 – rotor chulg‘amining o‘ramlar soni; κ_{r2} – rotor chulg‘amining chulg‘am koeffitsiyenti.

Asinxron mashinaning toransformatsiya koefitsienti

$$\kappa_{KP} = \frac{E_1}{E_2} = \frac{\omega_1 k_{r1}}{\omega_2 k_{r2}}. \qquad (2.3)$$

EYUK ning keltirilgan qiymati

$$E'_2 = k_{TP} E_2 = \frac{\omega_1 k_{r1}}{\omega_2 k_{r2}} \cdot 4{,}44\, f_1 \omega_1 k_{r2} \Phi = 4{,}44\, f_1 \omega_1 k_{r1} \Phi = E_1 = E\,. \qquad (2.4)$$

Tokning keltirilgan qiymati

$$I'_2 = \frac{m_2}{m_1} \cdot \frac{l_2}{k_{r1}}, \quad (2.5)$$

bu yerda: m_1, m_2 – stator va rotorning fazalar soni.

Keltirilgan aktiv karshilik

$$R'_2 = \frac{m_1}{m_2} k^2_{TP} R_2. \quad (2.6)$$

Keltirilgan induktiv qarshilik

$$x'_2 = \frac{m_1}{m_2} k^2_{TP} x_2. \quad (2.7)$$

Keltirilgan to‘la qarshilik

$$z'_2 = \frac{m_1}{m_2} k^2_{TP} z_2. \quad (2.8)$$

2.2. Asinxrom mashinadagi quvvat va isroflar

Uch fazali asinxron motor tarmoqdan P_1 quvvatni istemol qiladi

$$P_1 = 3U_1 I_1 \cos\varphi_1. \quad (2.9)$$

Stator po‘lat o‘zagidagi isrof P_{n1}, chulg‘amdagi isrof P_{r1}.

Po‘latdagi isrof

$$P_{n1} = P_{я1} + P_{T1}, \quad (2.10)$$

bu yerda: $P_{ß1}$, P_{T1} – stator yarmosidagi va tishlaridagi isrof.

Yarmodagi isrof

$$P_{Я1} = 2P_{1.0} B^2_{я1} m_{я1}; \quad (2.11)$$

Tishlardagi isrof 2

$$P_{T1} = 3P_{1.0} (B_{T1} \kappa_\delta)^2 m_{T1}, \quad (2.12)$$

bu yerda: $P_{1.0}$ – stator po‘latidagi solishtirma isrof, Vt/kg: $B_{Я1}$ – yarmodagi o‘rtacha induksiya, Tl; $m_{Я1}$ – yakorning massasi, kg; m_{T1} – tishlarning massasi, kg; B_{T1} – tishlardagi o‘rtacha induksiya, Tl; κ_δ -havo bo‘shlig‘i (zazor) koeffitsiyenti.

Stator chulg‘amidagi isrof

$$P_{r1} = 3I^2_1 R_1, \quad (2.13)$$

bu yerda: I_1 -stator fazasidagi tok; R_1-stator fazasi chulg‘amining 75^0C dagi aktiv qarshiligi.

$$R_1 = \rho_{75} \frac{l_1 2\omega_1}{a_1 c_1 A_1}, \quad (2.14)$$

bu yerda: l_1 -o‘tkazgichning (simning) o‘rtacha uzunligi; a_1-parallel shaxobchalar soni; c_1-pazdagi elementlar o‘tkazgichlar soni. Stator chulg‘amida bu isrofni mis simlar massasi va undagi tok zichligi orqali

xam topish mumkin.

$$P_{r1} = 2{,}42\, j^2{}_1 m_{r1}. \tag{2.15}$$

Elektromagnit quvvat

$$P_Э = P_1 - (P_{n1} + P_{r1}) = P_1 - P_{ИСТ1}, \tag{2.16}$$

bu yerda: P_{BCN1}-stator chulg‘ami istemol qilayotgan quvvat.

Rotordagi isrof po‘latdagi P_{n2} va chulg‘amdagi P_{r2} isroflardan iborat

$$P_{ИСТ2} = P_{n2} + P_{r2}.$$

Faza rotorli asinxron mashinada mexanik isrof

$$P_{mex} = P_Э - (P_{n2} + P_{r2} + P_{юк}), \tag{2.17}$$

bu yerda: $P_{юк}$-yuklama quvvati.

Valdagi quvvat

$$P = P_{mex} - P_{T.B}, \tag{2.18}$$

bu yerda: $P_{T.B}$-titrash va ventilyasiya isrofi..

Nominal sirpanishda rotor po‘latidagi quvvat isrofi juda kichik bo‘ladi shu sababli uni hisobga olmasa ham bo‘ladi.

Rotordagi elekt isrofi

$$P_{r2} = m_2 I^2{}_2 R_2 = m_1 (I'_2)^2 R'_2 \ . \tag{2.19}$$

Bu quvvat isrofini xuddi (2.15) formula singari yozish mumkin

$$P_{r2} = 2{,}42 I^2{}_2 m_{r2}. \tag{2.20}$$

Qisqa tutashgan rotorli asinxron motorlarda sterjen va kontakt halqadagi isroflar

$$\left.\begin{aligned} P_{стерж} &= z_2 I^2{}_{стерж} \rho \frac{l_{стерж}}{A_{стерж}} \\ P_{хал} &= 2 I^2{}_{хал} \rho \frac{D_{хал} \pi}{A_{хал}} \end{aligned}\right\} \tag{2.21}$$

Rotordagi isrof

$$P_{r2} = P_{стерж} + P_{хал}$$

Agarda sterjen va xalqalar bir xil materialdan tayyorlangan bo‘lsa, u xolda

$$P_{r2} = \frac{\rho}{\rho'} (m_{стерж} S^2{}_{стерж} + m_{хал} S^2{}_{хал}), \tag{2.22}$$

bu yerda: ρ – chulg‘am materialining solishtirma qarshiligi; ρ' – chulg‘am materialining zichligi.

To‘la mexanik quvvat

$$P_{mex} = P_Э (1 - S). \tag{2.23}$$

chulg‘amdagi isrof

$$P_r \approx P_Э S \ . \qquad (2.24)$$

2.3.3 Asinxron mashina momenti

Asinxron mashinaning elektromagnit quvvati moment bilan quyidagicha bog‘langan

$$P_Э = M \cdot 2\pi n . \qquad (2.25)$$

(3.19) va (3.24) formulalardan foydalanib, momentni taxminiy quyidagicha yozish mumkin

$$M = 9{,}55\frac{3}{n}U^2{}_1 \frac{R'_2 / S}{(R_1 + R'_2 / S)^2 + x^2}, \qquad (2.26)$$

bu yerda: $x = x_1 + x'_2$; n – sinxron aylanish chastotasi, ayl/min; U_1 – kuchlanish, V; R, x – aktiv va induktiv qarshiliklar, Om.

Yurgizish momenti ($S = 1$)

$$M_{юр} = 9{,}55\frac{3}{n} I'^2{}_{2K.T} R'_2, \qquad (2.27)$$

bu yerda: $I'_{1K.T}$ – rotordagi keltirilgan qisqa tutashuv toki.

Motorning taxminiy maksimal momenti

$$M_{mex} = 9{,}55\frac{3}{n}U^2{}_1 \frac{1}{2(R_1 + \sqrt{R^2{}_1 + x^2})}. \qquad (2.28)$$

Kritik sirpanish

$$S_{KP} \approx R'_2 / x .$$

(3.26) va (3.28) formulalardan foydalanib, $M / M_{\max}$ nisbatni topamiz

$$\frac{M}{M_{\max}} = \frac{2}{\frac{S_{KP}}{S} + \frac{S}{S_{KP}}}. \qquad (2.30)$$

2.4. Namunaviy masalalar yechish

2.4.1. Stator chulg‘ami Y ulangan uch fazli to‘rt qutbli asinxron motorning quyidagi parametlari berilgan:

$U_H = 380$ V, $I_H = 5{,}6A$, $P_H = 2{,}8кВТ$, $f = 50Гц$, $\eta_H = 84\%$,

$R_1 = 1{,}8$ Om, $R_2 = 2{,}9$ Om, $x_1 = 2{,}9$ Om, $x_2 = 3{,}6$ Om, $x_\mu = 102$ Om.

Quyidagilar aniqlansin:

a) rotor po‘latdagi isrof hisobga olinmasdan, $P_{T.B} = 0{,}01P_H$ uchun nominal aylanish chastotasi;
b) motorning qisqa tutashuv toki va yurgizish momenti.

Yechish.

a) motor istemol qilayotgan quvvat

$$P_{1H} = P_H / \eta = 2{,}8 / 0{,}84 = 3{,}33 \text{ kVt}.$$

Statordagi quvvat koeffitsiyenti

$$\cos\varphi_1 = \frac{P_{1H}}{\sqrt{3}U_H I_H} = \frac{3330}{\sqrt{3}\cdot 380\cdot 5{,}6} = 0{,}905.$$

Stator tokining vektor ko‘rinishi

$$\dot{I}_1 = I_1\cos\varphi_1 + jI_1\sin\varphi_1 = 5{,}6\cdot 0{,}905 + j5{,}6\cdot 0{,}436 = 5{,}07 + j2{,}44 \text{ A}$$

Taxminiy salt ishlash toki

$$\dot{I}_0 = j\frac{U_1}{x_1 + x_\mu} = j\frac{220}{2{,}9 + 102} = j2{,}1 \text{ A}$$

Rotor tokining keltirilgan qiymati

$$\dot{I}'_2 = \dot{I}_0 - \dot{I}_1 = j2{,}1 - 5{,}07 - j2{,}44 = -5{,}07 - j0{,}34 \text{ A}$$

Rotor chulg‘amidagi isrof

$$P_{r2} = 3I'^2_2 R'_2 = 3\cdot 5{,}08^2\cdot 2{,}9 = 224{,}5 \text{ Vt}$$

Mexanik quvvat

$$P_{mex} = P_H + P_{T.B} = P_H + 0{,}01P_H = 2{,}8 + 0{,}01\cdot 2{,}8 = 2{,}83 \text{ kVt}$$

Nominal sirpanish

$$S_H = \frac{P_{r2H}}{P_{Ý..H}} = \frac{P_{r2H}}{P_{r2H} + P_{mex}} = \frac{224{,}5}{224{,}5 + 2830} = 0{,}0735 = 7{,}35\%.$$

b) to‘la qarshilik

$$z_k = \sqrt{R^2 + x^2} = \sqrt{(1{,}8 + 2{,}9)^2 + (2{,}9 + 3{,}6)^2} = 8{,}02 \text{ Om.}$$

Qisqa tutashuv toki

$$I_{1K.T} = I'_{2K.T} = \frac{U_1}{z_k} = \frac{380/\sqrt{3}}{8{,}02} = 27{,}4 \text{ A.}$$

Sinxron aylanish chastotasi

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

Yurgizish momenti

$$M_{yur} = 9{,}55\frac{3}{n}I'^2_{2K.T}R'_2 = 9{,}55\frac{3}{n}(27{,}4)^2\cdot 2{,}9 = 41{,}6 \text{ H}\cdot\text{m}.$$

2.4.2. Stator chulg‘ami Δ ulangan uch fazali to‘rt qutbli asinxron motorning quyidagi nominal qiymatlari berilgan:

$U_H = 380$ V, $f = 50$ Gs, $P_H = 3{,}7$ kVt, $\cos\varphi_H = 0{,}7$

$\eta_H = 0{,}85$; $n_H = 1460$ ayl/min.

Quyidagilar topilsin:

a) statorning ichki diametri $D = 135$ mm, po‘lat o‘zak uzunligi $l = 175$ mm
b) stator pazlari soni $z_1 = 36$, pazlardagi simlar soni $z_1 = 36$, stator chulg‘amining chulg‘am koeffitsiyenti $\kappa_{r1} = 0{,}831$ bo‘lsa, havo bo‘shlig‘idagi o‘rtacha induksiya;
c) havo bo‘shlig‘i $\delta = 0{,}5$ mm, xavo bo‘shlig‘i koeffitsiyenti $\kappa_\delta = 1{,}128$,

tishlarning o‘lchamlari: $в_1 = 4{,}9$ mm, $L_{T1} = 18{,}5$ mm, $в_2 = 5{,}8$ mm, $L_{T2} = 25$ mm, rotor pazlari soni $z_2 = 30,$ paketlarni po‘lat bilan to‘ldirish koeffitsiyenti $\kappa_n = 0{,}93$ bo‘lsa, havo bo‘shlig‘idagi va tishlardagi magnit kuchlanishlar;

d) $h_{я1} = 35$ mm, $h_{я2} = 14{,}4$ mm bo‘lsa, yarmodagi induksiya;

e) chulg‘am ikkita parallel mis simdan tayyorlangan bo‘lsa ($c_1 = 2,\ d = 0{,}9$ mm), tok zichligi.

Yechish.

a) qutb va fazaga to‘g‘ri keluvchi pazlar soni

$$q_1 = \frac{z_1}{2pm_1} = \frac{36}{2 \cdot 2 \cdot 3} = 3.$$

Stator chulg‘ami fazasidagi o‘ramlar soni

$$\omega_1 = pq_1z_1 = 2 \cdot 3 \cdot 36 = 216.$$

Magnit oqim

$$\Phi \approx \frac{U_1}{4{,}44 f_1 \omega_1 k_1} = \frac{380}{4{,}44 \cdot 50 \cdot 216 \cdot 0{,}831} = 0{,}954 \cdot 10^{-2} \text{ Vb}.$$

Qutb bo‘linmasi

$$\tau = \frac{\pi D}{2p} = \frac{0{,}135 \cdot 3{,}14}{2 \cdot 2} = 0{,}106 \text{ m}.$$

Havo bo‘shlig‘idagi o‘rtacha induksiya

$$B_\delta = \frac{\Phi}{\tau \cdot l} = \frac{0{,}954 \cdot 10^{-2}}{0{,}106 \cdot 0{,}175} = 0{,}5143 \text{ Tl}.$$

b) $\alpha'_i = 0{,}77$ deb qabul qilamiz va havo bo‘shlig‘idagi maksimal induksiyani topamiz

$$B_{\delta m} = \frac{B_\delta}{\alpha'_i} = \frac{0{,}5143}{0{,}77} = 0{,}668 \text{ Tl}.$$

Havo bo‘shlig‘ining magnit kuchlanishi

$$F_{m\delta} = \frac{k_i \cdot \delta}{\mu_0} B_{\delta m} = \frac{1{,}128 \cdot 0{,}5 \cdot 10^{-3} \cdot 0{,}668}{1{,}257 \cdot 10^{-6}} = 299 \text{ A}.$$

Tishlardagi induksiyani topish uchun pazlar bo‘linmasini topish lozim

$$\tau_{n1} = \frac{\pi D}{z_1} = \frac{135 \cdot 3{,}14}{36} = 11{,}8 \text{ mm};$$

$$\tau_2 = \frac{\pi D}{z_2} = \frac{135 \cdot 3{,}14}{30} = 14{,}13 \text{ mm}.$$

Tishlardagi induksiya

$$B_{T1} = \frac{\tau_{n1} \cdot l}{в_1 l_{n1}} B_\delta = \frac{11{,}8 \cdot 175}{4{,}9 \cdot 0{,}93 \cdot 175} = 0{,}668 = 1{,}725 \text{ Tl};$$

$$B_{T2} = 0{,}95\frac{\tau_{n2} l}{\hat{a}_2 l_{n1}} B_{\delta} = 0{,}95 \cdot \frac{14{,}13 \cdot 174}{5{,}8 \cdot 0{,}93 \cdot 175} \cdot 0{,}668 = 1{,}66 \text{ Tl.}$$

Shu induksiyalarga mos keluvchi

Maydon kuchlanganliklari

$$H_{T1} = 110A \text{ / см; } H_{T2} = 75A \text{ / см.}$$

Magnit kuchlanishlar

$$F_{mT1} = H_{T1} L_{T1} = 110 \cdot 1{,}85 = 204A \text{ .}$$

$$F_{mT2} = H_{T2} L_{T2} = 75 \cdot 2{,}5 = 188A \text{ .}$$

To‘yinish koeffitsiyenti

$$k_T = \frac{F_{mT1} + F_{mT2}}{F_{m\delta}} = \frac{204 + 188}{299} = 1{,}31;$$

c) yarmodagi induksiya

$$B_{я1} = \frac{\phi}{2h_{я1} l_1 k_n} = \frac{0{,}954 \cdot 10^{-2}}{2 \cdot 0{,}035 \cdot 0{,}39 \cdot 0{,}175} = 0{,}837 \text{ Tl}$$

$$B_{я2} = 0{,}95\frac{\phi}{2h_{я2} l_2 k_n} = 0{,}95\frac{0{,}954 \cdot 10^{-2}}{2 \cdot 0{,}0144 \cdot 0{,}93 \cdot 0{,}175} = 2{,}035 \text{ Tl.}$$

d) motorning to‘la quvvati

$$S_H = \frac{P_H}{\eta_H \cos\varphi_H} = \frac{3{,}7}{0{,}85 \cdot 0{,}7} = 6{,}22 \text{ kVA.}$$

Nominal liniya toki

$$I = \frac{S_H}{\sqrt{3} U_H} = \frac{6{,}22 \cdot 10^3}{\sqrt{3} \cdot 380} = 9{,}5 \text{ A}$$

Faza toki $I_{1H} = I_{1Ёf} / \sqrt{3} = 9{,}5 / \sqrt{3} = 5{,}5$ A (Δ ulanishda)

Tok zichligi

$$J_1 = I_{1H} / c_1 a_1 A_1 = \frac{5{,}5}{2 \cdot 1 \cdot 0{,}636} = 4{,}32A \text{ / мм}^2 \text{.}$$

Parallel shaxobchalar soni va kesim $a_1 = 1$;

$A_1 = d^2\pi / 4 = 0{,}9^2 \cdot 3{,}14 / 4 = 0{,}636 \text{ мм}^2$.

2**.4.3.** Uch fazali qisqa tutashgan rotorli asinxron motorning quyidagi parametlari berilgan:

$U_{H\Delta} = 380B$, $I_H = 20{,}3A$, $P_H = 110 \text{ kBт}$, $f = 50$ Gs, $2p = 4$, $\eta_H = 87\%$ $P_n = 382$ Vt, $R_1 = 1{,}135$ Om, $R'_2 = 1{,}28$ Om, $x_\mu = 79$ Om, $x_1 = 2{,}7$ Om, $x'_2 = 3{,}8$ Om.

Topish kerak:

a) yurg’azish toki:

b) aylanma diogrammani qurish uchun kerak bo‘lgan qiymatlar;

c) ishchi va kritik sirpanish;

d) nominal, yurgizish va maksimal momentlar.

Yechish.

a) qisqa tutashuv to‘la qarshiligi

$$z_{K.T} = \sqrt{(R_1 + R'_2)^2 + (x_1 + x'_2)^2} = \sqrt{(1{,}135 + 1{,}28)^2 + (2{,}7 + 3{,}8)^2} = 6{,}93 \text{ Om}$$

Nominal kuchlanishdagi qisqa tutashuv toki

$$I_{K.TH} = \frac{U_1}{z_k} = \frac{380}{6{,}93} = 54{,}83 \text{ A.}$$

Nominal faza toki

$$I_{H\Phi} = I_H / \sqrt{3} = 20{,}3/\sqrt{3} = 11{,}73 \text{ A } (\Delta \text{ ulanganda})$$

Yurgizish tokining karraligi

$$\frac{I_{K.TH}}{I_{H\Phi}} = \frac{54{,}83}{11{,}73} = 4{,}67;$$

b) aylanma diagrammada qisqa tutashuv nuqtasi malum:

$$I_{K.TH} = 54{,}83 \text{ A.}$$

Qisqa tutashuvdagi quvvat koeffitsiyenti

$$\cos\varphi_{KT} = \frac{R}{z_{KT}} = \frac{R_1 + R'_2}{z_{KT}} = \frac{1{,}35 + 1{,}28}{6{,}93} = 0{,}348.$$

$S = \infty$ nuqtadagi qiymatlar

$$I_\infty = \frac{U_1}{\sqrt{R^2{}_1 + (x_1 + x'_2)^2}} = \frac{380}{\sqrt{1{,}135^2 + (2{,}7 + 3{,}8)^2}} = 57{,}6 \text{ A.}$$

$$\cos\varphi_\infty = \frac{R_1}{z_\infty} = \frac{1{,}135}{\sqrt{1{,}135^2 + (2{,}7 + 3{,}8)^2}} = 0{,}172.$$

$S = 0$ nuqtadagi qiymatlar

$$I_0 \approx \frac{U_1}{x_\mu + x_1} = \frac{380}{79 + 2{,}7} = 4{,}65 \text{ A}$$

$$\cos\varphi_0 = \frac{P_0}{3U_1 I_0};$$

$$P_0 = P_{r.0} + P_n + P_{T.B}$$

$$P_{r.0} = 3I^2{}_0 R_1 = 3 \cdot 4{,}65^2 \cdot 1{,}135 = 73{,}7 \text{ Vt;}$$

$$P_n = 382 \text{ Vt;}$$

$$P_{T.B} = 0{,}01 P_H = 0{,}01 \cdot 10 \cdot 10^3 = 100 \text{ Vt,}$$

$$P_0 = 73{,}7 + 382 + 100 = 555{,}7 \text{ Vt,}$$

$$\cos\varphi_0 = \frac{555{,}7}{3 \cdot 380 \cdot 4{,}65} = 0{,}105.$$

c) istemol qilinayotgan quvvat

$$P_1 = P_H / \eta_H = 10/0{,}87 = 11{,}5 \text{ Vt;}$$

Stator chulg‘amidagi isrof

$$P_{r1} = 3I^2{}_{rH} R_1 = 3 \cdot 11{,}73^2 \cdot 1{,}135 = 468{,}5 \text{ Vt;}$$

Elektromagnit quvvat

$P_Э = P_1 - P_{ucm} = P_1 - (P_{n1} - P_{r1}) = 11500 - (382 + 468{,}5) = 10650$ Vt

Rotor po‘latdagi isrofni hisobga olmasak rotor chulg‘amidagi isrof

$P_{r1} = P_Э - (P + P_{T.B}) = 10650 - (10000 + 100) = 550$ Vt.

Nominal sirpanish

$$S_H = \frac{P_{r.2.H}}{P_{Ý..H}} = \frac{550}{10650} = 0{,}0516 = 5{,}16\%$$

Kritik sirpanish

$$S_{SP} = \frac{R'_2}{\sqrt{R^2_1 + (x_1 + x'_2)^2}} = \frac{1{,}28}{\sqrt{1{,}135^2 + (2{,}7 + 3{,}8)^2}} = \frac{1{,}28}{6{,}6} = 0{,}194 = 19{,}4\%.$$

d) nominal momenti

$$M_H = 9{,}55\frac{P_Э}{b} = 9{,}55\frac{10650}{1500} = 67{,}8 \text{ Nm},$$

$$n = \frac{60f}{p} = \frac{3000}{2}1500 \text{ ayl/min}$$

Tekshiramiz:

$$M_H = 9{,}55\frac{P_H}{n_H} = 9{,}55\frac{P_H}{(1-S)n} = 9{,}55\frac{10000}{(1-0{,}0516)\cdot 1500} = 67{,}1 \text{ Nm.}$$

Farq 0,7 Nm, yani 1% ga yaqin.

Yurgizish momenti

$$M = 9{,}55\frac{3I'^2_{2K.T}R'_2}{n} \approx 9{,}55\frac{3I^2_{2K.T}R_2}{n} = 9{,}55\frac{3\cdot 54{,}83^2\cdot 1{,}28}{1500} = 73{,}6 \text{ Nm},$$

Yurgizish momentining nominal momentga nisbati

$$\frac{M_{юр}}{M_H} = \frac{73{,}6}{67{,}8} = 1{,}08 > 1.$$

Maksimal moment

$$M_{\max} = \frac{9{,}55}{1500}\cdot 3\cdot U^2_1 \frac{1}{2(R_1 + \sqrt{R^2_1 + x^2})} = \frac{9{,}55}{1500}\cdot 3\cdot 380^2 \cdot \frac{1}{2(1{,}135 + \sqrt{1{,}135^2 + 6{,}5^2})} = 166{,}8 \text{ Nm}$$

$x = (x_1 + x'_2) = (2{,}7 + 3{,}8) = 6{,}5$ Om.

Maksimal momentning nominal momentga nisbati

$$\frac{M_{\max}}{M_H} = \frac{166{,}8}{67{,}8} = 2{,}46.$$

2.4.4. 2.4.2-masaladan rotor chulg‘ami uzunligining yarmi $l_1 = 342$ mm.

Rotor chulg‘ami qisqa tutashtirilgan, sterjenning uzunligi $l_{стер} = 190$ mm, ko‘ndalang kesim yuzasi $A_{стер} = 72 мм^2$, qisqa tutashtiruvchi halqaning diametri $D_{хал} = 103 мм$, uning ko‘ndalang kesim yuzasi $A_{хал} = 310 мм$. Sterjen va halqa bir xil materialdan (AlSil2) tayyorlangan bo‘lib, solishtirma qarshiligi $\rho_{75} = 0{,}05$ mkOmm.

Quyidagilar topilsin:

a) stator va rotor chulg‘amining keltirilgan qarshiliklari:

b) agarda $m_{r1} = 5{,}05$ kg, $m_{стер} = 1{,}12$ kg, $m_{хал} = 0{,}25$ kg, tok zichligi $J_1 = 4{,}32 A/mm^2$, $J_{стер} = 1{,}92 A/мм^2$, $J_{хал} = 1{,}06 A/mm^2$ bo‘lsa, Chulg‘amlardagi isrof;

Yechish.

a) 2.4.2-masaladagi parametrlardan foydalanib

$$R_1 = \rho_{75}\frac{l_1 2\omega_1}{a_1 c_1 A_1} = 0{,}0216\frac{0{,}342\cdot 2\cdot 216}{1\cdot 2\cdot 0{,}636} = 2{,}51 \text{ Om.}$$

Rotor chulg‘amining keltirilgan qarshiligi

$$R'_2 = \frac{4m_1(\omega_1 k_{r1})^2}{z_2}\left(\rho_{стер}\frac{l_{стер}}{A_{стер}} + \frac{z^2}{4p^2\pi^2}\cdot 2\cdot\frac{D_{хал}\pi}{A_{хал}}\rho_{стер}\right) = \frac{43(216\cdot 0{,}831)^2}{30}\times$$

$$\times\left(0{,}05\frac{0{,}19}{72} + \frac{30}{4\cdot 2^2\cdot 3{,}14^2}\cdot\frac{2\cdot 0{,}103}{310}\cdot 0{,}05\right) = 1{,}71 + 0{,}26 = 1{,}97 \text{ Om.}$$

b) stator chulg‘amidagi isrof

$$P_{r1} = 2{,}47 J^2_r m_2 = 2{,}47\cdot 4{,}32^2\cdot 5{,}05 = 228{,}1 \text{ Vt}$$

Rotor chulg‘amidagi isrof

$$P_2 = 18{,}2(m_{стер}J^2_{стер} + t_{хал}J^2_{хал}) = 18{,}2(1{,}12\cdot 1{,}92^2 + 0{,}25\cdot 1{,}06^2) = 80{,}2 \text{ Vt.}$$

2.4.5. 2.4.2-masaladagi parametrlarga asosan asosiy magnit oqimiga to‘g‘ri keluvchi induktiv qarshilik hisoblansin. Uzunlik birligidagi solishtirma magnit o‘tkazuvchanliklar:

$\lambda_{n1} = 2{,}2\cdot 10^{-8}$ Gn, $\lambda_{n2} = 0{,}75\cdot 10^{-8}$ Gn, $\lambda_{тир} = 0{,}56\cdot 10^{-8}$ Gn, $\lambda_{лий} = 0{,}54\cdot 10^{-8}$ Gn.

Havo bo‘shlig‘idagi solishtirma koeffitsiyenti $\delta_{\delta 1} = 1{,}11\cdot 10^{-2}$, $\delta_{\delta 2} = 1{,}32\cdot 10^{-2}$. Dempfirlovchi koeffitsiyent $\Delta = 0{,}985.$

Yechish.

Havo bo‘shlig‘idagi asosiy magnit oqimga mos keluvchi induktiv qarshilik

$$x_\mu = \frac{4}{\pi}\mu_0 f_1 m_1 \omega^2_1 k^2_{r1}\frac{\tau\cdot l_n}{pk_\delta\delta(k_T+1)} = \frac{4}{\pi}\cdot 1{,}257\cdot 10^{-6}\cdot 50\cdot 3\cdot(216\cdot 0{,}831)^2\times$$

$$\times\frac{0{,}106\cdot 0{,}175}{2\cdot 1{,}128\cdot 0{,}5\cdot 10^{-3}(1{,}31+1)} = 55{,}1 \text{ Om.}$$

Pazdagi sochilma induktiv qarshilik

$$x_{sm_1} = 4 f_1\pi\frac{\omega^2_1}{p}\left(\frac{k_{r1}}{k_{r2}}\right)^2 l_p\frac{\lambda^2_n}{q'_2} = 4\cdot 3{,}14\cdot 50\cdot\frac{216^2}{2}\left(\frac{0{,}831}{1}\right)^2\times$$

$$\times 17{,}5\cdot\frac{0{,}75\cdot 10^{-8}}{2{,}5} = 0{,}53 \text{ Om.}$$

Chulg‘amning tirsak qismidagi sochilma induktiv qarshilik ($l_1 = 34{,}2$ sm)

$$x_{SEEE} = 4\pi \cdot f_1 \frac{\omega^2_1}{p} l_p \frac{\lambda_{mup}}{q_1} = 4 \cdot 3{,}14 \cdot 50 \cdot \frac{216^2}{2} \cdot 17{,}5 \cdot \frac{0{,}56 \cdot 10^{-8}}{3} = 0{,}48 \text{ Om.}$$

Havo bo‘shlig‘idagi sochilma induktiv qarshilik

$x_{s\delta 1} = \Delta\sigma_{\delta 1} x_\mu = 0{,}985 \cdot 1{,}11 \cdot 10^{-2} \cdot 55{,}1 = 0{,}6$ Om

$x'_{s\delta 2} = \sigma_{\delta 2} x_\mu = 1{,}32 \cdot 10^{-2} \cdot 55{,}1 = 0{,}73$ Om.

Paz qiyshiqligidagi sochilma induktiv qarshilik

$$x'_{SKKII} = 4\pi \cdot f_1 \frac{\omega^2_1}{p} l_p \frac{\lambda_{кий}}{q_1} = 4 \cdot 3{,}14 \cdot 50 \cdot \frac{216^2}{2} \cdot 17{,}5 \cdot \frac{0{,}54 \cdot 10^{-8}}{3} = 0{,}46 \text{ Om.}$$

Mashinaning yig‘indi induktiv qarshiligi

$x_s = x_{sn1} + x'_{sn1} + x_{SKKII} + x_{s\delta 1} + x'_{s\delta 2} + x'_{SKKII} = 1{,}88 + 0{,}53 + 0{,}48 + 0{,}6 + 0{,}73 + 0{,}46 = 4{,}68$ Om,

2.4.6. 8 qutbli uch fazali asinxron motorning nominal kuchlanishi $U_H = 380$ V; $I_H = 51$ A; $n_H = 725$ ayl/min; $\frac{M_{mfx}}{M_H} = 3{,}3$; rotor zanjirining aktiv qarshiligi $R_2 = 0{,}07$ Om (stator zanjiridagi aktiv qarshilik hisobiga olinmasin).

Quyidagilar topilsin:

a) kritik sirpanish
b) bir xil yuklamada kuchlanishni 350 V gacha kamaytirib, ishchi sirpanish;

Yechish.

a) sinxron aylanish chastotasi $n_1 = 750$ ayl/min.

Nominal sirpanish

$$S_H = \frac{n_1 - n}{n_1} = \frac{750 - 725}{750} 0{,}033.$$

$$\frac{M_H}{M_{\max}} = \frac{2}{\frac{S_H}{S_{KP}} + \frac{S_{KP}}{S_H}} = \frac{1}{3{,}3}.$$

bundan S_{KP} ni topib, S_H o‘rniga qo‘ysak $S^2_{KP} - 0{,}22 S_{KP} + 0{,}0011 = 0$ ko‘rinishdagi ikkinchi darajali tenglamaga ega bo‘lamiz. Uning yechimi $S_{KP1} = 0{,}21;\ S_{KP2} = 0{,}005$.

$S_{KP} = 0{,}005$ S_H dan kichik, shu sababli to‘g‘ri kelmaydi.

Demak, $S_{KP} = 0{,}21$ maksimum momentga to‘g‘ri keladi.

b) moment

$$\frac{M_H}{M_{KP}} = \left(\frac{U}{U_H}\right)^2 \frac{2}{\frac{S}{S_{KP}} + \frac{S_{KP}}{S}}.$$

$M_H / M_{\max} = 1/3{,}3$ ni hisobga olsak,

$\frac{S}{S_{KP}} + \frac{S_{KP}}{S} = 6{,}6(\frac{U}{U_H})^2$ ga ega bo‘lamiz.

Bu tenglamaga U va S_{KP} ning qiymatlarini qo‘yib, $S^2 - 1{,}18S + 0{,}044 = 0$ tenglamaga ega bo‘lamiz. Uning echimi $S_1 = 1{,}14$ va $S_2 = 0{,}038$ bo‘ladi. $S_1 = 1{,}14$ motorning tormoz ish xolatiga to‘g‘ri keladi. Shu sababli kuchlanish pasaygandagi ishchi sirpanish $S_2 = 0{,}038$ hisoblanadi.

2.4.7. Kuchlanish 380 V bo‘lgan uch fazali qisqa tutashtirilgan rotorli asinxron motorni qisqa tutashuv tajribasi natijasidan $z_{KT} = 6{,}2$ Om, $\cos\varphi_{KT} = 0{,}42$, $I_{KT} = 65$ A. Motorning stator chulg‘ami Y ulangan.

Motorni yurgizishda quyidagi ikkita talab bajarilishi kerak:

Yurgizish toki 40 A dan oshmasin;

Yurgizish momenti qisqa tutashuv momentidan 0,34 kichik bo‘lmasin ($M_{þð} \geq 0{,}34M_{þð}$). Motoro transformator yoki induktivlik orqali yurgizilsin.

Quyidagilar topilsin:

a) transformator bilan yurgizilgandagi transformatsiyalash koeffitsiyenti va tarmoq tokining sakrashi (κ_{TP}, $I'_{юр}$);

b) induktivlik yordamida yurgizilgan induktiv qarshilik $x_{юр}$.

Yechish.

a) $I'_{юр} < 40$ A va $м'_{юр} \geq 0{,}34м_{юр}$ ikki shartdan, momentlar bo‘yicha muhim hisoblanadi.

$м'_{юр} = 0{,}34м_{юр}$, yoki $м'_{юр} \geq м_{юр} / \kappa^2_{TP}$.

Ikki tenglamadan κ_{TP} ni topamiz

$\kappa'_{TP} = 2{,}94$ va $\kappa_{TP} = \sqrt{2{,}94} = 1{,}72.$

$\kappa_{TP} = 1{,}7$ deb qabul qilamiz.

Zarbiy tok

$I'_{юр} = \frac{I_{1KT}}{\kappa^2_{TP}} = \frac{65}{1{,}7^2} = 22{,}5$ A.

b) stator chulg‘amiga ketma-ket ulangan induktivlik zarbiy tokni κ martaga kamaytiradi ($I'_{юр} = \kappa I_{1KT}$).

$M'_{юр} = \kappa^2 M_{юр}$; $M'_{юр} \geq 0{,}34M_{юр}$.

Bu ikki tenglamadan

$M'_{юр} \geq 0{,}34M'_{юр} / \kappa^2$,

bundan

$\kappa^2 \geq 0{,}34$ yoki $\kappa \geq \sqrt{0{,}34} = 0{,}585$.

$\kappa = 0{,}59$ deb qabul qilamiz.

Zarbiy tok

$I'_{юр} = \kappa I_{1KT} = 0{,}59 \cdot 65 = 38{,}4$ A

To‘la yurgizish qarshiligi

$z_{юр} = jx + z_{KT} = R + j(x_S + x)$

$z_{юр} = z_{KT} / \kappa$.

Ikki tenglamadan x ni topamiz

$$x = \sqrt{\left(\frac{z_{KT}}{\kappa}\right)^2 - R^2 - x_S}.$$

$R = z_{KT} \cos\varphi_{KT} = 6{,}2 \cdot 0{,}42 = 2{,}6$ Om;

$x_S = z_{KT} \sin\varphi_{KT} = 6{,}2 \cdot 0{,}912 = 5{,}65$ Om;

$$x = \sqrt{\left(\frac{6{,}2}{0{,}59}\right)^2 - 2{,}6^2 - 5{,}65} = 4{,}53 \text{ Om}.$$

2.4.8. Qisqa tutashgan rotorli uch fazali motorning stator chulg‘ami Δ ulangan. Motorning nominal parametlari quyidagicha:

$P_H = 37$ kVt, $U_H = 380$ V, $\cos\varphi_H = 0{,}86$, $n_H = 1450$ ayl/min, $I_H = 73$ A.

Motorni tarmoqqa to‘g‘ridan to‘g‘ri ulashdagi shartlar:

$I_{юр} / I_H = 6$; $M_{юр} / M_H = 2$.

Quyidagilar aniqlansin:

a) Y dan Δ ga ulangandagi yurgizish toki $I_{\text{Þ}\text{Ð}Y}$ va momenti $M_{\text{Þ}\text{Ð}Y}$;

b) transformator yordamida yurgizilgandagi transformatsiyalash koeffitsiyenti.

Yechish.

a) nominal moment

$$M_H = \frac{P_H}{\omega} = \frac{37000}{2\pi \cdot 1450/60} = 243{,}3 H \cdot м.$$

Yurgizish momenti va toki (berilgan shartga asosan)

$M_{юр} = 2M_H = 2 \cdot 243{,}3 = 486{,}6 H \cdot м$;

$I_{юр} = 6I_H = 6 \cdot 73 = 438$ A

Y dan Δ ulab yurgizilgan tok va moment 3 marta kamayadi

$$I_{юрY} = \frac{I_{юр}}{3} = \frac{438}{3} = 146 \text{ A}.$$

$$M_{юрY} = \frac{M_{юр}}{3} = \frac{486{,}6}{3} = 162{,}2 H \cdot м.$$

b) transformator bilan yurgizilganda $M'_{юр} = M_{юр}/3$ shart bajarilishi lozim.

$M'_{юр} = M_{юр}/\kappa^2_{TP}$. Bu ikki tenglamadan κ_{TP} ni topamiz

$M_{юр}/3 = M'_{юр}/\kappa^2_{TP}$ bundan

$\kappa^2_{TP} = 3; \kappa_{TP} = \sqrt{3} = 1{,}73.$

Zarbiy tok

$$I_{юр} = \frac{I}{\kappa^2_{TP}} = \frac{438}{3} = 146 \text{ A}.$$

2.4.9. 4A180S4UZ tipdagi uch fazali qisqa tutashgan asinxron motorning stator chulg‘amlari Y sxemada ulangan bo‘lib, $f = 50$ Gs, liniya kuchlanishi $U_л = 380$ V bo‘lgan uch fazali tok tarmog‘iga ulangan.

Motorning pasportida quyidagi nominal malumotlar berilgan:

$P_H = 22$ kVt, $n = 1470$ ayl/min, $\eta_H = 0/9$; $\cos\varphi_H = 0{,}9$;

$2p = 4$, $M_{\max}/M_H = 2{,}3$; $M_{пд}/M_H$ 1,4; $I_{пд}/I_H = 6{,}5$

Quyidagilar topilsin:

a) rotorning nominal sirpanishi;
b) motorning nominal, yurgizish va maksimal momentlari;
c) motorning tarmoqdan istemol qiladigan quvvati;
d) motorning nominal va yurgizish toklari;
e) tarmoq kuchlanishi 10 va 20 % ga pasaygandagi yurgizish momenti va toki.

Yechish.

a) Motorning qutblar soni

$$p = \frac{60f}{n_1} = \frac{60 \cdot 50}{1500} = 2 \text{ ,}$$

n_1 – sinxron tezlik

Rotorning nominal sirpanishi

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

b) Nominal aylantiruvchi moment

$$M_H = 9550\frac{P_H}{n} = 9550\frac{22}{1470} = 143 H \cdot м$$

Yurgizish momenti

$$M_{юр} = 1{,}4M_H = 1{,}4 \cdot 143 = 200{,}2 H \cdot м$$

Maksimal aylantiruvchi moment

$$M_{\max} = 2{,}3M_H = 2{,}3 \cdot 143 = 328{,}9 H \cdot м$$

c) Momentning elektr tarmog‘idan istemol qiladigan quvvat

$$P_1 = \frac{P_H}{\eta_H} = \frac{22}{0{,}9} = 24{,}44 \text{ kVt};$$

d) Elektr tarmog‘idan qabul qiladigan nominal tok

$$I_H = \frac{P_H}{\sqrt{3}U_H \eta_H \cos\varphi_H} = \frac{22}{\sqrt{3}\cdot 0{,}22 \cdot 0{,}9 \cdot 0{,}9} = 71{,}43 \text{ A}$$

Yurgizish toki

$$I_{юр} = 6{,}5 I_H = 6{,}5 \cdot 71{,}43 = 464{,}3 \text{ A}$$

e) Asinxron motorning aylantiruvchi momenti tarmoq kuchlanishining kvadratiga proporsional (mutanosib). Agar tarmoq kuchlanishi 10% ga pasaysa, u $0{,}9U_{1H}$ ga teng bo‘ladi. U holda aylantiruvchi moment nominalga nisbatan $(0{,}9)^2 = 0{,}81$ ni tashkel etadi. Shu kuchlanishdagi yurgizish momenti

$$M'_{юр} = 0{,}81 M_{юр} = 0{,}81 \cdot 200{,}2 = 162{,}1 Н \cdot м$$

Yurgizish toki

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

Agar tarmoq kuchlanishi 20% ga kamaysa, u $0{,}8U_{1H}$ ga teng bo‘ladi.

Aylantiruvchi moment nominal momentning $(0{,}8)^2 = 0{,}64$ ni tashkil etadi. Shu kuchlanishdagi yurgizish momenti

$$M'_{юр} = 0{,}64 M_{юр} = 0{,}64 \cdot 200{,}2 = 128 Н \cdot м.$$

Yurgizish toki

$$I'_{юр} = 0{,}8 I_{юр} = 0{,}8 \cdot 464{,}3 = 371{,}5 \text{ A}.$$

2.4.10. Sexda o‘rnatilgan uch fazali asinxron motorning istemol qiladigan umumiy aktiv quvvati $P_M = 300$ kVt, kuchlanishi $U_H = 380$ V va quvvat koeffitsiyentining o‘rtacha qiymati $\cos\varphi_{ур} = 0{,}7$. Yoritgich chiroqlarining istemol qiladigan umumiy quvvat $P_{ёр} = 20$ kVt. Sexning quvvat koeffitsiyentini $\cos\varphi_2 = 0{,}95$ gacha oshirish uchun kondensatorlar batareyasidan foydalanish tavsiya etiladi.

Quyidagilar aniqlansin:

a) Kondensatorlar o‘rnatilmasdan avvalgi sex yuklamalarining umumiy quvvati P_1;
b) Kondensator batareyasining sig‘imi S;
c) Kondensator batareyasi o‘rnatilmasdan avval va o‘rnatilgandan so‘ng liniya simlaridagi I_1 va I_2 toklar.

Yechish.

a) kondensatorlar batareyasi o‘rnatilmasdan avvalgi umumiy aktiv quvvat

$$P_1 = P_{ї} + P_{ўд} = 300 + 20 = 320 \text{ kVt}.$$

Reaktiv quvvat

$$Q_1 = P_M tg\varphi_{óð} = 300 \cdot 1 = 300 \text{ kVt} \quad (tg\varphi_{ур} = 1)$$

$\cos\varphi_1$ ni topish uchun, $tg\varphi_1$ ni topamiz

$tg\varphi_1 = Q_1 / P_1 = 300/320 = 0{,}938$

U holda $\cos\varphi_1 = 0{,}734;\ \cos\varphi_2 = 0{,}95$ bo‘lganda $tg\varphi_2 = 0{,}328$

b) Kondensatorlar batareyasining sig‘imi

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

c) Liniya simlaridagi toklar

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

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

2.5. Mustaqil yechish uchun masalalar

2.5.1. Stator chulg‘amlari 2r=6 qutbli bo‘lgan asinxron motor rotorning sirpanishi $S = 0{,}04$, kuchlanish chastotasi $f = 50$ Gs. Rotorning aylanish chastotasi aniqlansin. (**J:** $n = 960$ ayl/min)

2.5.2. Asinxron motor stator chulg‘amidagi aylanuvchi magnit maydonning aylanish chastotasi $n_1 = 1000$ ayl/min. Sirpanishlar qiymati $S = 1;\ 0;\ -0{,}5;\ -1$ bo‘lganda rotorning tezligini aniqlang va olingan qiymatlarning fizik manosini tushuntirib bering.

(**J:** 0; 1000 ayl/min; 1500 ayl/min; 2000 ayl/min)

2.5.3. Uch fazali qisqa tutashgan rotorli asinxron motorning stator chulg‘amidan o‘tayotgan tok 10,6 A, tarmoqning faza kuchlanishi $U_\phi = 220$ V bo‘lganda istemol qiladigan quvvati $P_1 = 3{,}55$ kVt. Agar motorning foydali quvvati $P_2 = 3$ kVt bo‘lsa, motorning FIK va quvvat koeffitsiyenti nimaga teng? (**J:** $\eta = 0{,}845;\ \cos\varphi = 0{,}88.$)

2.5.4. Asinxron mashinaning chulg‘am koeffitsiyenti va magnit oqimi hisoblang. Mashinaning quyidagi parametlari berilgan:

$$U_H = 380/220 \text{ V};\ 2p = 4;\ f = 50 \text{ Gs};$$

Qutb va fazaga to‘g‘ri keluvchi pazlar soni $q_1 = 3;\ y/\tau = 7/9$ va har bir pazdagi uramlar soni $z_{n1} = 38$. (**J:** $\kappa_{r1} = 0{,}902;\ \Phi = 0{,}482 \cdot 10^{-2}$ Vb)

2.5.5. Uch fazali asinxron motorning nominal kuchlanishi $U_H = 380$ V, stator chulg‘ami Δ ulangandagi nominal tok $I_H = 14{,}5$ A. chulg‘am paramentlari:

$\omega_1 = 320$ va $\kappa_{r1} = 0{,}92;\ F_{é} = 716$ A. Salt ishlash tokining reaktiv tashkil etuvchisi nominal tokning necha foizini tashkel qiladi?

(**J:** $I_\mu = 1{,}8$ A (21,4%))

2.5.6. Rotorning aylanish chastotasi: 294; 1480; 985; 735 va 600

ayl/min dan bo‘lgan uch fazali qisqa tutashgan rotorli asinxron matorlarning nominal aylantiruvchi momentlari mos holda: 178,43; 355; 533,7; 715; 875,8;

$H \cdot м$. Motorlarning quvvati aniqlansin. (**J:** 55 kVt)

2.5.7. 4A200M6UZ tipdagi uch fazli qisqa tutashgan rotorli asinxron motorning nominal yuklamada $n_H = 975$ ayl/min tezlik bilan aylanmoqda.

Manba kuchlanishining chastotasi $f_1 = 50$ Gs. Motorning juft qutblar soni r, sinxron tezligi n, va nominal sirpanish S_H topilsin. Shuningdek $S = 5\%$ bo‘lganda motor rotorida xosil bo‘lgan EYUK ning chastotasi f_2 aniqlansin.

(**J:** $p = 3$; $n_H = 1000$ ayl/min; $S_H = 2{,}5\%$; $f_2 = 2{,}5$ Gs)

2.5.8. 4A160S2UZ tipdagi uch fazali tok tarmog‘ida ulangan.

Rotorning sirpanishi 2% va 6% ga teng bo‘lganda, rotorning aylanish burchak tezligi ω_2 aniqlansin. (**J:** $\omega_2 = 308$ rad/s; $\omega_2' = 295$ rad/s)

2.5.9. Ko‘p tezlikli asinxron matorning stator chulg‘amlarini qayta ulangan, uning juft qutblar soni 2 martaga ortadi. Aylanuvchi magnet maydonning va rotorning aylanish chastotasi qanday o‘zgaradi?

(**J:** 2 marta kamayadi)

2.5.10. Nominal quvvatlari $P_{2H}' = 0{,}5$ kVt, $P_{2H}'' = 1$ kVt bo‘lgan bir fazali asinxron motorlar chastotasi $f = 50$ Gs, faza kuchlanishi $U_ф = 220$ V bo‘lgan o‘zgaruvchi tok tarmog‘iga ulangan. Motorlarning quvvat koeffitsiyentlari tegishlicha $\cos\varphi_{2H}' = 0{,}7$; $\cos\varphi_{2H}'' = 0{,}9$.

Motorlar chulg‘amidan oqayotgan toklar, reaktiv va to‘la quvvatlar aniqlansin. (**J:** $I_{1H} = 3{,}25A$; **/** $_{2H} = 5{,}05A$; $Q_1 = Q_2 = 0{,}5$ kVA; $S_1 = 0{,}7$ kVA; $S_2 = 1{,}1$ kVA)

3. Sinxron mashinalar

(Asosiy kattaliklar va ularni aniqlash tenglamalari)

3.1. Salt ishlash rejimida sinxron mashinada bo‘ladigan elektromagnit jarayonlar

Salt ishlash rejimida sinxron mashinaning stator (yakor) toki nolga teng bo‘ladi. Magnit maydon qo‘zg‘atish chulg‘ami tomonidan hosil qilinadi.

Quzg‘atish chulg‘ami ikki xil bo‘ladi: tarqalgan chulg‘am (noayon qutbli rotorda) va yig‘ilgan chulg‘am (ayon qutbli rotorda).

Tarqalgan chulg‘amning MYUK

$$F_{fm} = I_f W_f, \qquad (3.1)$$

bu yerda: $W_f = W_k q/2 -$ qo‘zg‘atish chulg‘amining o‘ramlar soni;

q – qutbdagi o‘ralgan pazlar soni;

W_k – pazdagi g‘altak o‘ramlarining soni; I_f – quzg‘atish chulg‘amining toki.

Asosiy garmonika MYUK ning amplitudasi

$$F_{f\cdot 1m} = \frac{4\sin(p\pi/2)}{\pi p\pi/2} F_m, \qquad (3.2)$$

bu yerda: $p = â/\tau$ – qutbning chulg‘am o‘ralgan qismini nisbiy uzunligi;

v-qutb bo‘linmasining chulg‘am o‘ralgan qismi uzunligi.

Yig‘ilgan cho‘lg‘amning MYUK

$$F_{fm} = I_f W_f . \qquad (3.3)$$

Salt ishlash rejimida quzg‘atish chulg‘ami xosil qilgan magnit maydonining shakli quyidagi koeffitsiyentlarga bog‘liq bo‘ladi:

Qo‘zg‘atish chulg‘ami maydoni shaklining koeffitsiyenti

$$k_f = B_{\delta 1m} / B_\delta . \qquad (3.4)$$

bu yerda: $B_{\delta 1m}$ – xavo bo‘shlig‘idagi induksiyaning asosiy garmonika amplitudasi; $B_\delta = \mu_0 \frac{F_f}{\sigma}$-qutb o‘qidagi induksiyaning radial tashkel etuvchisi.

Noayon qutbli mashina uchun (to‘yinish hisobga olinmasin)

$$k_f = 8\sin\left(\frac{p\pi}{2}\right)/(\pi^2 p). \qquad (3.5)$$

Ayon qutbli mashina uchun (to‘yinish hisobga olinmasin)

$$k_f = f(\alpha, \gamma, \varepsilon), \qquad (3.6)$$

bu yerda: $a = â_p/\tau$ – nisbiy qutb yoyi; $\gamma = \delta_m/\delta'$ – qutb chekkalaridagi nisbiy havo bo‘shlig‘i. Bu yerda $\delta' = k_\delta \delta$ – ekvivalent havo bo‘shlig‘i, δ_m – masimal,

δ – minimum havo bo‘shlig‘i, k_δ – havo bo‘shlig‘i koeffitsieti.

Qo‘zg‘atish oqimi koeffitsiyenti

$$k_\phi = \Phi_{fm} / \Phi_{f1m}, \qquad (3.7)$$

bu yerda: $\Phi_{fm} = \tau \cdot l_\delta \Phi_{ðypm}$ – to‘la (real) o‘zaro induksiya oqimi;

$\Phi_{f1m} = \left(\frac{2}{\pi}\right)\tau \cdot l_\delta B_{\delta 1ь}$-induksiya asosiy garmonikasining oqimi; $B_{ðð}$ – havo bo‘shlig‘idagi o‘rtacha induksiya.

Qutb berkilish hisobiy koeffitsiyenti

$$a_\delta = B_{ðyp} / B_\delta . \qquad (3.8)$$

EDS shaklining koeffitsiyenti (to‘yinish hisobga olinmagan)

$$k_в = B_{\delta T1} / B_{\delta yp} = \pi / 2\sqrt{2k_ф}\,, \qquad (3.9)$$

bu yerda $B_{\delta T1} = B_{\delta 1T} / \sqrt{2}$ – induksiya asosiy garmonikasining tasir etuvchi qiymati.

O‘zaro induksiya to‘la qarshiligi

$$\Phi_m = \Phi_{fm} = k_ф \Phi_{f1m} = E_f / (4k_в f_1 \omega_1 k_{к1})\,, \qquad (3.10)$$

Qo‘zg‘atish chulg‘amidagi MYUK3

$$F_{fm} = F_1 + F_2\,, \qquad (3.11)$$

bu yerda: $F_1 = F_\delta + F_{z1} + F_{\alpha 1}$; F_δ – havo bo‘shlig‘ining magnit kuchlanishi;

F_{z1} – stator tishining magnit kuchlanishi;

$F_{\alpha 1}$ – stator yarmasining kuchlanishi;

F_2 – rotorning magtit kuchlanishi.

Stator magnit o‘tkazgichining to‘yinish koeffitsiyenti

$$\kappa_{Za} = (F_\delta + F_{Z1} + F_{a1}) / F_\delta\,. \qquad (3.12)$$

3.2. Yakor chulg‘amining magnit yurituvchi kuchi, magnit maydoni, EYUK va parametlari

Yakor (stator) chulg‘ami asosiy garmonikasining amplitudasi

$$F_{am} = (\sqrt{2} / \pi) m_1 (l \omega_1 k_{r1} / p). \qquad (3.13)$$

Yakor chulg‘ami MYUK ni bo‘ylama tashkil etuvchisining amplitudasi

$$F_{dm} = (\sqrt{2} / \pi) m_1 (I \omega_1 k_{r1} / p) \qquad (3.14)$$

Yakor chulg‘ami MYUK ni ko‘ndalang tashkil etuvchisining amplitudasi

$$F_{qm} = (\sqrt{2} / \pi) m_1 (I_d \omega_1 k_{r1} / p)\,. \qquad (3.15)$$

bu yerda: $I_d = I \sin\beta$ va $I_q = I \cos\beta$, β – EYUK $\dot{E}_f$ va tok $\dot{I}$ (yoki MYUK F_{fm}) orasidagi burchak.

Noayon qutbli sinxron mashina uchun:

Havo bo‘shlig‘idagi yakor maydoni induksiyasining asosiy garmonikasi amplitudasi

$$B_{alt} = \mu_0 F_{am} / (\delta k_\delta)\,. \qquad (3.16)$$

Yakor chulg‘ami bilan ilashgan o‘zaro induksiya magnit oqimi

$$\Phi_m = (2 / \pi) \tau \cdot l_\delta B_{ald}. \qquad (3.17)$$

O‘zaro induksiya oqimining magnit ilashimligi

$$\Psi_{am} = \omega_1 k_{01} \Phi_m. \qquad (3.18)$$

Yakor chulg‘ami fazasida o‘zaro induksiya oqimi tasirida hosil bo‘lgan EYUK

$$E_a = 4{,}44 f_1 \Phi_m \omega_1 \kappa_{r1}. \quad (3.19)$$

Ayon qutbli sinxron mashina uchun:

Bo‘ylama va ko‘ndalang MYUK hosil qilgan induksiyalarning asosiy garmonikalari amplitudasi

$$B_{adlm} = k_d B_{adm}; B_{aqm} = k_q B_{aqm}. \quad (3.20)$$

bu yerda: k_d va k_q-bo‘lma va ko‘ndalang o‘qlar bo‘yicha maydon shaklining koeffitsiyentlari; $B_{adm} = \mu_0 F_{dm} / \delta k_\delta$ va $B_{aqm} = \mu_0 F_{qm} / \delta k_\delta$ - bo‘ylama va ko‘ndalang yakor MYUK lari hosil qilgan induksiyalarning amplitudasi.

Tokning bo‘ylama tashkel etuvchisi I_d ga mos keluvchi o‘zaro induksiya magnit oqimi, oqim ilashimligi va EYUK:

$$\Phi_{adm} = (2/\pi)\tau \cdot l_\delta k_d B_{adm};$$
$$\Psi_{adm} = \omega_1 k_{01} \Phi_{фвв}; \quad (3.21)$$
$$E_{ad} = 4{,}44 \omega_1 k_{r1} f \Phi_{фвв}.$$

Yakor tokining ko‘ndalang tashkel etuvchisiga mos keluvchi o‘zaro induksiya magnit oqimi, oqim ilashimligi va EYUK:

$$\Phi_{aqm} = (2/\pi)\tau \cdot l_\delta k_q B_{aqm};$$
$$\Psi_{aqm} = \omega_1 k_{01} \Phi_{aqm}; \quad (3.22)$$
$$E_{aq} = 4{,}44 \omega_1 k_1 f \Phi_{aqm}.$$

To‘yinmagan noayon qutbli sinxron mashinada quzg‘atish chulg‘ami MYUK yakor chulg‘ami MYUK ga ekvivalent bo‘ladi:

$$F_{afm} = k_a F_{am}, \quad (3.23)$$

bu yerda: $k_a = 1/k_f$ -yakor reaksiyasi koeffitsiyenti.

To‘yingan ayon qutbli sinxron mashinaning qo‘zg‘atish chulg‘ami MYUK yakorning bo‘ylama va ko‘ndalang MYUK lariga ekvivalent bo‘ladi:

$$F_{adm} = k_{ad} F_{dm}; \; F_{aqm} = k_{aq} F_{qm}, \quad (3.24)$$

bu yerda: $k_{ad} = k_d / k_f$ –bo‘ylama o‘q bo‘yicha yakor reaksiyasi koeffitsiyenti;

$k_{aq} = k_q / k_f$ – ko‘ndalang o‘q bo‘yicha yakor reaksiyasi koeffitsiyenti.

Yakor chulg‘ami parametlari:

Yakor chulg‘ami fazasidagi sochilma (tarqoq) induktiv qarshilik

$$x_\delta = 4\pi\mu_0 f W_1^2 (l_\delta / p q_1) \lambda_{\delta 1}, \quad (3.25)$$

bu yerda: $\lambda_{\delta 1} = \lambda_{n1} + \lambda_{T1} + \lambda_{r1} + \lambda_{\partial 1}$ -sochilma oqim ilashimligi uchun o‘tkazuvchanlik koeffitsiyenti.

Noayon qutbli sinxron mashina yakor chulg‘amining asosiy induktiv

qarshiligi

$$x_a = 4\mu_0 m_1 f(\omega_1 k_{r1})^2 \lambda_\delta / (\pi p), \quad (3.26)$$

bu yerda: $\lambda_\delta = \tau \cdot l_\delta / (k_\delta \delta)$ -bir qutbli to‘g‘ri keluvchi havo bo‘shlig‘ining o‘tkazuvchanlik koeffitsiyenti. Bo‘ylama va ko‘ndalang o‘qlar bo‘yicha yakor chulg‘amining asosiy induktiv qarshiliklari.

$$x_{ad} = \frac{4\mu_0}{\pi p} m_1 f(\omega_1 k_{r1})^2 \lambda_{ad};$$

$$x_{aq} = \frac{4\mu_0}{\pi p} m_1 f(\omega_1 k_{r1})^2 \lambda_{aq}, \quad (3.27)$$

bu yerda: $\lambda_{ad} = k_d \tau \cdot l_\delta / (k_\delta \delta)$ va $\lambda_{aq} = k_q \tau \cdot l_\delta / (k_\delta \delta)$-bo‘ylama va ko‘ndalang o‘qlar bo‘yicha havo bo‘shlig‘ining o‘tkazuvchanlik koeffitsiyentlari.

Naoyon qutbli sinxron mashina yakor chulg‘amining induktiv qarshiligi

$$x_1 = x_\delta + x_a. \quad (3.28)$$

Ayon qutbli sinxron mashina yakor chulg‘amining bo‘ylama va ko‘ndalang o‘qlar bo‘yicha induktiv qarshiliklari

$$x_d = x_\delta + x_{ad}; \quad x_q = x_\delta + x_{aq}. \quad (3.29)$$

3.3. Sinxron mashina quvvati va foydali ish koeffitsiyenti (FIK)

Birlamchi motordan generatorga berilayotgan mexanik quvvat

$$P_1 = M_1 \Omega, \quad (3.30)$$

bu yerda: M_1 -motor aylaniyotgan tomonga yo‘nalgan aylantiruvchi moment;

Ω – burchak tezlik.

Generator rotoriga berilgan mexanik quvvat

$$P_B = P_1 - P_f / \eta_f = M_{мех} \Omega. \quad (3.31)$$

bu yerda: P_f / η_f -quzg‘atgichning aylantirishga sarf bo‘ladigan mexanik quvvati; $P_f = R_f I_f^2$-qo‘zg‘atish chulg‘amidagi quvvat isrofi; R_f – qo‘zg‘atish chulg‘amining aktiv qarshiligi; η_f – qo‘zg‘atgichning FIK; $M_B = M_1 - P_f / (\eta_f \Omega)$-mashina rotoriga tasir etuvchi moment.

Elektromagnit quvvatga aylantiruvchi mexanik quvvat

$$P_{мех} = P_B - P_T - P_{M,K} = M\Omega = P_{ЭМ}, \quad (3.32)$$

bu yerda: P_T – mexanik isrof, $P_{M.K}$ – magnit o‘tkazgichdagi qushimcha isrof.

Yuklamadagi generator tomonidan berilayotgan aktiv quvvat

$$P = m_1 UI \cos\varphi = P_{эл} - P_{э1}, \quad (3.33)$$

bu yerda: $P_{э1} = mRI^2$-yakor chulg‘amidagi elektr isrofi; R – yakor chulg‘amining aktiv qarshiligi.

Sinxron generatorning FIK

$$\eta = P / P_1 = 1 - \sum P / (P + \sum P), \qquad (3.34)$$

bu yerda: $\sum P = P_f / \eta_f + P_T + P_{м.к} + P_м + P_{э1}$ – yig‘indi isrof.

Elektromagnit quvvat

$$P_{эм} = T_1 E_y I' \cos \beta_v', \qquad (3.35)$$

bu yerda: E_v – o‘zaro induksiya EYUK;

$I = \sqrt{(I_M + I\cos\beta_v)^2 + (I\sin\beta_v)^2}$ – qo‘shimcha tok $I_M = P_M / (m_1 E_v)$ ni xisobga olingandagi yakor toki;

$\cos\beta_v' = (I\cos\beta_v + I_M)/I'$; $\beta_v - E_v$ va I orasidagi burchak.

3.4. Sinxron mashinalarning parallel ishlashi

Noayon qutbli sinxron mashinaning aktiv va reaktiv quvvati $P = \dfrac{m_1 U E_f \sin\gamma}{x_1}$;

$$Q = \frac{m_1 U E_f \cos\gamma}{x_1}. \qquad (3.36)$$

Ayon qutbli sinxron mashinaning aktiv va reaktiv quvvati

$$\begin{aligned} P &= \frac{m_1 U E_f \sin\gamma}{x_d} + \frac{m_1 U^2}{2}\left(\frac{1}{x_q} - \frac{1}{x_d}\right)\sin 2\gamma, \\ Q &= \frac{m_1 U E_f \cos\gamma}{x_d} - \frac{m_1 (U\cos\gamma)^2}{x_d} - \frac{m_1 (U\sin\gamma)^2}{x_q}. \end{aligned} \qquad (3.37)$$

Noayon va ayon qutbli sinxron mashinaning maksimal quvvati $P_m = m_1 E_f U / x_1$

$$P_m = P'\sin\gamma + P''\sin 2\gamma = P'\sin\gamma_m\left(1 + \frac{2}{n}\cos\gamma_m\right), \qquad (3.38)$$

bu yerda: $\gamma_m = \pm ark\cos(\sqrt{n^2 + 32} - n)/8$;

$n = P'/P'' = 2E_f x_q / \left[U(x_d - x_q)\right]$;

$$P' = \frac{m_1 U E_f}{x_d}; P'' = (m_1 U^2/2)(1/x_q - 1/x_d). \qquad (3.39)$$

Noayon qutbli sinxron generatorning statik yuklanish qobilyati

$$\kappa_{ю} = P_{TH} / P_H = E^*_{fH} / (x_d^* \cos\varphi_H) \qquad (3.40)$$

Ayon qutbli sinxron mashinaning solishtirma sinxronlovchi momenti

$$m_c = \frac{\Delta m}{\Delta \gamma} = \frac{m_1 U E_f}{\Omega x_d}\cos\gamma + m_1 U^2 \left(\frac{1}{x_q} - \frac{1}{x_d}\right)\cos 2\gamma . \qquad (3.41)$$

Ayon qutbli sinxron mashinaning maksimal momentining karrali (statik yuklanish qobilyati)

$$м_{TH} / м_H = E^*_{fH} / (x^*_d \cos\varphi_H) . \qquad (3.42)$$

3.5. Namunaviy masalalar yechish

3.5.1. Ikki qutbli noayon qutbli sinxron mashinaning ichki sinusoidalshaklida bo‘lishini ta’minlash uchun, rotor qutb bo‘linmasining chulg‘am o‘ralgan qismini uzunligini aniqlang.

Yechish.

$$\tau = \frac{\pi D_1}{2p} = \frac{\pi \cdot 1}{2} = 15{,}7 \text{ m}.$$

Qutb bo‘linmasining chulg‘am o‘ralgan qismi uzunligi

$в = p\tau = 0{,}67 \cdot 1{,}57 = 1{,}052$ m

bu yerda: $ð = 0{,}6 \div 0{,}75$ o‘zgaradi.

3.5.2. Noayon qutbli sinxron mashinaning qutbi o‘qidagi induksiya $B_\delta = 0{,}85$ Tl.

$в = 110$ sm, $D_i = 98$ sm, $2p = 2$ bo‘lsa, havo bo‘shlig‘idagi o‘rtacha induksiya topilsin.

Yechish. Qutb bo‘linmasi

$$\tau = \frac{\pi D_i}{2p} = \frac{\pi \cdot 98}{2} = 153{,}86 \text{ sm}$$

Qutbning chulg‘am o‘ralgan qismining nisbiy uzunligi

$\rho = в / \tau = 110 / 153{,}86 = 0{,}7149$

Qutb berkilish hisobiy koeffitsiyenti

$\alpha_\delta = 1 - 0{,}5p = 1 - 0{,}5 \cdot 0{,}7149 = 0{,}643$

O‘rtacha induksiya

$B_{\delta ур} = B\alpha = 0{,}85 \cdot 0{,}643 = 0{,}546$ Tl.

3.5.3. Sinxron mashina quzg‘atish chulg‘ami maydoni shaklining koeffitsiyenti $k_f = 1{,}05,$ qutb o‘qidagi induksiyaning radial tashkil etuvchisi $B_\delta = 0{,}75$ Tl bo‘lsa, g‘avo bushlig‘idagi quzg‘atish maydoni induksiyasi $B_{\delta 1m}$ aniqlansi.

Yechish. Qo‘zg‘atish maydoni induksiyasi

$B_{\delta 1m} = k_f B_\delta = 1{,}05 \cdot 0{,}75 = 0{,}79$ Tl.

3.5.4. Ayon qutbli sinxron mashina qutb bo‘linmasi $\tau = 17{,}7$ sm, hisobiy

uzunligi $l_\delta = 11{,}5$ sm, havo bo‘shlig‘idagi induksiyaning asosiy garmonikasi aniqlansin.

Yechish. Qo‘zg‘atish maydoni oqimining asosiy garmonikasi

$\Phi_{f1m} = (2/\pi)\tau l_\delta B_{\delta 1m} = (2/\pi)\cdot 17{,}7\cdot 11{,}5\cdot 0{,}68 = 0{,}88\cdot 10^{-2}$ Vb.

3.5.5. Ayon qutbli sinxron mashinani qutb bo‘linmasi $\tau = 23$ sm, hisobiy uzunligi $l_\delta = 12$ sm, qo‘zg‘atish maydoni shaklining koeffitsiyenti $k_f = 1{,}07$, qutb o‘zidagi induksiyaning radial tashkel etuvchisi $B_\delta = 0{,}72$ Tl bo‘lsa, quzg‘atish maydoni oqimining asosiy garmonikasi topilsin.

Yechish. Havo bo‘shlig‘idagi induksiyaning asosiy garmonikasi amplitudasi

$B_{\delta 1m} = k_f B_\delta = 1{,}07\cdot 0{,}72 = 0{,}77$ Tl

Qo‘zg‘atish maydoni oqimining asosiy garmonikasi

$\Phi_{f1m} = (2/\pi)\tau l_\delta B_{\delta 1m} = (2/\pi)\cdot 23\cdot 12\cdot 0{,}77 = 1{,}35\cdot 10^{-2}$ Vb.

3.5.6. Ayon qutbli sinxron mashinaning o‘zaro induksiya to‘la oqimi $\Phi_{fm} = 1{,}3\cdot 10^{-2}$, qutb bo‘linmasi $\tau = 16{,}5$ sm, hisobiy uzunligi $l_\delta = 14$ sm, qutb berkilish hisobiy koeffitsiyenti aniqlansin.

Yechish. Havo bo‘shlig‘idagi o‘rtacha induksiya

$$B_{\delta yp} = \frac{\phi_{fm}}{\tau l_\delta} = \frac{1{,}3\cdot 10^{-2}}{16{,}5\cdot 10^{-2}\cdot 14\cdot 10^{-2}} = 0{,}563 \text{ Tl.}$$

Qutb berkilish hisobiy koeffitsiyenti

$\alpha_\delta = B_{\delta yp} / B_\delta = 0{,}563/0{,}68 = 0{,}83$.

3.5.7. Ikki qutbli turbogeneratorning ichki diametri $D = 100$ sm, qutbning cho‘lg‘am o‘ralgan qismining uzunligi $в = 110$ sm, fazadagi o‘ramlar soni $\omega_1 = 16$, chulg‘am koeffitsiyenti $k_{r1} = 0{,}92$ bo‘lsa, $I = 1500$ A uchun yakorning MYUK ga ekvivalent bo‘lgan quzg‘atish MYUK topilsin.

Yechish. Qutb bo‘linmasi

$$\tau = \frac{\pi D}{2p} = \frac{\pi\cdot 100}{2} = 157 \text{ sm.}$$

Qutbning chulg‘am o‘ralgan nisbiy uzunligi

$\rho = в/\tau = 110/157 = 0{,}7$

Qo‘zg‘atish maydoni shaklining koeffitsiyenti

$k_f = 8\sin(p\pi/2)/(\pi^2 p) = 8\sin(0{,}7\cdot\pi/2)/(\pi^2\cdot 0{,}7) = 8\sin 0{,}159 = 1{,}03$

Yakor reaksiyasi koeffitsiyenti

$k_a = 1/k_f = 1/1{,}03 = 0{,}97$

Yakorning MYUK ga ekvivalent bo‘lgan, quzg‘atish chulg‘ami MYUK

$F_{am} = k_a F_{am} = 0{,}97\cdot 29744{,}7 = 28950$ A

3.5.8. $2p = 4$ qutbli ayon qutbli sinxron generatorning ichki diametri

$D = 340$ mm, hisobiy uzunligi $l_\delta = 185$ mm, hisobiy xavo bo‘shlig‘i $\delta' = 1{,}6$ mm, fazadagi o‘ramlar soni $\omega_1 = 40$, chulg‘am koeffitsiyenti $k_{r1} = 0{,}966$, maydon shakli koeffitsiyenti $k_d = 0{,}96$ va $k_q = 0{,}5$ bo‘lsa, yakorning asosiy induktiv qarshiliklari topilsin.

Yechish. Qutb bo‘linmasi

$$\tau = \frac{\pi D}{2p} = \frac{\pi \cdot 340}{2 \cdot 2} = 266{,}9 \text{ mm.}$$

Bo‘ylama o‘q bo‘yicha havo bo‘shlig‘ining o‘kazuvchanlik koeffitsiyenti

$$\lambda_{ad} = k_d \tau l_\delta / (k_\delta \delta) = 0{,}96 \cdot 266{,}9 \cdot 185 / 1{,}6 = 29{,}6.$$

Bo‘ylama o‘q bo‘yicha yakorning asosiy (bosh) induktiv qarshiligi

$$x_{ad} = \frac{4\mu_0}{\pi p} m_1 f (\omega_1 k_{r1})^2 \lambda_{ad} = \frac{4 \cdot 4 \cdot \pi \cdot 10^{-7}}{\pi \cdot 2} \cdot 3 \cdot 50 (40 \cdot 0{,}966)^2 \cdot 29{,}6 = 5{,}37 \text{ Om}$$

Ko‘ndalang o‘q bo‘yicha xavo bo‘shlig‘ining o‘tkazuvchanlik koeffitsiyenti

$$\lambda_{aq} = k_q \tau l_\delta / k_\delta \delta = 0{,}5 \cdot 0{,}2669 \cdot 0{,}185 / 1{,}6 \cdot 10^{-3} = 15{,}43$$

Ko‘ndalang o‘q yakorning asosiy **(bosh)** induktiv qarshiligi

$$x_{aq} = \frac{4\mu_0}{\pi p} m_1 f (\omega_1 k_{r1})^2 \lambda_{aq} = \frac{4 \cdot 4 \cdot \pi \cdot 10^{-7}}{\pi \cdot 2} \cdot 3 \cdot 50 (40 \cdot 0{,}966)^2 \cdot 15{,}43 = 2{,}79 \text{ Om.}$$

4.5.9. Sinxron generatorning faza kuchlanishi $U_\phi = 230$ V, faza toki $I_1 = 54$ A, quvvat koeffitsiyenti $\cos\varphi = 0{,}8.$ To‘la magnit isrofi $P_M + P_{MK} = 800$ Vt, to‘la elektr isrofi $P_{э1} = 1500$ Vt, mexanik $P_{мех}$ va P_τ / η_f isroflar elektr isrofining $\frac{2}{3}$ qismini tashkel qilsa , generatorning FIK topilsin.

Yechish. To‘la quvvat isrofi

$$\sum P = \left(\frac{P_f}{\eta_f} + P_{мех} \right) = \frac{2}{3} P_{э1} = \frac{2}{3} \cdot 1500 = 1000 \text{ Vt.}$$

Generatorning aktiv quvvati

$$P = m_1 UI \cos\varphi = 3 \cdot 230 \cdot 54 \cdot 0{,}8 = 29808 \text{ Vt}$$

Gneratorning FIK

$$\eta = 1 - \sum P / (P + \sum P) = 1 - 3300 / (29808 + 3300) = 0{,}9.$$

3.5.10. Turbogeneratorning nominal liniya kuchlanishi $U_{нл} = 10{,}5$ kV, yakor cho‘lg‘amining induktiv qarshiligi $x_1 = 23$ Om bo‘lib elektr tizimi bilan parallel ishlamoqda.

Nominal qo‘zg‘atish tokida generatorning salt ishlash kuchlanishi $U_л = 24{,}2$ bo‘lsa, EYUK va kuchlanish orasidagi burchak γ_H nominal yuklama $P_H = 6$ mVt da topilsin. Generatorning statik yuklanish qobilyati nimaga teng?

Yechish. Maksimal quvvat

$$P_{TH} = E_f U / x_1 = \frac{24200 \cdot 10500}{23} = 11{,}05 \text{ mVt}$$

$$\sin \gamma_H = \frac{P_H x_1}{U E_f} = \frac{6 \cdot 23}{10{,}5 \cdot 24{,}2} = 0{,}54$$

bunda $\gamma_H = 32{,}7^0$.

Generatorning statik yuklanish qobilyati

$$\kappa_n = P_{EP} / P_H = 11{,}05 / 6 = 1{,}84$$

3.6. Mustaqil yechish uchun masalalar

3.6.1. To‘rt qutbli sinxron mashinaning quyidagi parametrlari berilgan: fazadagi o‘ramlar soni $\omega = 105$, qisqartish koeffitsiyenti $\kappa_к = 0{,}951$, tarqatish koeffitsiyenti $\kappa_{T1} = 0{,}954$, yakor chulg‘ami toki $I = 18$ A. Uch fazali yakor chulg‘ami MYUK ning asosiy garmonikasi amplitudasi aniqlansin.

(**J:** $F_{am} = 1155$ A)

3.6.2. Ikki qutbli turbogenerator quvvati $S_H = 31250$ kVA, faza kuchlanishi $U_{u.ф} = 6060$ V bo‘lib, yakor chulg‘ami fazasidagi o‘ramlar soni $\omega_1 = 16$, qisqartish koeffitsiyenti $\kappa_{r1} = 0{,}966$, tarqatish koeffitsiyenti $\kappa_{TK} = 0{,}956$. Yakor chulg‘ami MYUK ning asosiy garmonikasi amplitudasi topilsin. (**J:** $F_{am} = 34281$ A)

3.6.3. Ayon qutbli sinxron mashinaning quyidagi parametrlari berilgan: maydon shakli koeffitsiyentlari: bo‘ylama o‘q bo‘yicha $\kappa_d = 0{,}9$ ko‘dalang o‘q bo‘yicha $\kappa_q = 0{,}58$ bo‘ylama o‘q bo‘yicha yakor magnit maydon induksiyasi $B_{adm} = 0{,}51$ Tl, ko‘ndalang o‘q bo‘yicha yakor magnit maydoni induksiyasi $B_{aqm} = 0{,}38$ Tl. Yakor MYUK ning bo‘ylama va ko‘ndalang tashkel etuvchilari hosil qilgan induksiyaning asosiy garmonikalari topilsin.

(**J:** $B_{adlm} = 0{,}459$ Tl, $B_{aqlm} = 0{,}22$ Tl)

3.6.4. Gidro generator yakor chulg‘amidagi magnit oqimining bo‘ylama va ko‘ndalang o‘qlar bo‘yicha tashkel etuvchilari $\Phi_{adm} = 0{,}265$ Vb va $\Phi_{aqm} = 0{,}05$ Vb. Juft qutblar soni $2p = 24$ fazadagi o‘ramlar soni $\omega_1 = 130$, chulg‘am koeffitsiyenti $\kappa_{ч1} = 0{,}94$, generator aylanish chastotasi $n = 125$ ayl/min. Magnit oqim Φ_{adm} va Φ_{aqm} lar xosil qilgan EYUK lar topilsin.

(**J:** $E_{ad} = 7189$ V; $E_{aq} = 1356$ V)

3.6.5. Nominal yuklamada turbogeneratorning faza kuchlanishi

$U_{н.ф} = 230$ V. Nominal toki $I_H = 1800$ A, $\cos\varphi_H = 0{,}8.$ Yakor chulg‘ami fazasining aktiv qarshiligi $R = 0{,}00162$ Om, to‘la induktiv qarshiligi $x_1 = 0{,}211$ Om bo‘lsa, qo‘zg‘atish EYUK ni toping. (**J:** $E_f = 550{,}5$ V)

3.6.6. Turbogenerator ko‘rsatilgan bo‘lib, yuklamada tok $I = 2150$ A, $\cos\varphi = 0{,}8$, $U_{л.д} = 0{,}4$ kV. Yakor chulg‘amining aktiv va asosiy (bosh) induktiv qarshiliklari: $R = 0{,}0015$ Om, $x_a = 0{,}17$ Om, induktiv solishtirma qarshiligi $x_\delta = 0{,}015$ Om. Qo‘zg‘atish EYUK ni aniqlang. (**J:** $E_f = 622{,}3$ V)

3.6.7. Gidrogeneratorning to‘la quvvati $S_H = 26MB \cdot F,\ \cos\varphi_H = 0{,}8$. Mexanik isrof $P_{мех} = 88$ kVt, yakor chulg‘amidagi elektr isrofi $P_{э1} = 185$ kVt, magnit isrof $P_м + P_{мк} = 138{,}5$ kVt, qo‘zg‘atgichni harakatga keltirishga sarflanayotgan quvvat $P_f / \eta_f = 167$ kVt. Generatorning to‘la quvvati va FIK topilsin. (**J:** $\sum P = 578{,}5$ kVt; $\eta = 0{,}973$)

3.6.8. Uch fazali sinxron generatordan yuklama $P_n = 26$ MVt quvvatni olmoqda, generatorning elektromagnit quvvati $P_{эм} = 26{,}2$ MVt, stator po‘lat o‘zagidagi magnit isrofi $P_м = 150$ kVt, faza toki $I = 1790$ A.

(**J:** $R = 0{,}0052$ Om)

3.6.9. Turbogeneratorning yuklamasi kamaygan vaqtdagi naminal qo‘zg‘atish toki $I^*_f = 15$. Generator normal salt ishlash tavsifiga ega. Kuchlanishning o‘zgarishi aniqlansin. (**J:** $\Delta U = 0{,}2$)

3.6.10. Ayon qutbli sinxron generatori normal salt ishlash tavsifiga ega bo‘lib, nominal faza kuchlanishi $U_{н.ф} = 6060$ V, faza toki $I = 2750$ A, yakor chulg‘amining bo‘ylama o‘qi bo‘yicha induktiv qarshiligi $x_d = 2{,}5$ Om. Salt ishlash rejimida (nominal kuchlanish) MYUK ga mos keluvchi qisqa tutashuv toki va qisqa tutashuv nisbati (QTN) aniqlansin.

(**J:** $OKZ = 0{,}934;\ I_{к.0} = 2569$ A)

4. O‘zgarmas tok mashinalari

(Asosiy kattaliklar va ularni aniqlash tenglamalari)

4.1. EYUK, kuchlanish va moment tenglamasi

O‘zgarmas tok mashinalarining tezligini boshqarish tekis amalga oshiriladi. Shu sababli ham bunday mashinalar keng ko‘lamda ishlatiladi.

O‘zgarmas tok mashinasi generator rejimida ishlaganda kuchlanishlar muvozanati tenglamasi quyidagicha bo‘ladi:

$$E = U + I_ß R_ß\ , \qquad (4.1)$$

bu yerda: *U*- yakordagi kuchlanish; *R*- yakordagi EYUK; $I_{ß}$ - yakor toki; $R_{ß}$ - yakor chulg‘amining aktiv qarshiligi.

Agarda o‘zgarmas tok mashinasi motor rejimida ishlasa, uning kuchlanishlar muvozanat tenglamasi quyidagicha topiladi.

$$U = E + I_{ß} R_{ß}, \tag{4.2}$$

Yakor chulg‘amidagi moment quyidagicha topiladi:

$$M = C_{Ÿ} \Phi I_{Ÿ}, \tag{4.3}$$

bu yerda: C_M – moment doimiysi; $C_{ì} = C_e / 2\pi$, F- magnit oqim.

Yakor chulg‘amidagi EYUK quyidagiga teng:

$$E = zn\hat{O}p / a = C_{\hat{a}} n\hat{O}, \tag{4.4}$$

Bu yerda: *n*- mashinaning aylanish chastotasi; C_e - mashina chulg‘amini xarakterlovchi doimiy; *z*- yakor chulg‘ami perimetri; *p*- juft qutblar soni; *a*- juft parallel shaxobchalar soni.

O‘zgarmas tok mshinasining aylanish chastotasi quyidagicha topiladi:

$$n = U \cdot 60 / C_e \Phi - I_{Ÿ} \cdot R \cdot 60 / C_e \Phi = U \cdot 60 / C_e \Phi - R \cdot M \cdot 60 / C_e \cdot K_M \cdot \Phi^2. \tag{4.5}$$

4.2. O‘zgarmas tok mashinalarida quvvat isroflari va FIK

O‘zgarmas tok mashinalarida quyidagi quvvat isroflari mavjud:

Po‘latdagi isrof

$$P = \kappa \cdot \left[P_{1.or} \cdot f \cdot B^2 / 50 + P_{1/oy} \cdot (f \cdot B / 50)^2 \right] \cdot m_n, \tag{4.6}$$

bu yerda: κ - isrof o‘zini koeffitsiyenti ($\kappa \approx 2 \div 2{,}5$); $P_{1or}, P_{1/oy}$ plastinkalardan yig‘ilgan o‘zak uchun xarakterli bo‘lgan uyurma toklar xosil qilgan solishtirma isrof va gisterezis solishtirma isrofi (bunda f =50 Gs va B = 1 Tl); B - induksiyaning maksimum qiymati; m_g - po‘lat massasi:

cho‘tkalardagi isrof

$$P_ç = 9{,}81 \vartheta_ê A_ê p \mu, \tag{4.7}$$

bu yerda: $\vartheta_ê$ - kollektorning aylanma tezligi; $A_ê$ - cho‘tkalarning kollektorga tegib turgan yuzasi; p - prujinalarning bosimi; μ - titrash koeffitsiyenti.

Cho‘tka kontaktlaridagi isrof

$$P_ê = \Delta U_k I_{Ÿ}, \tag{4.8}$$

bu yerda: ΔU_k - cho‘tkalardagi kuchlanish pasayishi (elektrografit cho‘tkalar uchun 2 V.).

Mexanik isroflar R_{mex} mashinaning aylanuvchi qismlariga yuzaga keladi.

Yakor chulg‘amidagi isrof

$$P_{я.ч} = I_я^2 R_я, \quad (4.9)$$

Qo‘shimcha isroflar

$$P_{уш} = (0{,}005 \div 0{,}01) P_н, \quad (4.10)$$

bu yerda: $P_í$ - mashinaning nominal quvvati.

Qo‘zg‘atish chulg‘amidagi isrof

$$P_к = U_к I_к = U_к I / R_к, \quad (4.11)$$

Yig‘indi quvvat isrofi

$$\Sigma P = P_ч + P_к + P_{мех} + P_{я.ч} + P_{уш} + P_r \quad (4.12)$$

Mashinaning FIK

$$\eta = P_н / (P_н + \Sigma P) \quad (4.13)$$

4.3. Namunaviy masalalar yechish

4.3.1. Chiqish klemmalarida U=220B bo‘lgan parallel qo‘zg‘atishli o‘zgarmas tok generatori nominal yuklama $P_н$=120 kVt va n=1440 ayl/min tezlik bilan ishlamoqda. Agarda generatorni motor rejimida R=60 kVt yuklama bilan ishlatilsa, motorning aylanish chastotasini toping. Yakor chulg‘amining ichki qarshiligi $R_к$=38 Om, cho‘tkalardagi kuchlanish pasayishi $\Delta U_к = 2$ V.

Generator rejimidagi EYUK $E = U + I_{þê} R_{ÿ} + \Delta U_ê$

bu yerda

$$I_{юк} = I_я + I_к = P_н / U + U / R_r = 120 \cdot 10^3 / 220 + 220 / 38 = 551 \text{ A}.$$

EYUK ni topamiz:

$$E = 220 + 551 \cdot 0{,}011 + 2 = 228 \text{ V},$$

bu yerda

$C_e = E \cdot 60 / n = 228 \cdot 60 / 1440 = 9{,}5 \ B \cdot c$.

Motor rejimida EYUK quyidagicha topiladi:

$E = U - I_z R_z - \Delta U_x$,

bunda

$$I_я = I_{ист} - I = P / U - U / R_к = 60 \cdot 10^3 / 220 - 220 / 38 = 267 \text{ A}.$$

$E = C_e n$ tenglikdan foydalanib,

$n = (U - I_я R_я - \Delta U_к) \cdot 60 / C_e = (220 - 267 \cdot 0 / 011 - 2) \cdot 60 / 9{,}5 = 1358$ ayl/min.

4.3.2. Mustaqil qo‘zg‘atishli generatorning texnik malumotlari quyidagicha: nominal quvvati $P_к = 16$ Om, qo‘zg‘atish zanjirining kuchlanishi $U_к = 230$ V, yakor chulg‘amining qarshiligi $R_я = 0{,}12$ Om, quzg‘atish zanjirining qarshiligi $R_к = 18$ Om, qo‘zg‘atish zanjirining

kuchlanishi $U_k = 110$ V.

Mexanik va magnit isroflar generator nominal quvvatining 4,5% ni tashkil etadi. Generatorning EYUK, FIK aniqlansin.

Yechish. Generatorning EYUK

$E = U + I_я R_я$

Mustaqil qo‘zg‘atishli generatorda

$I_я = I_к$

Generatorning nominal toki

$I_н = P_н / U_н = 16 \cdot 10^3 / 230 = 69{,}57$ A,

u holda

$E = 230 + 69{,}57 \cdot 0{,}12 = 138{,}35$ V.

Generatorning nominal rejimdagi FIK

$$\eta = \frac{P_н}{P + \sum P}.$$

Qo‘zg‘atish chulg‘amidagi quvvat isrofi

$$P_к = \frac{U^2{}_к}{R_к} = \frac{110^2}{18} = 672 \text{ Vt} = 0{,}672 \text{ kVt}.$$

Yakor chulg‘amidagi quvvat isrofi

$P_я = I^2{}_{я.н} R_я = 69{,}57^2 \cdot 0{,}12 = 581$ Vt = 0,581 kVt.

Shart bo‘yicha

$P_{тех} + P_{маг} = 0.045 P_н = 0.045 \cdot 16 \cdot 10^3 = 720$ Vt =0,72 kVt.

FIK

$$\eta = \frac{P_н}{P_н + P_к + R_я + P_{мех} + P_{маг}} = \frac{16}{16 + 0{,}672 + 0{,}581 + 0{,}72} = 0{,}89.$$

4.3.3. To‘lqinsimon chulg‘amli o‘zgarmas tok mashinasining quyidagi parametlari berilgan: yakor pazlari soni z=25; juft qutblar soni r=2, seksiyadagi (g‘altakdagi) o‘ramlar soni $\omega = 4$, bitta pazga va bitta qatlamga tegishli g‘altak tomonlari soni U=3, magnit oqim $\Phi = 0{,}65 \cdot 10^{-2}$ Vb, yakor toki $I_я = 27$ A, aylanish chastotasi n=1500 ayl/min. Mashinaning elektomagnit quvvati aniqlansin.

Yechish. Mashinaning elektromagnit quvvati $P_{э.м} = EI_я$.

EYUK $E = zpn\Phi / a = C_e n\Phi$.

Yakor chulg‘amining effektiv simlarini sonini topamiz

$Z = 2n\omega z = 2 \cdot 3 \cdot 4 \cdot 25 = 600$.

Mashina chulg‘amini xarakterlovchi doimiy

$C_e = \frac{zp}{a} = \frac{600 \cdot 2}{1} = 1200$, bu yerda a=1.

EYUKni aniqlaymiz

$E = C_e \Phi n / 60 = 1200 \cdot 0{,}0065 \cdot 1500 / 60 = 195$ V.

Elektromagnit quvvat

$P_{эм} = EI_я = 195 \cdot 27 = 5265$ Vt.

4.3.4. Mustaqil qo‘zg‘atishli generator salt ishlaganda uning klemmalaridagi (uchlaridagi) kuchlanish $U_0 = 248$ V. Yakorning aylanish chastotasi $n = 1000$ ayl/min, yakor chulg‘amining qarshiligi $R_ў = 0{,}19$ Om. Yaklama ulanganda tok $I = 53$ A, kuchlanish $U = 220$ V bo‘ladi. Yuklama ulangandan keyingi yakorning aylanish Chastotasi aniqlansa, magnit oqiminingo‘zgarishi etiborga olinmasin.

Yechish. Generatorning salt ishlagandagi EYUK

$E_0 = U_0 = 248$ V.

Salt ishlaganda EYUK

$E_0 = Cn_0\Phi$.

Yuklama bilan ishlaganda esa:

$E = Cn\Phi$, chunki shart bo‘yicha $\Phi \approx const$.

U holda

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

Bunda

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

4.3.5. Uchlarida kuchlanishi $U = 110$ V bo‘lgan mustaqil qo‘zg‘atishli o‘zgarmas tok generatorining yuklamasi 3 kVt dan 1,5 kVt gacha kamaysa, magnit oqimini necha foizga kamaytirish kerak. Bunda kuchlanish o‘zgarmas, yani $U = 110B = const$ bo‘lsin. cho‘tkalardagi kuchlanish pasayishi $\Delta U_k = 2$ V, quvvat isroflari hisobga olinmasin, yakor reaksiyasi tasiri va yakor chulg‘amidagi quvvat isrofi hisobga olinsin. Yakor chulg‘ami qarshiligi $R_я = 0{,}5$ Om.

Yechish. Yuklamaning ikki qiymati uchun kuchlanishlar muvozanat tenglamasi

$U = E_1 - I_{я1}R_я - \Delta U_к$; $\quad U = E_2 - I_{я2}R_я - \Delta U_к$;

va $E_1 = \frac{zp}{a}\Phi_1 n / 60 = C_e \Phi_1 n / 60 = \kappa\Phi_1$ xuddi shuningdek, $E_2 = \kappa\Phi_2$.

Yakor chulg‘amidagi toklar

$I_{z1} = \frac{P_1}{U} = \frac{3000}{110} = 27{,}3A$;

$I_{z2} = \frac{P_2}{U} = \frac{1500}{110} = 13{,}65A$.

Quyidagi nisbatni yozish mumkin

$$\frac{E_2}{E_1}=\frac{\kappa\Phi_2}{\kappa\Phi_1}=\frac{U+I_{я2}R_я+\Delta U_к}{U+I_{я1}R_я+\Delta U_к}-1=\frac{110=13{,}65\cdot 0{,}5+2}{110+27{,}3\cdot 0{,}5+2}-1=0{,}055.$$

Demak, magnit oqimni 5,5% ga kamaytirish kerak ekan.

4.3.6. Parallel qo‘zg‘atishli generatorning nominal kuchlanishi $U_я=230\,\text{V}$, yuklama toki $I=160$ A. Yakor chulg‘amining qarshiligi $R_я=0{,}11\,\text{Om}$.

Yakor chulg‘amidagi EYUK $Å$ va tok $I_ÿ$, generator berayotgan quvvat P_2 va yakor chulg‘amidagi quvvat isrofi P_z aniqlansin.

Yechish. Qo‘zg‘atish zanjiridagi tok

$$I_к=\frac{U}{R_к}=\frac{230}{72}=3{,}2\ \text{A}.$$

Yakor chulg‘amidagi tok

$$I_я=I+I_к=160+3{,}2=163{,}2\ \text{A}.$$

Yakordagi EYUK

$$E=U+I_яR_я=230+163{,}2\cdot 0{,}11=248\ \text{V}.$$

Foydali quvvat

$$P_2=UI=230\cdot 160=36800\ \text{Vt}=36{,}8\ \text{kVt}.$$

Yakor chulg‘amidagi quvvat isrofi

$$P_я=I^2{}_яR_я=163{,}2\cdot 0{,}11=2930\ \text{Vt}=2{,}93\ \text{kVt}.$$

4.3.7. Kuchlanish $U=110$ V bo‘lgan elektr tarmog‘ida parallel qo‘zg‘atishli o‘zgarmas tok matori ulanadi. Yakor chulg‘amning qarshiligi $R_ÿ=0{,}07$ Om. Yuklamaning yarim qiymatida matorning aylanish chastotasi $n=1400$ ayl/min, yakor toki $I_я=74$ A. Agarda yakor chulg‘amida tashqi qarshilik $R_ý=0{,}3$ Om ulansa va yuklama mometi ikki martaga oshganda, motorning aylanish chastotasini aniqlang. Bunda yakor reaksiyasi xisobga olinmasin, cho‘tkalardagi kuchlanish pasayishi $\Delta U_к=2$ V.

Yechish. Bu ikki hol uchun momentlar tenglamasi

$$M_1=C_м\Phi I_{я1}\ ;M_2=2C_м\Phi I_{я1}.$$

Bunda, $I_{ÿ2}=2I_{ÿ1}=2\cdot 74=148$ A.

Birinchi hol uchun kuchlanishlar muvozanat tenglamasi

$$E_1=U-I_{я1}R_я-\Delta U_к=110-74\cdot 0{,}07-2=102{,}8\ \text{V}.$$

bu yerda: $C_e\Phi=\frac{E}{n}60=\frac{102{,}8}{1400}60=4{,}41$ Vb

Ikkinchi hol uchun kuchlanishlar muvozanat tenglamasi

$$E_2=U-I_{я2}(R_Я+R_T)-\Delta U_к=110-148(0{,}07+0{,}3)-2=53{,}2\ \text{V}.$$

Motor aylanish chastotasi

$$n = \frac{E_2 \cdot 60}{c_e \phi} = \frac{53{,}2 \cdot 60}{4{,}41} = 724 \text{ ayl/min.}$$

4.3.8. Ikki qutbli parallel qo‘zg‘atishli generatorning yakor chulg‘amlarini kesib o‘tayotgan magnit oqimi F=0,03 Vb. chulg‘am aktiv simlari sonining juft parallel shaxobchalar soniga nisbati $N/a = 300$. Yakorning aylanish chastotasi $n = 2000$ ayl/min.

Agar yakor zanjirining qarshiligi $R_я = 0{,}2$ Om, yuklama toki 56 A, qo‘zg‘atish toki $I_к = 4$ A bo‘lsa, generatorning elektromagnit (tormozlovchi) momenti va uchlaridagi kuchlanishni toping.

Yechish. Generatorning EYUK

$$E = \frac{N}{a} \cdot \frac{pn}{60} \Phi = 300 \cdot \frac{1 \cdot 2000}{60} \cdot 0{,}03 = 300 \text{ V,}$$

bu yerda: r-juft qutblar soni. Generator ikki qutbli bo‘lgani uchun r=1.

Generator uchlaridagi kuchlanish

$$U_r = E - I_{ÿ} R_{ÿ} = 300 - 60 \cdot 0{,}2 = 288 \text{ V,}$$

bu yerda: $I_{ÿ} = I + I_{ê} = 56 + 4 = 60$ A.

Generatorning elektromagnit momenti

$$M = \frac{N}{a} \cdot \frac{p}{2\pi} \Phi I_я = C_m \Phi I_я .$$

bu yerda: $C_m = \frac{N}{a} \cdot \frac{p}{2\pi} = 300 \cdot \frac{1}{2 \cdot 3{,}14} = 47{,}8$, u xolda

$$M = 47{,}8 \cdot 0{,}03 \cdot 60 = 86 \text{ Н} \cdot м .$$

4.3.9. Ikki qutbli o‘zgarmas tok generatorning yakor chulg‘ami $z = 1200$ simdan iborat. Bitta simning chulg‘am tirsak qismi bilan birgalikdagi uzunligi $l = 0{,}39$ m. Simning ko‘ndalang kesim yuzasi $A_{см} = 2 \text{ мм}^2$. uchlaridagi kuchlanish $U = 110$ V bo‘lganda generator tarmoqga $P = 3{,}5$ kVt quvvat beradi. Generatorning yakor chulg‘ami qarshiligi $R_я = 20$ ºCda aniqlansin va 75ºCda yakor chulg‘amidagi quvvat isrofi topilsin. Mustaqil qo‘zg‘atishli generator yakor chulg‘ami misdan tayyorlangan bo‘lib, 20^0 S da misning solishtirma qarshiligi $p = 0{,}0172 \text{ мкОм} \cdot м$.

Yechish. Bitta parallel shaxobchadagi yakor chulg‘amining qarshiligi

$$R_я = \frac{z}{2a} \cdot \rho \frac{l}{A_{cu}} = \frac{1200}{2 \cdot 2} \cdot 0{,}0172 \cdot \frac{0{,}39}{2} = 1 \text{ Om.}$$

Cho‘tkalar orasidagi yakorning qarshiligi

$$R_я = \frac{1}{2a} R_я = \frac{1}{4} \cdot 1 = 0{,}25 \text{ Om.}$$

Yakor toki

$$I_я = \frac{P_н}{U} = \frac{3{,}5 \cdot 10^3}{110} = 31{,}8 \text{ A}.$$

Yakor chulg‘amidagi kuchlanish pasayishi

$$\Delta U_я = I_я R_я = 31{,}8 \cdot 0{,}25 = 7{,}95 \text{ V}.$$

75ºCdagi yakor qarshiligi

$$R_{я.75} = R_{я.20} \cdot \frac{235+75}{235+20} = 0{,}25 \cdot \frac{310}{225} = 0{,}304 \text{ Om}.$$

75ºC dagi yakor chulg‘amining isrofi

$$P_я = I^2_я R_{я.75} = 31{,}8^2 \cdot 0{,}304 = 307 \text{ Vt}.$$

4.3.10. Aylanish chastotasi $n = 1000$ ayl/min bo‘lgan o‘zgarmas tok motori yuksiz ishlamoqda; undagi gisterezis isrofi $P_г = 2500$ Vt, uyurma toklar hosil qilgan quvvat isrofi $P_y = 1000$ Vt. Magnit oqim o‘zgarmas $\Phi = const$ deb qabul qilingan xol uchun, qanday aylanish chastotasida po‘latdagi istoflar ikki martaga kamayadi, Bunda qo‘zg‘atish chulg‘amidagi va mexanik isroflar hisobga olinmagan.

Yechish. Gisterezis isrofi

$$P_Г = P_{1.OГ} \frac{f}{50} B^2 \cdot G_{пул} = \kappa_1 \cdot f = \kappa^*_1 \cdot n,$$

bunda

$$\kappa^*_1 = \frac{P_Г}{n} = \frac{2500}{1000} \cdot 60 = 150 \, Вт \cdot с.$$

Uyurma toklar hosil qilgan isrof

$$P_y = P_{1.oy} \frac{f}{50^2} B^2 G_{пул} = \kappa_2 f^2 = \kappa^*_1 \cdot n^2;$$

$$\kappa^*_2 = \frac{P_y}{n^2} = \frac{1000}{1000^2} \cdot 60^2 = 3{,}6 \, Вт \cdot с^2.$$

Po‘latdagi isrof $n = 1000$ ayl/min

$$P_{пул} = P_Г + P_y = 2500 + 1000 = 3500 \text{ Vt}.$$

Quyidagi tezlikda n, po‘latdagi isrof ikki martaga kamayadi

$$\frac{P_{пул}}{2} = \kappa^*_1 n_1 + \kappa^*_2 n^2_1.$$

Bu hol uchun ikkinchi darajali tenglama

$$3{,}6 n^2_1 + 150 n_1 - 1750 = 0.$$

Bu tenglama yechimi:

$$n_{1/2} = \frac{-150 \pm \sqrt{150^2 + 4 \cdot 1750 \cdot 3{,}6}}{7{,}2} \cdot 60 = -1250 \pm 1820 = \begin{Bmatrix} 570 айл/мин, \\ -3070 айл/мин. \end{Bmatrix}$$

$n = -3070$ ayl/min fizik jihatdan mumkin emas, demak $n = 570$ ayl/min to‘g‘ri bo‘ladi.

4.4. Mustaqil yechish uchun masalalar

4.4.1. O‘zgarmas tok motorining kuchlanish $U = 440$ V. naminal quvvati $P_н = 120$ kVt, FIK $\eta = 92\%$ bo‘lsa, motor tarmoqdan tokni istemol qiladi?

(**J:** $I_ÿ = 296$ A)

4.4.2. Mustaqil qo‘zg‘atishli generator salt ishlayotganda kuchlanish $U_0 = E_{Г\backslash} = 150$ V. Yakorning aylanish chastotasi $n = 1800$ ayl/min bo‘lib, chulg‘amlarni kesib o‘tayotgan magnit oqimi F=2,5 Vb bo‘lsa, generatorning doimiysi C_E aniqlansin. (**J:** $C_e = 2$)

4.4.3. To‘rt qutbli o‘zgarmas tok generatorni chulg‘amlarini kesib o‘tayotgan magnit oqimi $\hat{O} = 1 \cdot 10^{-2}$ Vb. Yakorning aylanish chastotasi $n = 1500$ ayl/min, chulg‘amdagi aktiv simlarning soni $N = 600$, juft parallel shaxobchalarning soni a=4. Yakor chulg‘amlarida induktivlangan EYUK ni toping. (**J:** $E = 75$ V)

4.4.4. O‘zgarmas tok generatorning yakor chulg‘amlarini kesib o‘tayotgan magnit oqimi F=0,02 Vb, mashina diamiysi $C_e = 10$. Yakorning aylanish chastotasi 1000, 1500, va 2000 ayl/min bo‘lganda yakor chulg‘amidagi inuktivlangan EYUK lar aniqlansin. (**J:** 200 V, 300 V, 400 V)

4.4.5. Parallel qo‘zg‘atilgan motorning klemmalariga berilgan kuchlanish $U = 200$ V. Qo‘zg‘atish chulg‘amining qarshiligi $R_k = 40$ Om. Qo‘zg‘atish chulg‘amining toki $I_k = 2{,}5$ A dan ortmasligi uchun rostlash reostatining qarshiligi necha Om ga teng bo‘lishi kerak? (**J:** $r_p = 48$ Om)

4.4.6. Parallel qo‘zg‘atishli generator nominal kuchlanishi $U_í = 120$ V, yakorning naminal aylanish chastotasi $n_í = 1000$ ayl/min, nominal toki $I_{я.н} = 80$ A va yakor chulg‘amining qarshiligi $R_ÿ = 0{,}15$ Om. Generatorning motor sifatida ishlatganda yakor chulg‘amida induktivlangan teskari EYUK va yakorning aylanish chastotasi topilsin. Mashinaning magnit oqimi ikkala rejimda ham o‘zgarmas deb hisoblansin. (**J:** $E_r = 108$ V, $n = 818$ V)

4.4.7. O‘zgarmas tok generatori klemmasidagi kuchlanish $U = 170$ V, yakor toki $I_ÿ = 765$ A. Agarda FIK $\eta = 91\%$ bo‘lsa generator va birinchi motor berayotgan quvvatlarni toping. (**J:** $P_r = 130$ kVt $P_m = 143$ kVt)

4.4.8. Yakor chulg‘ami qarshiligi $R_я = 0{,}43$ Om bo‘lgan ketma-ket qo‘zg‘atishli o‘zgarmas tok motori kuchlanishi $U = 110$ V bo‘lgan tarmoq ulangan. Ma`lum yuklamada yakor toki $I_я = 30$ A, aylanish chastotasi $n = 1500$ ayl/min. Agarda yakor chulg‘amiga ketma-ket qilib qo‘shimcha

$R_{уш} = 2$ Om qarshilik ulab, yuklama shunday tanlansinki, yakor toki $I_я = 30$ A qolishi uchun, $U = 110$ V kuchlanishda motorning aylanish chastotasi topilsin. Bunda cho‘tkalardagi kuchlanish pasayishi hisobga olinmasin. (**J:** $n = 573$ ayl/min)

4.4.9. Ikki qutbli parallel qo‘zg‘atishli o‘zgarmas tok motori kuchlanishi $U = 220$ V bo‘lgan tarmoqqa ulangan. Yakordagi to‘lqinsimon chulg‘am simlarining soni $z = 650$, yakor chulg‘ami qarshiligi $R_я = 0{,}8$ Om, magnit oqim $\Phi = 0{,}63 \cdot 10^{-2}$ Vb, yakor toki $I_я = 27$ A bo‘lganda motorning aylanish chastotasi aniqlansin. cho‘tkalardagi kuchlanishning pasayishi $\Delta U_к = 2$ V. YAkor reaksiyasining tasiri hisobga olinmasin. (**J:** $n = 2878$ ayl/min)

4.4.10. Mustaqil qo‘zg‘atish o‘zgarmas tok motori kuchlanishi $U = 220$ V bo‘lgan tarmoqqa ulangan. Motorning yuklama momenti nominal momentiga teng, aylanish chastotasi $n = 1440$ ayl/min, yakor toki $I_я = 50$ A, yakor chulg‘ami qarshiligi $R_я = 0{,}4$ Om. Agarda yuklama motenti ikki martaga kamaysa, motorning tezligi qancha bo‘ladi, cho‘tkalardagi kuchlanish pasayishi $\Delta U_к = 2$ V. (**J:** $n = 1513$ ayl/min.)

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