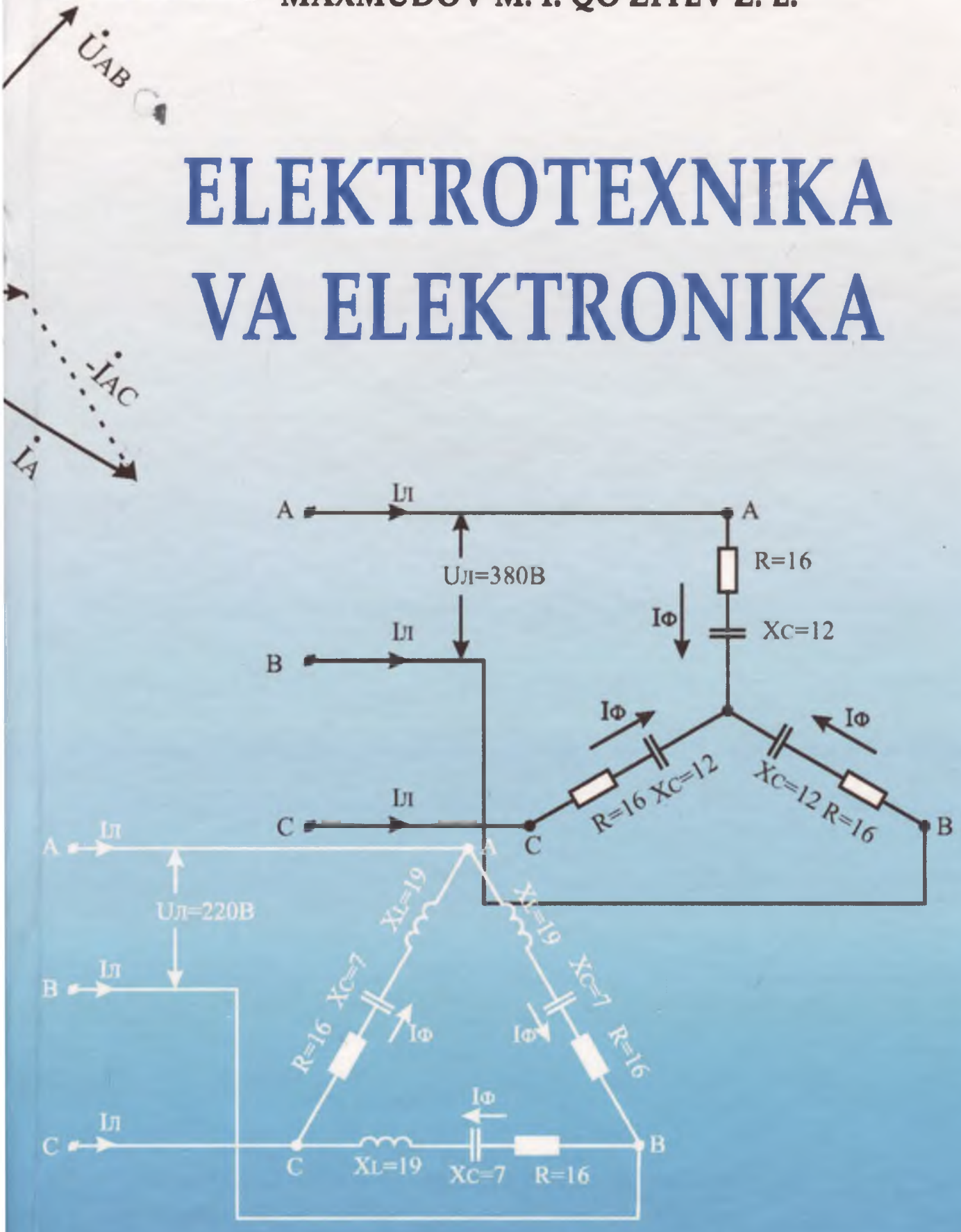
MAXMUDOV M. I. QO'ZIYEV Z. E.

ELEKTROTEXNIKA VA ELEKTRONIKA



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O‘RTA MAXSUS TA’LIM VAZIRLIGI

M. I. Maxmudov, Z. E. Qo'ziyev

ELEKTROTEXNIKA VA ELEKTRONIKA

5312100 – Energoaudit va sanoat korxonalarining energetik tekshiruvi ta`lim yo`nalishi talabalari uchun

BUXORO – 2020
«DURDONA» NASHRIYOTI

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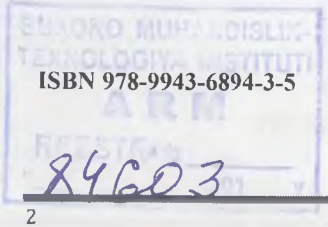
Ushbu o`quv qo`llanma 13 bob 39 paragrafdan iborat bo`lib, unda elektr zanjirlar, elektr mashinalar, elektr yuritmalar, sanoat korxonalarining elektr ta`minoti va elektronika asoslariga oid masalalarni yechish namunalari, mustaqil ishlash uchun masalalar hamda bu ishlarni bajarishni yengillashtirish maqsadida nazariy ma`lumotlar batafsil, aniq va ravon bayon etilgan. O`quv qo`llanma Energoaudit va sanoat korxonalarining energetik tekshiruvi ta`lim yo`nalishi Elektrotexnika va elektronika fan dasturi asosida yozilgan bo`lib mazkur yo`nalish talabalariga mo`ljallangan.

Mazkur o`quv qo`llanma Oliy va o`rta maxsus ta`lim vazirligining 2020 yil 07 dekabr 648-sonli buyrug`iga asosan nashr qilishga ruxsat etilgan.



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ANNOTATSIYA

Ushbu o'quv qo'llanma texnik yo'nalishlar bo'yicha ta'lim olayotgan barcha oliy o'quv yurtlari talabalarini amaliy mashg`ulotlarni bajarishi uchun mo'ljallangan.

Ushbu qo'llanmada elektr zanjirlar, elektr mashinalar, elektr yuritmalar, sanoat korxonalarining elektr ta`minoti va elektronikaga oid masalalarni yechish namunalari, mustaqil ishlash uchun masalalar hamda bu ishlarni bajarishni yengillashtirish maqsadida nazariy ma`lumotlar bayon etilgan.

SUMMARY

This training manual is intended to perform practical work for all students of higher educational institutions of the technical field.

The book illustrates how to solve electrical circuits, electrical machines, electric drives, power and electronic devices for industrial enterprises, questions for independent work and theoretical information to facilitate this work.

АННОТАЦИЯ

Данное учебно-методическое пособие предназначено для выполнения практической работы для всех студентов высших учебных заведений технической области .

Книга иллюстрирует, как решать электрические схемы, электрические машины, электроприводы, силовые и электронные устройства для промышленных предприятий, вопросы для самостоятельной работы и теоретическую информацию для облегчения этой работы.

KIRISH

O'quv qo'llanma "Elektrotexnika va elektronika" fani dasturi asosida tuzilgan bo'lib, elektr zanjirlar, elektr mashinalar, elektr yuritmalar, sanoat korxonalarining elektr ta`minoti va elektronikaga oid masalalar yechish uchun namunalar ko'rsatilgan hamda mustaqil yechish uchun masalalar berilgan.

Har bir bobga oid masala yechish uchun zarur bo'lgan asosiy: qonun qoidalar, formula, tenglamalar, analitik, grafik, vektor, kompleks ifodalari va hisoblash usullari bo'yicha fanning nazariy qismidan qisqacha tushunchalar berilgan.

O'quv qo'llanma barcha texnika yo`nalishlari bo'yicha ta'lim oladigan talabalarga mo'ljallangan bo'lib, undan soha mutaxasislari, muhandislar, magistratura talabalari va aspirantlar ham foydalanishlari mumkin.

Elektrotexnika va elektronika kursini mustaqil o`rganuvchi sirtqi bo`lim talabalariga yordam berish maqsadida barcha bo`limlar bo`yicha namuna sifatida masalalar yechimlari batafsil bayon etilgan.

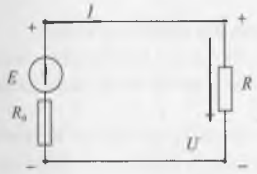
O'quv qo'llanma talabalarga amaliy mashg'ulot darsini o'tishda foydalanishga tavsiya etilib, mustaqil masala yechishni o'rganish va nazariy bilimlarini amalda sinab ko'rishlarida yordam beradi.

1-BOB. O'ZGARMAS TOK ELEKTR ZANJIRLARI

O'zgarmas tok – vaqt bo'yicha o'zgarmas bo'lib, $I = \frac{q}{t}$ (A).

O'zgarmas tok generatori, akkumulyator, galvanik elementlar, fotoelementlar, termopara va hokazolar o'zgarmas tok manbai hisoblanadi.

O`zgarmas tok manbai, elektr iste`molchi va ularni bog`lovchi simlardan tashkil topgan majmua o`zgarmas elektr tok zanjiri deyilib quyidagi sxema ko'rinishida ifodalash mumkin.



E – manba e.y.k.
R – istemolchi qarshiligi.
R_0–manba ichki qarshiligi (ko`pincha manbaning ichki qarshiligi nolga teng deb olinadi)

Elektr tok zanjirlari tarmoqlanmagan va tarmoqlangan bo'lib, istemolchilarni birlashtiruvchi simlarga – shaxobcha(shoxa, tarmoq) va uchtadan ko'p tarmoqlarni birlashtiruvchi nuqtalarga – tugun deb ataladi.

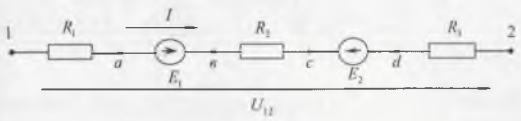
Elektr kuchlanish(potensillar farqi) deb – elektr maydon Ye (manba) tasirida biror musbat q zaryadning l masofaga ko'chirilishida bajarilgan ishga aytiladi va Voltda o'lchanadi.

$$U_{AB} = \frac{A}{q} = \int_A^B Edl = \varphi_a - \varphi_e \quad (V) \qquad (1.1)$$

Elektr zanjirlari uchun Om qonuni

Aktiv qarshiligi bo'lgan zanjirning bir qismi uchun Om qonuni

$$U_{an} = U = RI\ (V) \quad yoki \quad I = \frac{U}{R}\ (A) \qquad (1.2)$$



Elektr tok zanjiriga manba ulangan holda butun zanjir uchun Om qonuni quyidagicha tenglama bilan ifodalaniladi.

Potensiallar tenglamasiga asosan:

$$\varphi_d = \varphi_2 + R_3 I,\ \varphi_C = \varphi_d + E_2,\quad \varphi_a = \varphi_C + R_2 I,$$

$$\varphi_a = \varphi_a - E_1,\quad \varphi_1 = \varphi_a + R_1 I$$

Yoki $\varphi_1 = \varphi_2 + R_3 I + E_2 + R_2 I - E_1 + R_1 I,\quad \varphi_1 - \varphi_C = U_{12}$

$$U_{12} = (R_1 + R_2 + R_3) I - E_1 + E_2$$

Bundan: $$I = \frac{E_1 - E_2 + U_{12}}{R_1 + R_2 + R_3} \qquad (1.3)$$

Elektr tok zanjirlari uchun Kirxgoff qonunlari.

Kirxgoff qonunlari elektr tok zanjirlarini hisoblashda asosiy qonunlardan bo'lib, barcha hisoblash usullarning ham negizi hisoblanadi.

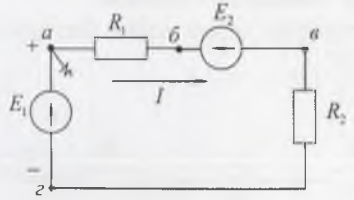
Kirxgof qonunlariga asosan ρ - tarmoq. q- tugundan tashkil topgan elektr tok zanjirini hisoblab tarmoq toklari uchun $K = \rho - (q-1)$ tuzilgan tenglamani yechish bilan bajariladi.

Kirxgoffning 1 - qonuni: $\sum I = 0$ - tarmoq toklarining algebraik yig'indisi nolga teng.

Kirxgoffning 2 - qonuni: $\sum E = \sum RI$ - kontur e.yu.k algebraik yig'indisi shu konturga kiruvchi qarshiliklardagi kuchlanishlarning algebraik yig'indisiga teng.

Masala yechish namunalari

1.1-masala. Ketma-ket ulangan elektr tok zanjirining e.y.k lari $E_1=4$ V, $E_2=2$ V, qarshiliklari $R_1=4$ Om, $R_2=6$ Om teng. Tok qiymati va potensallari aniqlanib, diagrammasi tuzilsin?



Yechish: Om qonuniga asosan tok qiymatini topamiz:

$$I = \frac{E_1 - E_2}{R_{um}} \quad \frac{4-2}{R_1 + R_2} = \frac{2}{10} = 0{,}2 \ (A)$$

Bunda: $E_1 > E_2$ bo'lganligi uchun tok soat strelkasiga mos yo'nalgan bo'ladi.

Potensiallar farqini aniqlash uchun $\varphi_a = 0$ deb olamiz.

Bunda: $\varphi_б - \varphi_а = R_1 I$, *yoki* $\varphi_б = \varphi_а + IR_1 = 0 + 0{,}2 \cdot 4 = 0{,}8 \ \ (V)$

$\varphi_в$ - potensiali:

$$\varphi_б - \varphi_в = E_1 \ \ yoki \ \ \varphi_в = \varphi_б - E_1 = -3{,}2 \ \ (V)$$

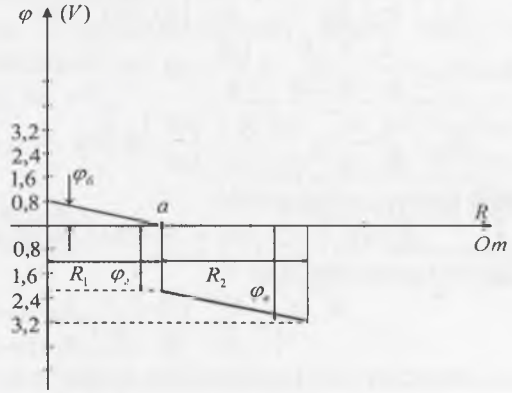
$\varphi_г$ -potensiali:

$$\varphi_г - \varphi_в = IR_2 \ \ yoki \ \ \varphi_г = IR_2 + \varphi_в = 0{,}2 \cdot 6 - 3{,}2 = -2 \ \ (V)$$

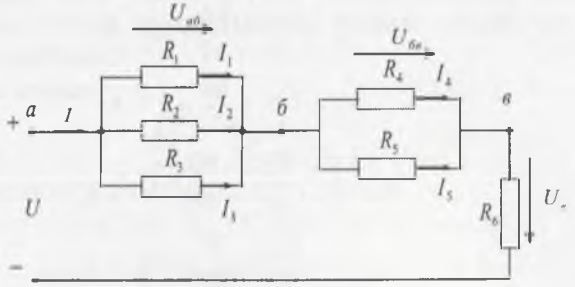
Ushbu tenglamalardan: $\varphi_а - \varphi_г = E_2$ bo'lib:

$$\varphi_а = E_2 + \varphi_2 = 2 - 2 = 0 \ \ (V)$$

Potensial diagrammasini tuzamiz.

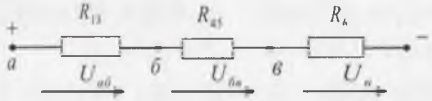


1.2-masala. Tarmoqlangan elektr tok zanjiri parametrlari R_1=40 *Om*, R_2=120 *Om*, R_3=60 *Om*, R_4=90 *Om*, R_5=10 *Om*, R_6=10 *Om* bo'lib, *U=120 V* o'zgarmas kuchlanishga ulangan. Ekvivalent qarshiligi va tarmoq toklari aniqlansin.



Yechish:

Ekvivalent qarshiliklar sxemasini tuzamiz:



Zanjirning ekvivalent yoki umumiy qarshiligini topamiz

Buning uchun birinchi navbatda R_{13} va R_{45} qarshiliklarni paralell qo'shamiz:

$$\frac{1}{R_{13}} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3} = \frac{1}{40} + \frac{1}{120} + \frac{1}{60} = \frac{6}{120}$$

Bundan: $R_{13} = \frac{R_1 \cdot R_2 \cdot R_3}{R_1 + R_2 + R_3} = \frac{120}{6} = 20\ Om$

$$R_{45} = \frac{R_4 \cdot R_5}{R_4 + R_5} = \frac{90 \cdot 10}{90 + 10} = \frac{900}{100} = 9\ Om$$

Umumiy ekvivalent qarshilik:

$$R = R_{13} + R_{45} + R_6 = 20 + 9 + 11 = 40\ Om.$$

Umumiy tokni aniqlaymiz:

$$I = \frac{U}{R} = \frac{120}{40} = 3\ A$$

Tugun potensiali yoki kuchlanishni aniqlaymiz:

$$U_{аб} = I \cdot R_{13} = 3 \cdot 20 = 60\ V$$

$$U_{бв} = I \cdot R_{45} = 3 \cdot 9 = 27\ V$$

$$U_в = I \cdot R_6 = 3 \cdot 11 = 33\ V$$

Endi tarmoq toklarini topamiz:

$$I_1 = \frac{U_{аб}}{R_1} = \frac{60}{40} = 1{,}5\ A$$

$$I_2 = \frac{U_{аб}}{R_2} = \frac{60}{120} = 0{,}5\ A$$

$$I_3 = \frac{U_{аб}}{R_3} = \frac{60}{60} = 1\ A$$

$$I_4 = \frac{U_{бв}}{R_4} = \frac{27}{90} = 0{,}3\ A$$

$$I_5 = \frac{U_{6a}}{R_5} = \frac{27}{10} = 2{,}7 \ A$$

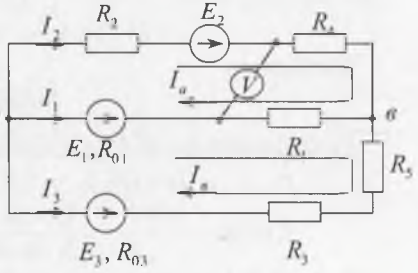
1.3-masala. Ikki konturli elektr tok zanjiri manba kuchlanishlari: E_1=8 V, E_2=6 V, E_3=36 V qarshiliklari: R_1=3 Om, R_2=1 Om, R_3=2 Om, R_{01}=1,3 Om, R_{03}=1,2 Om, R_4=6 Om, R_5=8 Om teng. Konturli tok va tugunlararo kuchlanishlar usuliga asosan tarmoq toklari, voltmetr kuchlanishi va quvvatlar balansi aniqlansin.

Yechish:

1-usul. Mustaqil konturlardagi kontur toklari I_a, I_v yo'nalishlarini belgilaymiz.

Kirxgofning 2- qonuniga asosan, kontur toklar tenglamasi quyidagicha ifodalanadi:

$$\left.\begin{aligned} R_{11}\cdot Ia - R_{12}\cdot Ia &= E_{11} \\ -R_{21}\cdot Iв + R_{22}\cdot Iв &= E_{22} \end{aligned}\right\}$$



Bu yerda: R_{11}, R_{22} – konturlarning xususiy qarshiliklari.

$R_{11}=R_1+R_{01}+R_2+R_4$

$R_{22}=R_1+R_{01}+R_3+R_{03}+R_5$

$R_{12} = R_{21}$ - konturlararo qarshilik:

$$R_{12} = R_{21} = R_1 + R_{01}$$

E_{11} va E_{22} – mos konturga alaqodor bo'lgan manbalarning EYK larning algebrik yig'indisi.

Bu xolda, agar manbai e.y.k yo'nalishi bilan kontur toki yo'nalish mos bo'lsa, uning ishorasi musbat olinadi va aksincha manfiy ishora olinadi.

Shunga asosan:

$$E_{11} = E_2 - E_1$$

$$E_{22} = E_1 - E_3$$

Tenglamalarga son qiymatlarini qo'ysak :

$$\left.\begin{aligned} (3+1{,}3+6+2)\cdot I_a - (3+1{,}3)\cdot I_в &= 6-8 \\ -(3+1{,}3)\cdot I_a + (3+1{,}3+1+1{,}2)\cdot I_в &= 8-36 \end{aligned}\right\}$$

Yoki:
$$\left.\begin{aligned} 12{,}3 \cdot I_a - 4{,}3 \cdot I_e &= -2 \\ -4{,}3 \cdot I_a + 14{,}5 \cdot I_e &= -28 \end{aligned}\right\}$$

Tenglamalar sistemasini Kramer usulida yechamiz:

$$\Delta = \begin{vmatrix} 12{,}3 & -4{,}3 \\ -4{,}3 & 14{,}5 \end{vmatrix} = 178{,}35 - 18{,}49 = 159{,}86$$

$$\Delta_1 = \begin{vmatrix} -2 & -4{,}3 \\ -2{,}8 & 14{,}5 \end{vmatrix} = -29 - 120{,}4 = -149{,}4$$

$$\Delta_2 = \begin{vmatrix} 12{,}3 & -2 \\ -4{,}3 & -28 \end{vmatrix} = -344{,}4 - 8{,}6 = -353{,}0$$

Bundan:
$$I_a = \frac{\Delta_1}{\Delta} = \frac{-149{,}4}{159{,}86} = -0{,}93A$$

$$I_e = \frac{\Delta_2}{\Delta} = \frac{-353{,}0}{159{,}86} = -2{,}21A$$

Endi shaxobchalardagi toklarni aniqlaymiz:

$I_1 = I_v - I_a$ =- 2,21 – (-0,93) =- 1,28 A;

$I_2 = I_a$ = - 0,93 A ;

$I_3 = - I_v$ = 2, 21 A;

I_1 va I_2 toklarning minus ishorali bo'lishi, ularning zanjirdagi haqiqiy yo'nalishi, biz qabul qilganga nisbatan teskari ekanligini ifodalaydi.

2-usul. Tugun potensiallari usuliga asosan hisoblash. Bu usulga asosan, shaxobchalardagi toklarni tugun potensiallari orqali ifodalaymiz. Noma'lum potensiallarni aniqlash uchun $q - 1$ ta tenglama tuzish kerak, ya'ni ixtiyoriy tugun potensiali "ma'lum" yoki "nolga" teng deb qabul qilinadi. Berilgan sxema ikki tugundan iborat, demak φ_a tugun potensialini "nol", deb qabul qilib bitta tenglama tuzamiz.

$$g_{vv} \cdot \varphi_v = J_v$$

Bu yerda: φ_v – aniqlashi kerak bo'lgan tugun potensiali.

g_{vv} - «v» tugunga kiruvchi shaxobchalarning o'tkazuvchanliklari yig'indisi.

J_v – EYK ga ekvivalent bo'lgan tok manbalarining algebraik yig'indisi.

Bunda, agar tok manbai yo'nalishi tugunga yo'nalgan bo'lsa, "musbat" va aksincha "manfiy" ishora bilan olinadi.

Demak:

$$g_{ek} = \frac{1}{R_2 + R_4} + \frac{1}{R_1 + R_{01}} + \frac{1}{R_3 + R_{03} + R_5};\ (\frac{1}{Om})$$

$$J_e = \frac{E_1}{R_1 + R_{01}} + \frac{E_2}{R_2 + R_4} + \frac{E_3}{R_3 + R_{03} + R_5};\ (A)$$

Son qiymatlari qo'yilsa:

$$\left(\frac{1}{2+6} + \frac{1}{3+1,3} + \frac{1}{1+1,2+8}\right)\varphi_e = \frac{8}{3+1,3} + \frac{6}{2+6} + \frac{36}{1+1,2+86}$$

Yoki: $\varphi_v = 13,49\ (V)$

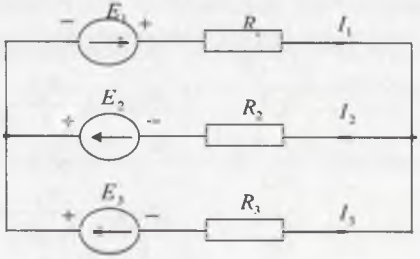
2. Shaxobchalardagi toklar esa:

$$I_1 = \frac{-\varphi_e + E_1}{R_1 + R_{01}} = \frac{-13,49+8}{3+1,3} = \frac{-5,49}{4,3} = -1,28A;$$

$$I_2 = \frac{-\varphi_e + E_2}{R_2 + R_4} = \frac{-13,49+6}{2+6} = \frac{-7,49}{8} = -0,936A;$$

$$I_3 = \frac{-\varphi_e + E_3}{R_3 + R_{03} + R_5} = \frac{-13,49+36}{1+1,2+8} = \frac{22,51}{10,2} = 2,206A;$$

1.4-masala. Elektr tok zanjirining manba kuchlanishlari $E_1 = 10$ *V*, $E_2 = 40$ *V*, $E_3 = 5$ *V* qarshiliklari $R_1 = 35$ *Om*, $R_2 = 5$ *Om*, $R_3 = 10$ *Om* teng. Ustma – ustlash usuliga asosan tarmoq toklari aniqlansin.



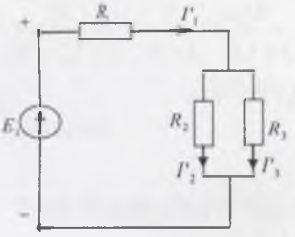
Yechish:

Ustma – ustlash usuliga asosan zanjir tarmoqlaridan oqib o'tadigan tok har bir e.y.k alohida tasirida oqadigan tarmoq toklarning algebraik yig'indisiga teng bo'ladi:

$$I_1 = I_1' + I_1'' + I_1'''$$
$$I_2 = I_2' + I_2'' + I_2'''$$
$$I_3 = I_3' + I_3'' + I_3'''$$

Ushbu toklarni aniqlash uchun berilgan sxemani bitta e.y.k dan iborat bo'lgan oddiy ekvivalent sxemalarga ajratamiz.

a) $E_1=10\ V,\ E_2=E_3=0$ bo'lgan holat uchun tarmoq toklari I_1' aniqlaymiz:

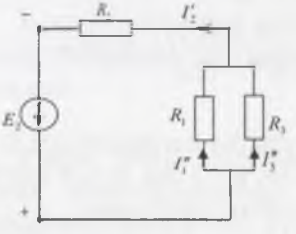


$$I_1' = \frac{E_1}{R_{ekv}} = \frac{E_1}{R_1 + \frac{R_2 \cdot R_3}{R_2 + R_3}} = \frac{10}{\frac{115}{3}} = \frac{6}{23}\ A$$

$$I_2' = I_1' \frac{R_2}{R_2 + R_3} = \frac{6}{23} \cdot \frac{10}{5+10} = \frac{4}{23}\ A$$

$$I_3' = I_1' \frac{R_3}{R_2 + R_3} = \frac{6}{23} \cdot \frac{5}{5+10} = \frac{2}{23}\ A$$

b) $E_2=40\ V,\ E_1=E_3=0$ bo'lganda I_1'' tarmoq toklarini topamiz:

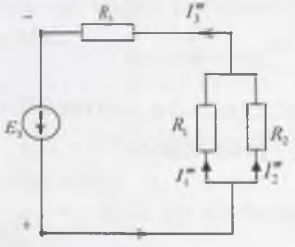


$$I_2' = \frac{E_2}{R_{ekv}} = \frac{E_2}{R_2 + \frac{R_1 \cdot R_3}{R_1 + R_3}} = \frac{40}{\frac{115}{9}} = \frac{72}{23}\ A$$

$$I_1'' = I_2'' \cdot \frac{R_3}{R_1 + R_3} = \frac{72}{23} \cdot \frac{10}{35+10} = \frac{16}{23}\ A$$

$$I_3'' = I_2'' \cdot \frac{R_1}{R_1 + R_3} = \frac{72}{23} \cdot \frac{35}{35+10} = \frac{56}{23}\ A$$

v) $E_3=5\ V,\ E_1=E_2=0$ bo'lgan I_1''' tarmoq toklari aniqlaymiz:



$$I_3''' = \frac{E_3}{R_3 + \frac{R_1 \cdot R_2}{R_1 + R_2}} = \frac{5}{\frac{115}{9}} = \frac{8}{23}\ A$$

$$I_1''' = I_3''' \cdot \frac{R_2}{R_1 + R_2} = \frac{8}{23} \cdot \frac{5}{40} = \frac{1}{23}\ A$$

$$I_2''' = I_2''' \cdot \frac{R_1}{R_1 + R_2} = \frac{6}{23} - \frac{1}{23} = \frac{7}{23}\ A$$

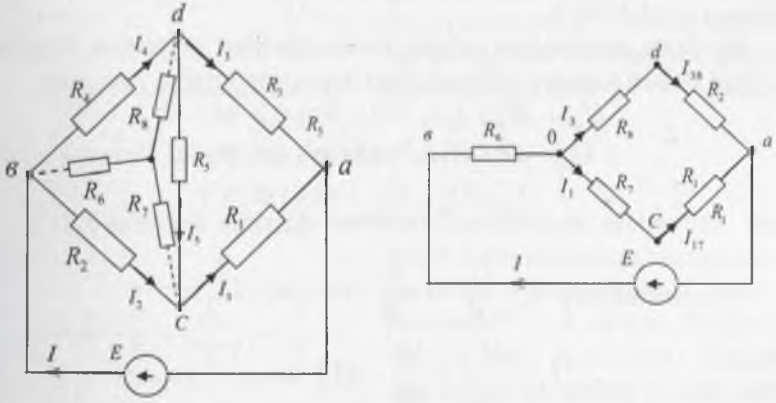
Endi toklar yo'nalishi va ishorasini hisobga olgan holda haqiqiy tarmoq toklarini aniqlaymiz:

$$I_1 = I_1' + I_1'' + I_1''' = \frac{6}{23} + \frac{16}{23} + \frac{1}{23} = 1 \ A$$

$$I_2 = I_2' + I_2'' + I_2''' = \frac{4}{23} + \frac{72}{23} - \frac{7}{23} = 3 \ A$$

$$I_3 = I_3' + I_3'' + I_3''' = -\frac{2}{23} + \frac{56}{23} - \frac{8}{23} = 2 \ A$$

1.5-masala. Ko'prik sxemada ulangan elektr tok zanjiri parametrlari: $R_1=60\ Om$, $R_3=80\ Om$, $R_4=R_5=120\ Om$, $R_2=80\ Om$ bo'lib, $E=30\ V$ o'zgarmas manbaga ulangan. Uchburchak sxemadan ekvivalent yulduzcha sxemaga o'tish bilan tarmoq toklari va istemolchilarda sarf bo'ladigan elektr tok quvvati aniqlansin.



Yechish:

Berilgan sxemadan *bcd* uchburchak potensialarini ekvivalent yulduzcha sxemaga o'tish ifodasidan foydalanamiz:

$$R_6 = \frac{R_2 \cdot R_4}{R_2 + R_4 + R_5} = \frac{80 \cdot 120}{320} = 30\ Om$$

$$R_7 = \frac{R_2 \cdot R_5}{R_2 + R_4 + R_5} = \frac{120 \cdot 120}{320} = 45\ Om$$

$$R_8 = \frac{R_4 \cdot R_5}{R_2 + R_4 + R_5} = \frac{80 \cdot 120}{320} = 30\ Om$$

Tuzilgan yulduzcha sxemadan qarshiliklarni ketma – ket va paralell qo'shish bilan zanjir umumiy qarshiligini aniqlaymiz:

$$R_{um} = R_6 + \frac{(R_3 + R_8)(R_1 + R_7)}{R_3 + R_8 + R_1 + R_7} = 30 + \frac{210 \cdot 105}{315} = 100\ Om$$

Umumiy tarmoq toki: $I = \frac{E}{R_{um}} = \frac{30}{100} = 0{,}3\ A$

Paralell tarmoq toklarini aniqlaymiz:

$$I_{17} = I\frac{R_8 + R_3}{R_3 + R_8 + R_1 + R_7} = \frac{210 \cdot 0{,}3}{315} = 0{,}2\ A$$

$$I_{38} = I\frac{R_1 + R_7}{R_3 + R_8 + R_1 + R_7} = \frac{105 \cdot 0{,}3}{315} = 0{,}1\ A$$

Bu yerda $R_1=R_3$ ga teng bo'lganligi uchun aniqlangan $I_{17}=I_1=0{,}2$ A va $I_{38}=I_3=0{,}1$ A teng.

Berilgan sxemaning qolgan tarmoqlaridan oqadigan toklarni aniqlash uchun tugun potensiallariga asosan tenglama yozamiz:

$$U_{ac} = IR_6 + I_1R_7 = 0{,}3 \cdot 30 + 0{,}2 \cdot 45 = 18\ V$$

$$U_{ad} = IR_8 + I_3R_8 = 0{,}3 \cdot 30 + 0{,}1 \cdot 30 = 12\ V$$

$$U_{dc} = U_{ac} - U_{ad} = 18 - 12 = 6\ V$$

Tarmoq toklari: $I_2 = \frac{U_{ac}}{R_2} = \frac{18}{120} = 0{,}15\ A$,

$$I_4 = \frac{U_{ad}}{R_4} = \frac{12}{80} = 0{,}15\ A$$

$$I_5 = \frac{U_{cd}}{R_5} = \frac{6}{120} = 0{,}05\ A$$

Masalaning yechimini tekshirib ko'ramiz:

a – tugundagi tarmoq toklar:

$$I = I_1 + I_3 = 0{,}2 + 0{,}1 = 0{,}3\ A$$

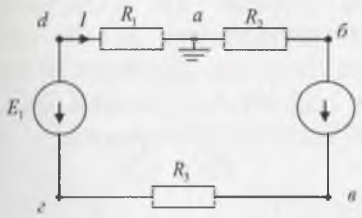
b – tugunda: $I = I_4 + I_2 = 0{,}15 + 0{,}15 = 0{,}3\ A$

Zanjirda sarf bo'ladigan quvvat:

$$P = UI = I^2R_{y.m} = 30 \cdot 0{,}3 = 9\ W$$

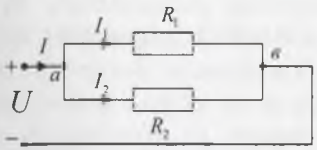
Mustaqil yechish uchun masalalar

1.6-masala. Ketma – ket sxemada ulangan elektr tok zanjir parametrlari: $E_1=20\ V$, $E_2=12\ V$, $R_1=5\ Om$, $R_2=6\ Om$, $R_3=9\ Om$ teng. Tarmoq toki va potensiallari aniqlanib, potensiallar diagrammasi tuzilsin.



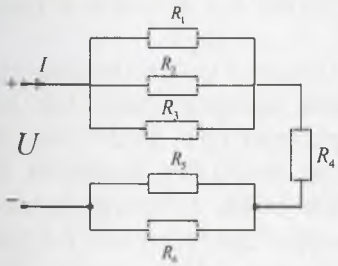
Javob: $I_v=0,4\ A$, $\varphi_A=0$, $\varphi_b=2,4\ V$, $\varphi_v=-14,4\ V$, $\varphi_g=-18\ V$, $\varphi_a=2\ V$.

1.7-masala. Paralell sxemada biriktirilgan tok zanjirlarining *a* va *b* tugun potensiallaridagi kuchlanish $U_{av}=60\ V$ bo'lib, kiruvchi tarmoq toki $I=1,5\ A$ va qarshilik $R_2=120\ Om$ teng. Tarmoq toklari, R_1 qarshiligi va ekvivalent qarshiligi hisoblab topilsin.



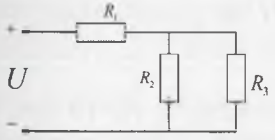
Javob: $R_1=60\ Om$, $R_{ekv}=40\ Om$, $I_1=1\ A$, $I_2=0,5\ A$.

1.8-masala. Aralash sxemada biriktirilgan elektr tok zanjiri $U=26\ V$ kuchlanishga ulangan bo'lib, qarshilik parametrlari: $R_1=8\ Om$, $R_2=14\ Om$, $R_3=4\ Om$, $R_4=5,16\ Om$, $R_5=7,5\ Om$, $R_6=5\ Om$. Zanjirning ekvivalent qarshiligi hamda tarmoq toklari aniqlansin.



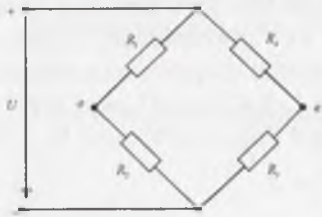
Javob: $R_{ekv}=10,4\ Om$, $I=2,5\ A$, $I_1=0,7\ A$, $I_2=0,4\ A$, $I_3=1,4\ A$, $I_5=1\ A$, $I_6=1,5\ A$.

1.9-masala. Elektr tok zanjiri $U=60\ V$ kuchlanishga ulanganda, $P=300\ W$ quvvat sarflanadi. Qarshilik parametrlari $R_2=15\ Om$, $R_3=5\ Om$ teng bo'lganda, R_1 qarshilik qiymati va tarmoq toklari aniqlansin.



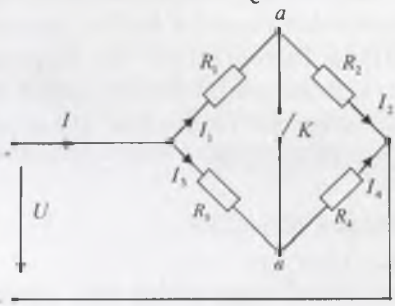
Javob: $R_1=8,25Om$, $I_1=3,75\ A$, $I_2=1,25\ A$, $I=5\ A$.

1.10-masala. Ko'prik sxemada ulangan tok zanjirining qarshilik parametrlari $R_1=10$ *Om*, $R_2=20$ *Om*, $R_3=40$ *Om*, $R_4=30$ *Om* bo'lib, $U=210$ *V* kuchlanishga ulangan. U_{av} – potensial kuchlanishi aniqlansin.



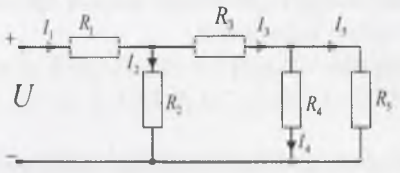
Javob: $U_{av}=20$ *V.*

1.11-masala. Qarshiliklari ko'prik sxemada ulangan tok zanjirining parametrlari: $R_1=10$ *Om*, $R_2=20$ *Om*, $R_3=40$*Om*, $R_4=30$ *Om* kuchlanishi $U=15,6$ *V.* Kalit ulangan va uzilgan xollar uchun ekvivalent qarshilik va qarshiliklardan oqib o'tuvchi toklar qiymati aniqlansin.



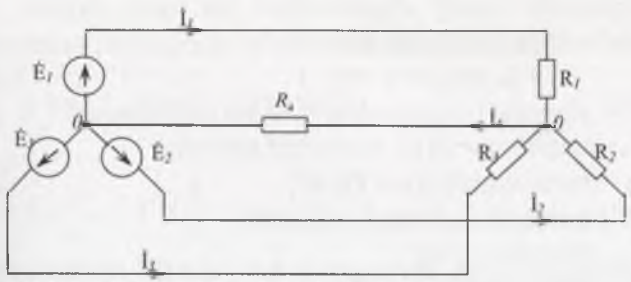
Javob: *a)* $R_{ekv}=8$ *Om*, $I=1,95$ *A*, $I_1=I_2=0,65$ *A*, $I_3=I_4=1,3$ *A*, *b)*$R_{ekv}=7,8$ *Om*, $I=2$ *A*, $I_1=0,5$ *A*, $I_2=0,8$ *A*, $I_3=1,5$ *A*, $I_4=1,2$ *A.*

1.12-masala. Aralash sxemada ulangan elektr tok zanjiri parametrlari: $R_1=50$ *Om*, $R_2=80$ *Om*, $R_3=20$ *Om*, $R_4=30$ *Om*, $R_5=60$ *Om* bo'lib, to'rtinchi tarmoqdan oqib o'tuvchi tok $I_4=0,2$ *A* ga teng. Tarmoq toklari, zanjir umumiy kuchlanishi va sarf bo'ladigan elektr tok quvvati aniqlansin.



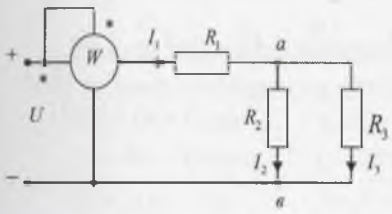
Javob: $U=34,5$ *V*, $P=15,5$ *W.*

1.13-masala. Berilgan sxema parametrlari: $R_1=10$ *Om*, $R_2=20$ *Om*, $R_3=4$ *Om*. e.y.k $E_1=20V$, $E_2=100$ *V*, $E_3=80$ *V*, bo'lganda tugunlararo kuchlanishlar usuliga asosan tarmoq toklari aniqlansin.



Javob: *I_1=-3,4A, I_2=2,3 A, I_3=6,5 A,I_4=-5,4 A.*

1.14-masala. Aralash sxemada ulangan tok zanjiri qarshilik parametrlari: *R_2=20 Om, R_3=30 Om* bo'lib, *U=625 V* kuchlanishga ulangan. Vattmetr ko'rsatishi P=32,25 kW bo'lgan holatda R_1– qarshilik, tarmoq toklari I_2, I_3 va R_2, R_3– qarshiliklarda sarf bo'ladigan quvvat aniqlansin.



Javob: *I_2=3 A, I_3=2 A, R_1=113 Om, P_2=180 W, P_3=2 W.*

2 – BOB. SINUSOIDAL O'ZGARUVCHAN TOK ZANJIRLARI

Sinusoidal davriy o'zgaruvchan tok oniy qiymati quyidagi funksiya ko'rinishda ifodalanadi.

$$i = I_m \sin(\omega t + \varphi_i) \qquad (2.1)$$

i – sinusoid o'zgaruvchan tokning oniy qiymati

I_m – amplituda yoki maksimal qiymat

φ_i – boshlangich faza – (grad)

ω - burchak chastota – (rad/sek)

f – chastota – (Gs)

T – davr – (sek)

Sinusoidal o'zgaruvchan tokning effektiv yoki ta'sir etuvchi qiymati:

$$I = \sqrt{\frac{1}{T}\int_0^T i_2 dt} = \frac{I_m}{\sqrt{2}} \qquad (2.2)$$

Sinusoidal o'zgaruvchan tok zanjiri uchun Om qonuni:

$$I = \frac{U}{z} = Uy \qquad (2.3)$$

yoki: burchak koeffisientlari:

$$\cos\varphi = \frac{R}{z} = \frac{g}{y}; \quad \sin\varphi = \frac{x}{y} = \frac{b}{y};$$

$$\operatorname{tg}\varphi = \frac{x}{R} = \frac{b}{g}; \quad \varphi = arcctg\frac{x}{R} = \frac{b}{g}; \qquad (2.4)$$

To'la qarshilik:

$$Z = \sqrt{R^2 + x^2}; \qquad (2.5)$$

Ketma–ket ulangan R–aktiv; L–induktiv; C–sig'im qarshiliklar bo'lganda, reaktiv qarshilik:

$$X = X_L - X_c \qquad (2.6)$$

Elektr zanjiri induktiv harakterga ega bo'lganda: $\omega L > \frac{1}{\omega c}$; $X_L > 0$; $\varphi > 0$

Sig'im harakterga ega bo'lsa: $\omega L < \frac{1}{\omega c}$; $\varphi < 0$; $x_c < 0$.

To'la o'tkazuvchanlik: $y = \sqrt{g^2 + b^2} \left(\frac{1}{Om} = Simens \right)$; (2.7)

Ekvivalent parametrlar o'xshashlik tenglamalari:

$$g = \frac{R}{z^2}; \quad b = \frac{X}{z^2}; \quad y = \frac{1}{z}; \tag{2.8}$$

$$R = \frac{g}{y^2}; \quad X = \frac{b}{y^2}; \quad z = \frac{1}{y}; \tag{2.9}$$

Istemolchilari ketma – ket ulangan tok zanjirlarida ekvivalent qarshilik:

$$R_e = \sum_{k=1}^{n} R_n; \quad X_e = \sum_{k=1}^{n} X_n \tag{2.10}$$

Parallel ulangan holda:

$$g_e = \sum_{k=1}^{n} g_n; \quad b_e = \sum_{k=1}^{n} b_n \tag{2.11}$$

Tok va kuchlanishlarning aktiv va reaktiv tashkil etuvchilari:

$$U_a = IR = U\cos\varphi; \quad I_a = Ug = U\cos\varphi;$$
$$U_p = IX = U\sin\varphi; \quad I_p = Ub = U\sin\varphi; \tag{2.12}$$
$$U = \sqrt{Ua^2 + Up^2}; \quad I = \sqrt{Ia^2 + Ip^2};$$

Aktiv quvvat:

$$P = UI\cos\varphi = I^2R = U^2g = U I_a = U_a I \tag{2.13}$$

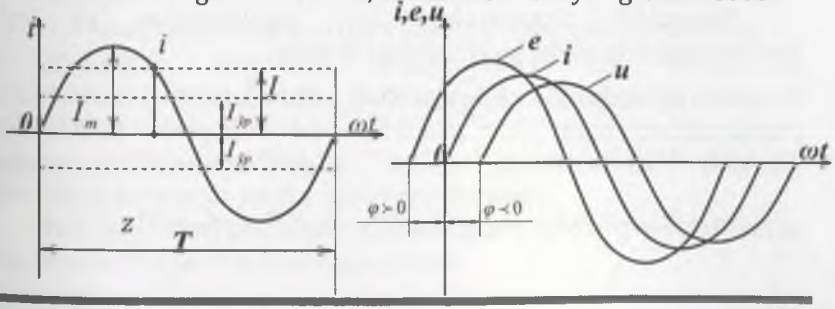
Reaktiv quvvat:

$$Q = UI\sin\varphi = I^2x = U^2b = U I_p = U_p I \tag{2.14}$$

To'la quvvat:

$$S = \sqrt{P^2 + Q^2} = UI = I^2z = U^2y \tag{2.15}$$

Sinusoidal o'zgaruvchan tok, kuchlanish va e.y.k. grafik ifodasi:



Analitik ifodasi:

$$e=E_m\sin(\omega t+\varphi_e);\ u=U_m\sin(\omega t+\varphi_u);\ i=I_m\sin(\omega t+\varphi_u-\varphi_i) \quad (2.16)$$

Faza farqi:

$$\varphi=\varphi_u-\varphi_i \quad (2.17)$$

Sinusoidal o'zgaruvchan tok zanjirlarini kompleks(simvolik) usulda hisoblash

Kompleks son Eyler formulasiga asosan $e^{\pm j\varphi}=\cos\varphi+j\sin\varphi$ ifodalanadi, kompleks teksilikda esa nuqta yoki vektor ko'rinishda tasvir qilish mumkin bo'lib, kompleks son uch xil ko'rinishda ifoda qilinadi.

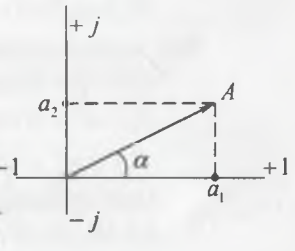
$\dot{A}=a_1+ja_2$ - algebrik

$\dot{A}=a(\cos\alpha+j\sin\alpha)$ - trigonometrik

$\dot{A}=ae^{j\alpha}$ - ko'rsatkichli

Bunda $a_1=a\cos\alpha=\mathrm{Re}\,\dot{A}$ - haqiqiy qismi.

$a_2=a\sin\alpha=Jm\,\dot{A}$ - mavhum qism.



a – kompleks son moduli: $|a|=\sqrt{a_1^2+a_2^2}$

α - kompleks son argumenti: $\alpha=arctg\frac{a_2}{a_1}$

Shuningdek $e^{\pm\pi/2}=\pm j;\ \frac{1}{j}=-j;\ j^2=1\ \ j^3=-j$ *va* $j^4=1$

Kompleks sonlarni qo'shish yoki ayirish amalini bajarishda algebrik ko'rinishda, ko'paytirish va bo'lish amalini bajarishda esa ko'rsatkichli ifodasidan foydalaniladi.

Sinusoidal o'zgaruvchan tok, kuchlanishlar va e.y.k funksiyasini kompleks ko'rinishdagi ifodasi:

$$i=I_m\sin(\omega t+\varphi i)=\dot{I}_m e^{j\omega t}\cdot I_m e^{j\varphi i}=\dot{I}_m e^{j\omega t}$$

$$u=U_m\sin(\omega t+\varphi_u)=\dot{U}_m e^{j\omega t}\cdot U_m e^{j\varphi u}=\dot{U}_m e^{j\omega t} \quad (2.18)$$

$$e=E_m\sin(\omega t+\varphi e)=\dot{E}_m e^{j\omega t}\cdot E_m e^{j\varphi e}=\dot{E}_m e^{j\omega t}$$

Bunda: $\dot{I}_m, \dot{U}_m, \dot{E}_m$ - sinusoidal o'zgaruvchan tok, kuchlanish, va E.Y.K kompleks amplitudasi.

Elektr zanjirlarini kompleks usulda hisoblash jarayonida $\dot{I}, \dot{U}, \dot{E}$ lar faqatgina vaqt funksiyasi tarzida emas, balki uning xosilasi yoki integral tarzida ham uchirashishi mumkin.

$$\frac{di}{dt} = \omega I_m \sin\left(\omega t + \psi_i + \frac{\pi}{2}\right) \Rightarrow \omega \dot{I}_m e^{j(\omega t + \varphi_i + \frac{\pi}{2})} = j\omega \dot{I}_m \; e^{j\varphi_i} \cdot e^{j\omega t} = j\omega \dot{I}_m \; e^{j\omega t}$$

$$\int i dt = \frac{I_m}{\omega} \sin\left(\omega t + \varphi_i - \frac{\pi}{2}\right) \Rightarrow \frac{\dot{I}}{\omega} e^{j\left(\omega t + \varphi_i - \frac{\pi}{2}\right)} = \frac{I_m}{j\omega} e^{j\varphi_i} \cdot e^{j\omega t} = \frac{\dot{I}_m}{j\omega} e^{j\omega t}$$

Demak, kompleks shaklda berilgan xar qanday sinusoidal funksiya tasviri

$\dot{I} m e^{j\omega t}$ bo'lsa, u funksiyadan hosila olish "$j\omega$" ko'pavtirish yoki integrallash esa "$j\omega$" ga bo'lish bilan barobar ekan.

Sinusoidal o'zgaruvchan tok zanjirlarini kompleks usulda hisoblash

Om qonuning kompleks ifodasi:

$$\dot{I} = \frac{\dot{U}}{\underline{Z}} = \underline{y}\dot{U} \qquad (2.19)$$

To'la qarshilik: $\underline{Z} = R + jx = Ze^{j\varphi}$ (2.20)

To'la o'tkazuvchanlik: $\underline{y} = \frac{1}{\underline{Z}} = g - j\beta = ye^{-j\varphi}$ (2.21)

To'la quvvatlar kompleks ifodasi:

$$\tilde{S} = \dot{U}\dot{I} = \dot{U}e^{j\varphi_u} \cdot \dot{I}e^{-j\varphi_i} = \dot{U}\dot{I}e^{j\varphi} = \dot{U}\dot{I}\cos\varphi + j\dot{U}\dot{I}\sin\varphi = P + jQ \qquad (2.22)$$

$\dot{I}$ – kompleks tokning teskari ishorasi bilan olingan qiymati.

Murakkab sinusoidal o'zgaruvchan tok zanjirlarini hisoblashda; (Om va Kirxgoff qonunlari bilan bir qatorda) Kirxgoff qonunlarini tadbiq etish, konturli toklar usuli, tugun kuchlanishlar, ustma–ustlash(superpozisiya) usuli, mutanosiblik prinsipi, ekvivalent generator usullaridan foydalaniladi.

Iste`molchilari ketma-ket ulangan oddiy elektr tok zanjirlarida tok umumiy bo'lib Om qonuniga asosan.

$\dot{I} = \frac{\dot{U}}{Z}$; bunda $\underline{z} = \underline{z}_1 + \underline{z}_2 + \ldots\ldots\ldots\ldots \underline{z}_n = \sum_{b=1}^{n=v} \underline{z}_n$ (2.23)

Iste`molchilari paralell ulangan tok zanjirida kuchlanish umumiy bo'lib:

$\dot{I} = \dot{U}\,\underline{y}$; bunda $\underline{y} = \underline{y}_1 + \underline{y}_2 + \ldots\ldots\ldots\ldots \underline{y}_n = \sum_{b=1}^{n=v} \underline{y}_n$ (2.24)

Aralash sxemada ulangan tok zanjiri uchun kompleks qarshiligi

$Z_{12} = \frac{Z_1 \cdot Z_2}{Z_1 + Z_2}$ bo'lib, tarmoq toklari:

$$\dot{I}_1 = \frac{Z_2}{Z_1 + Z_2}\dot{I}; \qquad \dot{I}_2 = \frac{Z_1}{Z_1 + Z_2}\dot{I} \tag{2.25}$$

$\dot{I}$ - umumiy tokning kompleks qiymati.

Kirxgof qonunlarining kompleks ifodasi.

1 qonun: $\sum_{k=1}^{n} \dot{I}_k = 0$ (2.26)

2 qonun: $\sum_{k=1}^{n} \dot{E}_k = \sum_{k=1}^{n} Z_k \dot{I}_k$ (2.27)

Masala yechish namunalari.

2.1-masala. O'zgaruvchan magnit oqimi *Φ=0,01sin314t (Vb)* bo'lib, cho'lg'amlar soni w=50 bo'lganda g'altak aylanma harakatlanishi natijasida hosil bo'ladigan e.y.k.ni aniqlang.

Yechish:

G'altakning ilashgan magnit oqimi: $\psi = w\phi = 0{,}5\sin 314t = \psi_m \sin t$

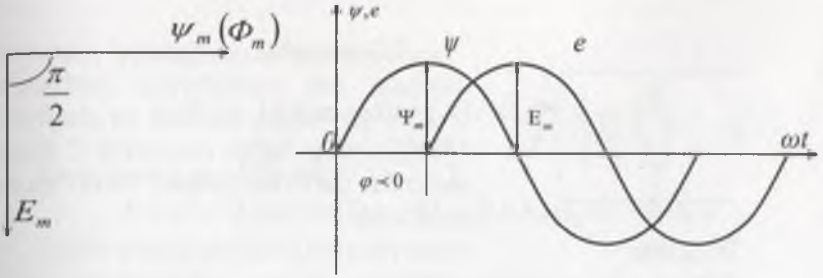
O'zinduksiya qonuniga asosan:

$$e = -\frac{d\psi}{dt} = \omega\psi_m \cos\omega t = E_m \sin(\omega t - 90^\circ)$$

yoki: $E_m = \omega\psi_m = 157(V)$

e.y.k. effektiv qiymati: $E = \frac{E_m}{\sqrt{2}} = 90(V)$

Vektor ifodasi va grafigini chizamiz.



2.2-masala. Sinusoidal o'zgaruvchan tok kuchlanishi *U=120sin1000t* bo'lgan generatorga induktiv qarshilik ulangan bo'lib, sinusoidal tok oqib o'tadi:

$$i = 8\sin(1000 \cdot t - 53^\circ).$$

O'zgaruvchan kuchlanish chastotasi 2 martaga kamayganda: induktiv g'altakning aktiv qarshiligi, induktivligi, tok qiymati va faza burchagi aniqlansin.

Yechish:

Masalaning sharti bo'yicha umumiy qarshilik:

$Z = \frac{U_m}{I_m} = 15(Om)$ bo'lib, faza burchagi $\varphi = \varphi_u - \varphi_i = 53^\circ$

Qarshiliklar uchburchak ifodasiga asosan:

$$R = Z\cos\varphi = 15\cos 53^\circ = 9(Om)$$

$$X = Z\sin\varphi = 15\sin 53^\circ = 12(Om)$$

Induktivlik: $L = \frac{x_L}{\omega} = \frac{12}{1000} = 0{,}012 гн = 12(mHn)$

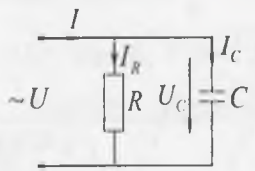
Kuchlanish chastotasi ikki martaga kamaytirilgan holda, induktiv qarshilik ham ikki martaga kamayadi: $x'_L = 6(Om)$

Faza farqi esa: $\varphi' = arctg\frac{x'_L}{R} = \frac{6}{9} = 33^\circ 40'$

To'la qarshilik: $Z' = \frac{x'_L}{\sin\varphi'} = 10{,}8(Om)$

Tok amplitudasi: $I'_m = \frac{U_m}{z'} = \frac{120}{10,8} = 11,09(A)$

Tokning oniy qiymati: $i = 11,09\sin(500t - 33^\circ 40')$



2.3-masala. Parallel sxemada ulangan tok zanjirining kuchlanishi *U=150(V), I=5(A), I_R=3(A)* va chastotasi *f=50(Gs)* teng. Sig'im parametri *C*, hamda zanjirda sarf bo'ladigan to'la quvvat aniqlansin.

Yechish:

Pifagor teoremasiga asosan toklar uchburchak vektor ifodasidan:

$$I_C^2 = I^2 - I_R^2 = \sqrt{25-9} = 4(A)$$

Sig'imdagi kuchlanish: $U_C = \frac{I_C}{x_C} = \frac{I_C}{\omega c}(V)$

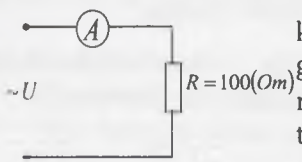
Bundan sig'im parametri: $C = \frac{I_C}{U_C \omega} = \frac{4}{150 \cdot 314} = 85(\mu F)$

Elektr zanjirning to'la quvvati: *S = UI = 1505 = 750 (VA)*

Aktiv qarshilik quvvati: *P = UI_R = 150 3 = 450 (W)*

Sig'im qarshilik reaktiv quvvati:

$$Q_C = \sqrt{S^2 - P^2} = \sqrt{750^2 - 450^2} = 600\ (Var)$$



2.4-masala. O'zgaruvchan tok kuchlanishi $U = 283\sin t$ bo'lgan generatorga, aktiv qarshiligi *R = 10(Om)* reostat ulangan, Reostatdan oqib o'tuvchi tokning effektiv, oniy qiymati va o'rtacha quvvat qiymati aniqlanib, vaqt bo'yicha o'zgaruvchan diagrammasi chizilsin.

Yechish:

Tokning amplituda qiymati $I_m = \frac{U_m}{R} = \frac{283}{10} = 28,3(A)$;

Effektiv qiymati: $I = \frac{I_m}{\sqrt{2}} = 20(A)$

Oniy qiymati esa: $i = I_m \sin \omega t = 28{,}3 \sin 314t$

Aktiv quvvatning o'rtacha qiymati:

$$P_{o'r} = \frac{1}{T}\int_0^T Pdt = UI = I^2R = 4000W = 4(kW)$$

Quvvatning oniy qiymati:

$$P = ui = UI + UI\sin(2\omega t - 90) = [4 + 4\sin(2\omega t - 90)]kW$$

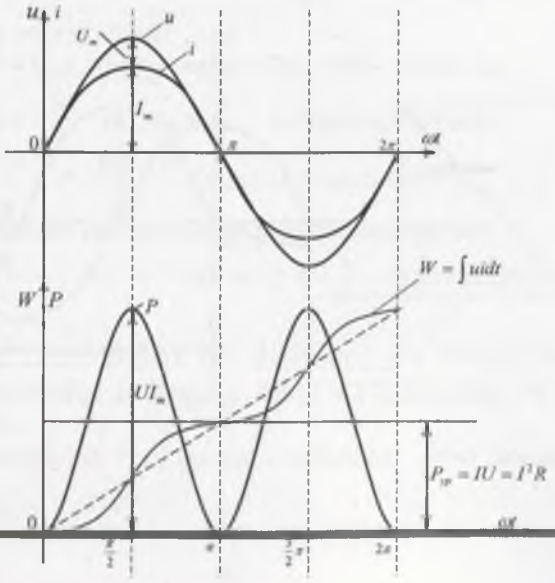
Elektr energiyasining oniy qiymati:

$$W = \int Pdt = UIt - \frac{UI}{2\omega}\sin 2\omega t = 4000t - \frac{4000}{2 \cdot 314}\sin \omega t = (4000 - 6{,}37\sin 2\omega t)(J)$$

Djoul-Lens qonuniga asosan aktiv qarshilikda (reostatda) o'zgaruvchan elektr tok energiyasi issiqlik energiyasi ajiralib sarf bo'ladi.

Aktiv quvvat vaqt bo'yicha o'zgaruvgan diagrammasi chizmada keltirilgan.

Bunda tok va kuchlanish orasidagi burchak $\varphi = 0$ bo'lib, I_m va U_m vektor ifodalari ustma-ust tushadi.



2.5-masala. Induktivligi L=0,27(Gn), aktiv qarshiligi R=49(Om) bo'lgan reaktiv g'altak, sinusoidal o'zgaruvchan tok chastotasi f = 50 (Gs), $U = 220(V)$ kuchlanishga ulangan.

Tokning effektiv qiymati I, tok va kuchlanish orasidagi burchak φ aniqlanib vektor ifodasi tuzilsin.

Yechish:

Om qonuniga asosan: $I = \frac{U}{z} = \frac{220}{\sqrt{R^2 + (\omega L)^2}} = \frac{220}{\sqrt{49^2 + (314 \cdot 0{,}27)^2}} = 2{,}24(A)$

Bunda: $\omega = 2\pi f = 314 \cdot 2 \cdot 50 = 314(rad/s)$

Burchak fazasi: $\varphi = arctg\frac{x}{R} = \frac{100}{49} = 2 = 60^\circ$

yoki faza farqi $\varphi = \varphi_u - \varphi_i = 0 - 60^\circ = -60^\circ$

Tokning oniy qiymati: $i = \sqrt{2}I = 3{,}16\sin(\omega t - 60^\circ)(A)$

Kuchlanish oniy qiymati: $u=220\ sin\ \omega t(V)$

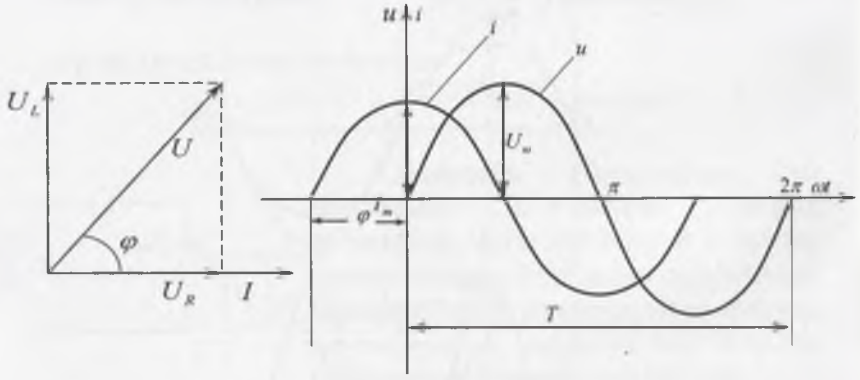
Bundan: $U_m = \sqrt{2}U = 1{,}41 \cdot 220 = 310(V)$

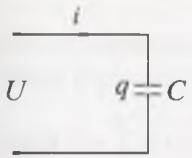
Masshtab tanlab, tok va kuchlanishlar vektor ifodasini va vaqt bo'yicha o'zgaruvchan diagrammasini tuzamiz.

Bunda R va x_L qarshiliklardagi kuchlanish:

$U_R = IR = 2{,}24 \cdot 49 = 115(V)$;

$U_L = I_L X_L = 2{,}24 \cdot 100 = 224(V)$;





2.6-masala. Sig'imi $S=41,6(\mu F)$ bo'lgan kondensator $u=120\sin(314t+\frac{\pi}{4})$ kuchlanishga ulangan. Sig'im, toki i, zaryadi Q, quvvati P_c va elektr maydon energiyasi We aniqlansin.

Yechish:

Sig'im qarshiligini aniqlaymiz:

$$X_c=\frac{1}{\omega c}=76,6(Om)$$

Tokning amplituda qiymati:

$$I_m=\frac{U_m}{x_c}=1,57(A)$$

Tok va kuchlanish orasidagi faza farqi:

$$\varphi=\varphi_U-\varphi_i=\frac{\pi}{4}+\frac{\pi}{2}=\frac{3}{4}\pi$$

Tokning oniy qiymati:

$$i=1,57\sin(314t+\frac{3}{4}\pi)(A)$$

Sig'imdagi zaryadning oniy qiymati:

$$Q=CU=416\cdot10^{-6}\cdot120\sin(314t+\frac{\pi}{4})=5\sin(314t+\frac{\pi}{4})(Var)$$

Quvvatning oniy qiymati:

$$P=U_mI_m[\cos\varphi-\cos(2\omega t+2\varphi_U-\varphi)]=-UI\cos2\omega t$$

Bunda $\varphi=-\frac{\pi}{2}$ va $\varphi_U=\frac{\pi}{4}$ bo'lganligi uchun:

$$P=\frac{120\cdot1,57}{2}\cos2\omega t=93,2\cos2\omega t(W)$$

Sig'imda hosil bo'ladigan elektr maydon energiyasi:

$$W_s=\frac{CU^2}{2}=\frac{1}{2}\cdot41,6\cdot10^{-6}\cdot120^2\sin^2(314t+\frac{\pi}{4})=0,15(1+\sin628t)(J)$$

2.7-masala. O'zgaruvchan tok chastotasi f = 500(Gs) bo'lgan tok zanjirida induktivligi L=5(mGn), toki I = 10(A) bo'lib, P= 1(kW) quvvat sarflanadi.

Umumiy kuchlanish U va quvvat koeffisienti $\cos\varphi$ aniqlansin.

Yechish:

Aktiv quvvat tenglamasidan:

$$P = I^2R;\ R = \frac{P}{I^2} = \frac{1000}{10} = 100(Om)$$

G'altak to'la qarshiligi:

$$Z_k = \sqrt{R^2 + (\omega L)^2} = \sqrt{100^2 + (6{,}28 \cdot 500 \cdot 5 \cdot 10^{-3})^2} = 18{,}6(Om)$$

Kuchlanish:

$$U = IZ_k = 10\ 18{,}6 = 186\ (V)$$

Quvvat koeffisienti:

$$\cos\varphi = \frac{P}{S} = \frac{1000}{IU} = \frac{1000}{186 \cdot 10} = 0{,}54$$

2.8-masala. Kuchlanish $U = 283\sin 500t$ bo'lgan generatorga, parametrlari $L = 0{,}016\ Gn,\ R = 6\ Om$ bo'lgan induktiv g'altak ulangan bo'lib, shu g'altakdan oqib o'tuvchi tokning oniy qiymati(i_i) aktiv, reaktiv kuchlanishlari(U_a, U_p), to'la quvvat(S) aniqlanib, kuchlanishlar uchburchak vektor ifodasi chizilsin.

Yechish:

Induktiv qarshilik: $X_i = \omega L = 500 \cdot 0{,}016 = 8(Om)$

Faza farqi:

$$\varphi = arctg\frac{x}{R} = arctg\frac{8}{6} = 53^\circ$$

$$\varphi_i = \varphi_U - \varphi = -53^\circ$$

To'la qarshilik: $Z = \sqrt{R^2 + x^2} = \sqrt{6^2 + 8^2} = 10(Om)$

Tok amplitudasi: $I_m = \frac{U_m}{z} = \frac{283}{10} = 28{,}3(A)$

Oniy qiymati: $i_m = 28{,}3\sin(500t - 53^\circ)(A)$

Aktiv va reakiv kuchlanishlar:

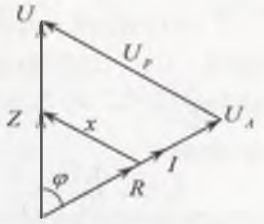
$$U_{mu} = U_m\cos\varphi = 170(V),\ U_{mp} = U_m\sin\varphi = 226(V)$$

To'la quvvat: $S = UI = \frac{U_m}{\sqrt{2}} \cdot \frac{I_m}{\sqrt{2}} = 4000VA = 4(kVa)$

Aktiv quvvat: $P = S\cos\varphi = 4 \cdot 0{,}6 = 2{,}4(kW)$

Reaktiv quvvat: $Q = S\sin\varphi = 4 \cdot 0{,}8 = 3{,}2(kVar)$

Vektor ifodasini tuzamiz.

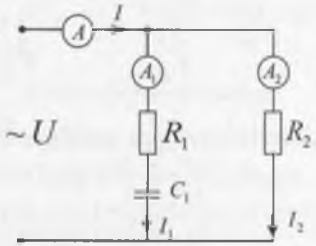


Aktiv qarshilikdagi kuchlanish vektori(U_a), tok vektori bilan ustma- ust tushadi shu sababli $\varphi_{ua} = -53^\circ$.

U_P - kuchlanish esa tok vektoriga nisbatan 90° farq qilib $\varphi_{Up} = 37^\circ$ teng.

$$U_a = 170\sin(500t - 53^\circ)V, \quad U_p = 226\sin(500t + 37^\circ)V$$

2.9-masala. Sxemaga ulangan ampermetrlarning ko'rsatish: $I = 25A$, $I_1 = 13{,}5A$, $I_2 = 15(A)$ va $R_2 = 20\,Om, f = 50\,(Gs)$ teng bo'lgan holat uchun zanjir parametrlari va sarf bo'ladigan aktiv quvvat (P) hamda quvvat koeffisenti $(\cos\varphi)$ hisoblab topilsin.



Yechish:

Parallel ulangan xolatda umumiy kuchlanish:

$$U = I_2 R_2 = 20 \cdot 15 = 300(V)$$

Umumiy tok esa: $I = \sqrt{I_a^2 + I_p^2}$

Bundan: $I_a = I_2 + I_1\cos\varphi_1, \quad I_p = I_1\sin\varphi$

Yoki: $I^2 = \left(I_1^2 + I_1\cos\varphi_1\right)^2 = I_1^2\sin^2\varphi_1 = I_1^2 + I_2^2 + 2I_1I_2\cos\psi_1$

Birinchi tarmoq burchagi: $\cos\varphi_1 = \dfrac{I^2 - I_1^{\,2} - I_2^{\,2}}{2I_1I_2} = 0{,}538$

To'la qarshilik: $z_1 = \dfrac{U}{I_1} = \dfrac{300}{13{,}5} = 22{,}2(Om)$

Aktiv qarshilik: $R_1 = z_1\cos\varphi_1 = 11{,}9(Om)$

Sig'im karshiligi: $x_1 = \sqrt{z_1^{\,2} - R_1^{\,2}} = 18{,}8(Om)$

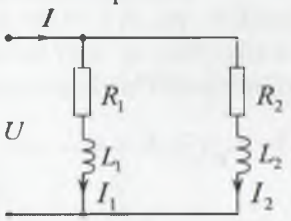
Sig'im parametri: $C_1 = \dfrac{1}{x_1\omega} = 169\cdot10^{-6}\Phi = 169(\mu F)$

Elektr zanjirning quvvat koeffisienti: $\cos\varphi = \dfrac{I_a}{I} = \dfrac{I_2 + I_1\cos\varphi_1}{I} = 0{,}89$

Zanjirda sarf bo'ladigan aktiv quvvat:

$$P = UI\cos\varphi = 300\cdot25\cdot0{,}89 = 6680W = 6{,}68(kW)$$

2.10-masala. Kuchlanish $U = 120\,V$ chastotasi $f = 50\,Gs$ bo'lgan tok zanjiriga parametrlari: $R_1 = 4\,Om$, $L_1 = 0{,}6\,mGn$, $R_2 = 6\,Om$, $L_2 = 25{,}5\,mGn$, bo'lgan ikkita induktiv g'altak istemolchilar parallel ulangan. Tarmaq toklari, zanjirning quvvat koeffisienti va istemolchilarda sarf bo'ladigan aktiv quvvat aniqlansin.



Yechish:

Birinchi g'altak induktivligini aniqlaymiz:

$$x_{L_1} = 2\pi fL_1 = 2\cdot3{,}14\cdot50\cdot0{,}6\cdot10^{-3} = 3\,Om$$

Birinchi g'altak to'la qarshiligini aniqlaymiz:

$$Z_1 = \sqrt{R_1^2 + x^2{}_{L_1}} = \sqrt{4^2 + 3^2} = 5\,Om$$

Birinchi tarmoq toki:

$$I_1 = \frac{U}{Z} = \frac{120}{5} = 24\,A$$

Birinchi g'altak quvvat koeffisienti:

$$\cos\varphi_1 = \frac{R_1}{Z} = \frac{4}{5} = 0{,}8$$

(burchak $\varphi_1 = 36^\circ50'$ bo'lganda $\sin\varphi_1 = 0{,}6$)

Bunda birinchi tarmoq toki aktiv tashkil etuvchisi:

$$I_{a_1} = I_1 \cos\varphi_1 = 24 \cdot 0{,}8 = 19{,}2 \ A$$

Reaktiv tashkil etuvchisi:

$$I_{P_1} = I_1 \sin\varphi_1 = 24 \cdot 0{,}6 = 14{,}4 \ A$$

Ikkinchi g'altak induktiv qarshiligi:

$$x_{L_2} = 2\pi f L_2 = 6{,}28 \cdot 50 \cdot 2{,}5 \cdot 10^{-3} = 10 \ Om$$

Ikkinchi tarmoq toki:

$$I_2 = \frac{U_2}{Z_2} = \frac{120}{10} = 12 \ A$$

Ikkinchi g'altak quvvat koeffisienti:

$$\cos\varphi_2 = \frac{R_2}{Z_2} = \frac{6}{10} = 0{,}6$$

(burchak $\varphi_2 = 52^0 10'$ bo'lganda $\sin\varphi_2 = 0{,}8$)

Ikkinchi tarmoq toki aktiv tashkil etuvchisi:

$$I_{a_2} = I_2 \cos\varphi_2 = 12 \cdot 0{,}6 = 7{,}2 \ A$$

Reaktiv tashkil etuvchisi:

$$I_{P_2} = I_2 \sin\varphi_2 = 12 \cdot 0{,}8 = 9{,}6 \ A$$

Umumiy tokning aktiv tashkil etuvchisi qismi:

$$I_a = I_{a_1} + I_{a_2} = 19{,}2 + 7{,}2 = 26{,}4 \ A$$

Reaktiv tashkil etuvchisi:

$$I_P = I_{P_1} + I_{P_2} = 14{,}4 + 9{,}6 = 24 \ A$$

Umumiy tok qiymati:

$$I = \sqrt{I_a^2 + I_P^2} = 36 \ A$$

Zanjir quvvat koeffisienti:

$$\cos\varphi = \frac{I_a}{I} = \frac{26{,}4}{36} = 0{,}733$$

Birinchi g'altakda sarf bo'ladigan aktiv quvvati:

$$P_1 = UI_1 \cos\varphi_1 = 120 \cdot 24 \cdot 0{,}8 = 2304 W$$

Ikkinchi g'altakda sarf bo'ladigan aktiv quvvati:

$$P_2 = UI_2 \cos\varphi_2 = 120 \cdot 12 \cdot 0{,}6 = 864 \ W$$

Iste`molchilarda sarf bo'ladigan aktiv quvvat:

$$P = P_1 + P_2 = 2304 + 864 = 3168 \ W$$

2.11-masala. Chizmada keltirilgan sxemada o'zgaruvchan kuchlanish chastotasi *f=50Gs* bo'lgan generatorning aktiv quvvati

I_1 R_1 X_1 n

R=31,25 (kW) zanjir qarshiliklari R_1=2 Om, x_1 = 36(Om), R_2 = 75 Om, x_3=100 (Om) teng. Shu zanjir uchun tarmoq toklari va kuchlanishlari hisoblansin.

Yechish:

Parallel ulangan tarmoq o'tqazuvchanligi:

$$g_{ab} = \frac{1}{R_2} = 1{,}33 \cdot 10^{-2}\left(\frac{1}{Om}\right); \qquad b_{ab} = \frac{1}{x_2} = -0{,}01\left(\frac{1}{Om}\right)$$

Umumiy o'tqazuvchanlik: $y_{ab} = \sqrt{g_{ab}^{\,2} + b_{ab}^{\,2}} = 1{,}67 \cdot 10^{-2}\left(\frac{1}{Om}\right)$

Ikki qutbli tok zanjirlari ekvivalent o'xshashlik tenglamasidan:

$$R_{ab} = \frac{g_{ab}}{y_{ab}^{\,2}} = 48(Om); \qquad x_{ab} = \frac{b_{ab}}{y_{ab}^{\,2}} = -\frac{0{,}01}{2{,}78 \cdot 10^{-4}} = 36(Om)$$

Zanjirning umumiy aktiv va reaktiv qarshiliklari:

$$R = R_1 + R_{ab} = 50\ (Om);\ x = x_1 + x_{ab} = 36\text{-}36 = 0$$

To'la qarshilik: $Z = \sqrt{R^2 + x^2} = 50(Om)$

Birinchi tarmoq toki: $I_1 = \sqrt{\frac{P}{R}} = \sqrt{\frac{31250}{50}} = 25(A)$

Umumiy kuchlanish esa $U = I_1 z = 1250\ (V)$ bo'lib, faza burchagi $\varphi = 0$.

Birinchi tarmoq kuchlanishilari: $U_{1a}=R_1 I_1=25 \cdot 2=50\ (V)$,

$$U_{1p}=x_1 I_1=25 \cdot 36=900(V)$$

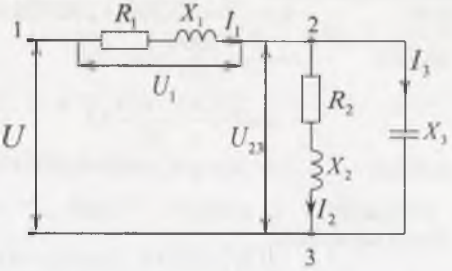
$$U_1 = \sqrt{U_{a1}^{\,2} + U_{p1}^{\,2}} = 900(V)$$

Parallel ulangan tarmoqdagi kuchlanish:

$$U_{ab} = \frac{I_1}{y_{ab}} = \frac{25}{1{,}67 \cdot 10^{-2}} = 1500(V)$$

Tarmoq toklari: $I_2 = \frac{U_{ab}}{R_2} = 20(A)$, $I_3 = \frac{U_{ab}}{x_3} = 15(A)$

2.12-masala. Qarshiliklari aralash sxemada ulangan elektr zanjirida sarf bo'ladigan aktiv quvvat *P=1,2 (kW)* bo'lib parametr qiymatlari: *R=2 (Om)*, *x=26 (Om)*, R_2=10 (Om), x_2=10 (Om), x_3=-10 (Om) teng. Zanjirdagi umumiy kuchlanish *U* tarmoq toklari I_1, I_2, I_3, reaktiv quvvati Q aniqlanib vektor diagrammasi tuzilsin.



Zanjirning aktiv va reaktiv qarshiliklarini, qarshiliklar ekvivalent parametr o'xshashlik tenglamasiga asosan aniqlaymiz:

$$g_2 = \frac{R_2}{R_2^2 + x_2^2} = \frac{10}{200} = 0{,}05\left(\frac{1}{Om}\right); \qquad b_2 = \frac{x_2}{R_2^2 + x_2^2} = \frac{10}{200} = 0{,}05\left(\frac{1}{Om}\right)$$

Uchinchi tarmoq o'tkazuvchanligi:

$$g_3 = 0, b_3 = \frac{1}{x_3} = -0{,}1\left(\frac{1}{Om}\right)$$

Tarmoqlar parallel ulangan qismi uchun: $g_{23} = g_2 + g_3 = 0{,}05\left(\frac{1}{Om}\right)$

Umumiy o'tqazuvchanlik: $y_{23} = \sqrt{g_{23}^2 + b_{23}^2} = 0{,}005\left(\frac{1}{Om}\right)$

O'xshashlik ekvivalent parametrlar tenglamasiga asosan aktiv qarshilik:

$$R_{23} = \frac{g_{23}}{y_{23}^2} = \frac{0{,}05}{0{,}005} = 10(Om)$$

Reaktiv qarshilik: $$x_{23} = \frac{b_{23}}{y_{23}^2} = -\frac{0{,}05}{0{,}005} = -10(Om)$$

To'la qarshilik: $$z_{23} = \sqrt{R_{23}^2 + x_{23}^2} = 14{,}1(Om)$$

Zanjirning umumiy aktiv qarshiligi: $R = R_1 + R_{23} = 12(Om)$

Umumiy reaktiv qarshiligi: $x = x_1 + x_{23} = 16(Om)$

Aktiv quvvat tenglamasiga asosan: $P = I^2 R$

Bunda $$I = \sqrt{\frac{P}{R}} = \sqrt{\frac{1200}{12}} = 10(A)$$

Burchak fazasi: $$\varphi = arctg\frac{x}{R} = \frac{16}{12} = 1{,}33 = 53^\circ 10'$$

Umumiy kuchlanish: $$U = \frac{P}{I\cos\varphi} = \frac{1200}{10 \cdot 0{,}6} = 200V$$

To'la quvvat: $S = UI = 200 \cdot 10 = 2000VA = 2kVA$

To'la qarshilik: $z = \frac{S}{I^2} = \frac{2000}{100} = 20\ Om;$

Burchak: $\sin\varphi = \frac{x}{z} = \frac{16}{20} = 0{,}8$

Reaktiv quvvat: $Q = S\sin\varphi = 2 \cdot 0{,}8 = 1600Var = 1{,}6kVar$

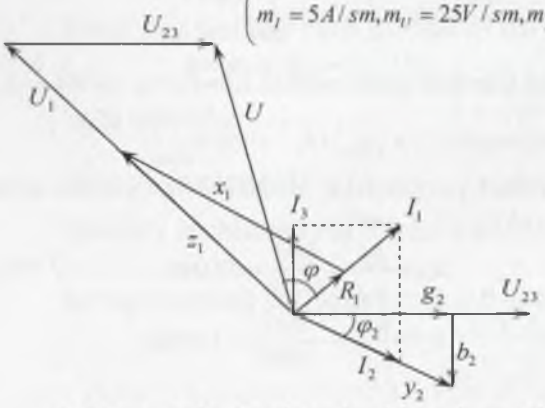
Tarmoq kuchlanishlari:

$$U_1 = z_1 I_1 = 26{,}2 \cdot 10 = 262V,\quad U_{23} = z_{23} I_1 = 14{,}1 \cdot 10 = 141V$$

Tarmoq toklari: $I_2 = \frac{U_{23}}{z_{23}} = \frac{141}{14{,}1} = 10A,\quad I_3 = \frac{U_{23}}{z_3} = \frac{141}{10} = 14{,}1A$

Vektor diagramma tuzish uchun tok va kuchlanish masshtablari tanlanadi:

$$\left(m_I = 5A/sm, m_U = 25V/sm, m_r = 0{,}02\frac{1}{Om \cdot sm}, m_z = 5\frac{Om}{sm}\right)$$



2.13-masala. Berilgan kuchlanish va tok $u = 100\sin\left(\omega t + \frac{\pi}{6}\right)(V)$ $i = 5\sin\left(\omega t - \pi/6\right)(A)$ funksiyalarining kompleks ifodasi, kompleks to'la qarshilik $\underline{Z}$ to'la o'tkazuvchanlik $\underline{U}$ va to'la quvvati $\overline{S}$ aniqlansin.

Yechish:

$$u = 100\sin(\omega t + 30^0) = \dot{100}e^{j30^0}V$$

$$i = 5\sin(\omega t - 30^0) = \dot{5}e^{-j30^0}A$$

Kompleks to'la qarshilik:

$$\underline{Z} = \frac{\dot{U}_m}{\dot{I}_m} = \frac{100e^{j30}}{5e^{-j30}} = 20e^{j60^0} = 10 + j17{,}3\ (Om)$$

Kompleks to'la o'tkazuvchanlik: $\underline{Y} = \frac{1}{\underline{Z}} = 0{,}1 + j0{,}06 \left(\frac{1}{Om} = Sm\right)$

Kompleks to'la quvvat:

$$\underline{\tilde{S}} = \dot{U}\,\dot{I} = \dot{U}\cdot\dot{I}\,e^{j(\varphi_U - \varphi_I)} = 500e^{j60^0} = 500\cos 30^0 + j500\sin 30^0 = 250 + j430\ \ (Var)$$

Bunday aktiv quvvat: *P=250 (W);*
Reaktiv quvvat: *Q=430 (Var).*

2.14-masala. Qarshiliklari *R = 3 Om, X = ± 4 Om.* teng bo'lgan elektr zanjiri kuchlanish *U = 100 V.* Tok va to'la quvvatlarning kompleks qiymatlari hisoblab topilsin.

Yechish:

To'la qarshilik kompleks ifodasi:

$$\underline{Z} = R \pm jx = 3 \pm j4 = 5e^{\pm j53^0}$$

Tok esa: $\dot{I} = \frac{\dot{U}}{\underline{Z}} = \frac{100e^{j0}}{5e^{\pm j53^0}} = 20e^{\mp j53^0} = 12 \pm j16$

To'la quvvat kompleks ifodasi:

$$\underline{\tilde{S}} = \dot{U}\,\dot{I} = 100\cdot 20e^{\pm j53^0} = 2000\cos 53^0 \pm j2000\sin 53^0 = 1200 \pm j1600$$

2.15-masala. Kuchlanish $\dot{U} = (80 + j60)$ tok $\dot{I} = (24 - j7)$ kompleks ifodalari uchun aktiv va reaktiv qarshiliklar qiymalari aniqlanib tok va kuchlanish vektor ifodasi chizilsin.

Yechish:

Tok va kuchlanishning ko'rsatkichli ifodasini aniqlaymiz

$$\dot{U} = (80 + j60) = 100e^{j36^0 50'}\ \ (V)$$

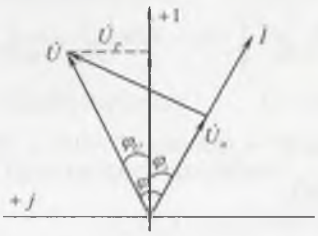
$$\dot{I} = (24 - j7) = 25e^{-j16^0 15'}\ \ (A)$$

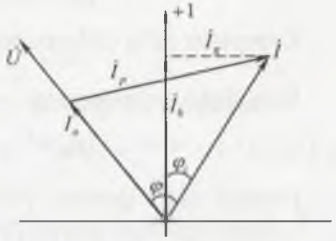
Kompleks to'la qarshilik: $\underline{Z} = \frac{\dot{U}}{\dot{I}} = 4e^{j53^0} = (2{,}4 + j3{,}2)\ Om$

Bundan aktiv qarshilik *R=2,4 Om*; reaktiv qarshilik *X=3,2 Om.*

Kuchlanish va tok orasidagi faza farqi: $\varphi = \varphi_u - \varphi_1 = 53^0$

Kompleks teksilikda tok va kuchlanishlar vektor diagrammasini tuzamiz.





Vektor diagrammadan

$$\dot{U}_a = U\cos\varphi \qquad \dot{I}_a = I\cos\varphi$$

$$\dot{U}_p = U\sin\varphi \qquad \dot{I}_p = I\sin\varphi$$

$$U = \sqrt{U_a^2 + U_p^2} \qquad I = \sqrt{I_a^2 + I_p^2}$$

Mustaqil yechish uchun masalalar

2.16-masala. Qutblar soni *p=3* berk halqa magnit maydonida *n=1000 ayl/min* tezlik bilan aylanganda, hosil bo'ladigan e.y.k chastotasi aniqlansin.

Javob: *f=50 Gs.*

2.17-masala. O'zgaruvchan tok generatorining yakor aylanish tezligi *n=500 ayl/min* bo'lib, *f=50 Gs* chastotali, e.y.k hosil qilganda qutblar soni nechta bo'ladi?

Javob: *R = 6 Om.*

2.18-masala. O'zgaruvchan e.y.k amplituda qiymati E_m*=120 V* chastotasi, *f=100 Gs* bo'lganda, *t=0,0075 s* vaqtda e.y.k oniy qiymati aniqlansin.

Javob: $e=120\sin 270^0 V$; $e=E_m=-120$ *V.*

2.19-masala. Kuchlanish va tok oniy qiymatlari $U = 170\sin(\omega t + 45^0)$ $i = 10\sin(\omega t - 45^0)$ bo'lganda bular orasidagi burchak φ topilib, *t = 0* bo'lganda oniy qiymatlari aniqlansin.

Javob: U_m*=120 V,* I_m *= 7 A,* $\varphi = 90^0$

2.20-masala. Tok va kuchlanishlarning kompleks ifodalari:

1. $\dot{U} = 100\ (V)$ $\dot{I} = (16 + j12)\ A$

2. $\dot{U} = 60 + j80\ (V)$ $\dot{I} = 20\ A$

3. $\dot{U} = 60 + j80\ (V)$ $\dot{I} = j20\ A$

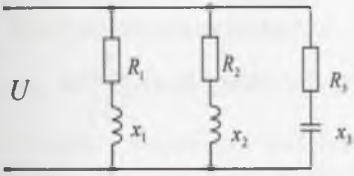
4. $\dot{U} = 100e^{j\frac{\pi}{3}}\ (V)$ $\dot{I} = 20e^{j\frac{\pi}{6}}\ A$

bo'lgan qiymatlari uchun kompleks to'la qarshilik, aktiv va reaktiv tashkil etuvchi parametrlar aniqlansin.

2.21-masala. Qarshilik parametrlari *R=20 Om, X_L=10 Om* bo'lgan induktiv g'altak chastotasi *f= 50 Gs* bo'lgan *U=100sin(φt+45⁰) (V)* kuchlanish ulangan. Chastota ikki martagacha ko'paygan holat uchun kompleks to'la qarshiligi, tok va to'la quvvati aniqlansin.

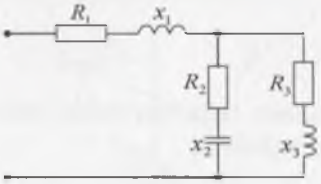
Javob: $\dot{I} = 2{,}5\ A,\ \bar{S} = 177\ VA$

2.22-masala. Paralell sxemada ulangan uchta iste'molchi parametrlari: *R_1=5 Om, X_1=2 Om, R_2=2,5 Om, X_2=5 Om, R_3=1,25 Om, X_3=-2,5 Om* teng. Ekvivalent kompleks o'tkazuvchanlik parametrlari va umumiy zanjir uchun burchak *cosφ* aniqlansin.



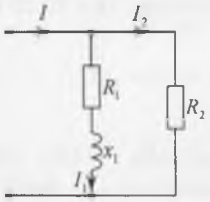
Javob: $\underline{y} = 0{,}425\ (\frac{1}{Om})$; *cosφ=0,995*

2.23-masala. Elektr zanjir parametrlari: $R_1=3$ *Om*, $X_1=20$ *Om*, $R_2=50$ *Om*, $X_2=-100$ *Om*, $R_3=100$ *Om*, $X_3=50$ *Om* teng. Zanjirning ekvivalent aktiv va reaktiv qarshilik qiymatlari aniqlansin.



Javob: *R=105,5(Om), X=-5,3(Om).*

2.24-masala. Berilgan elektr tok zanjirning tormoq toklari $I=1,6$ *A*, $I_1=8,93A$, $I_2=10$ *A* va qarshilik $R_2=2$ *Om* bo'lganda, R_1 aktiv quvvat, $cos\varphi$-quvvat koeffisienti va R_1, X_1 - qarshilik parametrlari aniqlansin.

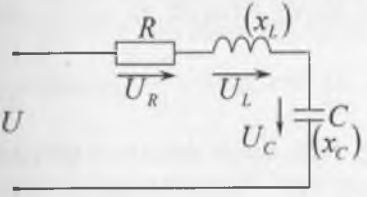


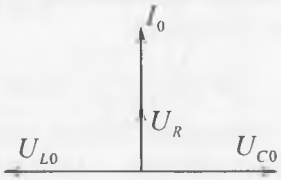
Javob: $P_1=800$ *W*, $cos\varphi=0,446$, $R_1=100m$, $X_1=\pm 20$ *Om*.

3 -BOB. ELEKTR ZANJIRLARIDA REZONANS HODISALARI

Reaktiv elementlar, induktivlik va sigim karshiliklaridan tarkib topgan elektr tok zanjirlarida tok va kuchlanish vektorlari ustma – ust tushib, bular orasidagi burchak $\varphi = 0$ bo'lgan holda, rezonans hodisasi yuzaga keladi.

Ketma – ket ulangan R,L,C zanjirda kuchlanishlar rezonansi





Ushbu zanjirda rezonans holat vaqtida $X_L=X_C$, yoki: $\omega_o L - \frac{1}{\omega_o C} = 0$

Bundan rezonans chastota:

$$\omega_O = \frac{1}{\sqrt{LC}}(rad/sek) \qquad (3.1)$$

Demak rezonans xodisasiga o`zgaruvchan tok chastotasi f, induktivlik va sig`im parametrlarini o`zgartirish bilan erishiladi.

Rezonans paytida reaktiv elementlar qarshiliklari:

$$\omega_o L = \frac{1}{\omega_o C} = \rho \qquad (3.2)$$

Yoki $\rho = \sqrt{\frac{L}{C}}$ to`lqin qarshiligi deyilib (Om) da o`lchanadi.

Rezonans holatda tok maksimal qiymatiga erishib:

$$I_o = \frac{U}{R} = I_{max} \qquad (3.3)$$

Reaktiv elementlardagi kuchlanish:

$$U_{LO} = U_{CO} = I_o \rho \qquad (3.4)$$

Agar $\rho > R$ bo`lsa reaktiv karshiliklardagi kuchlanishlar manba kuchlanishidan katta bo`ladi. Necha martaga katta bo`lishi quyidagi nisbat bilan aniqlanadi:

$$Q = \frac{U_{L0}}{U} = \frac{U_{C0}}{U} = \frac{\omega_{0L}}{R} = \frac{\rho}{R} \qquad (3.5)$$

Bunda, Q – kontur asilligi deyiladi, ba`zan sifat koeffisienti ham deyiladi.

Unga teskari bo`lgan qiymat $d = \frac{1}{Q} = \frac{R}{\rho}$ konturning so`nishi deyiladi.

Reaktiv qarshiliklardagi kuchlanishlar U_{Lmax} va U_{Cmax} maksimal qiymatga rezonansdan oldin yoki keyin erishadi va quyidagi ifoda bilan izohlanadi.

$$\omega_L = \omega_0 \sqrt{\frac{2}{2-d^2}} \text{ va } \omega_C = \omega_0 \sqrt{\frac{2-d^2}{2}} \qquad (3.6)$$

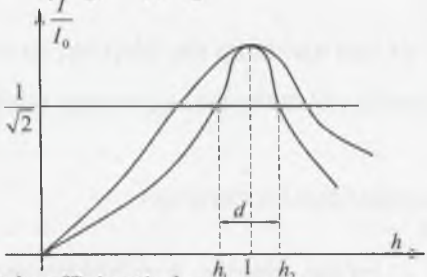
Rezonans kontur chastotasi (ω), zanjir parametrlari, tok va kuchlanishlarga nisbatan bog`liq funksiyasiga chastotali xarakteristikasi deyiladi.

$$(I_{(U)}, U_{(\omega)}, U_{L(\omega)}, U_{C(\omega)}, X_{L(\omega)}, X_{C(\omega)}, z_{(\omega)})$$

Bu xarakteristikalarni tahlil qilishda tok yoki chastotani nisbiy qiymat orqali ifodalash ancha qulay bo`lib, koeffisient $\eta = \frac{\omega}{\omega_0}$ teng deb olinadi. Bunda: $\omega_0 = \frac{1}{\sqrt{LC}} (rad/s)$;

$$I_0 = \frac{U}{R} \qquad (3.7)$$

U holda: $\frac{I}{I_0} = \frac{1}{\sqrt{1 + \left[\left(\eta - \frac{1}{\eta}\right) : d\right]^2}}$ (3.8)



So`ndirish koeffisienti: d = η1 – η2

Rezonans konturining ma'lum bir chastotani o`tkazish chegarasi:

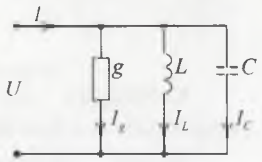
$\omega_0(\eta_2 - \eta_1) = \omega_0 d.$ (3.9)

Rezonans holatda tebranuvchan elektromagnit maydon energiyasi uzgarmas buladi.

$$W_0 = W_M + W_E = \frac{1}{2}LI^2 + \frac{1}{2}CU^2 = const \quad (3.10)$$

Parallel ulangan g, L, C zanjirida toklar rezonansi

Paralell ulangan tok zanjirlarida rezonans xolatda $\theta_L = \theta_C$ bo`lib rezonans chastota: $\frac{1}{\omega_0 L} - \omega_0 C = 0$



yoki: $\omega_0 = \frac{1}{\sqrt{LC}}(rad/s)$

Reaktiv elementlarning o`tkazuvchanligi:

$\frac{1}{\omega_0 L} = \omega_0 C = \gamma$ - teng bo`lib, to`lqin o`tkazuvchanligi deyiladi.

Rezonans holatda umumiy tok: $I_0 = Ug$.

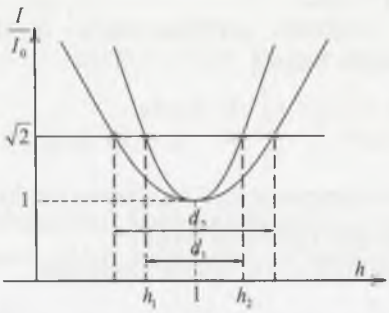
Reaktiv elementlardagi toklar: $I_{L0} = I_{C0} = U\gamma$

Agarda $g < \gamma$ bulganda, reaktiv qarshiliklarda tok, umumiy tokdan katta bo`lib: $d = \frac{I}{I_{L0}} = \frac{I}{I_{C0}} = \frac{Ug}{U\gamma} = \frac{g}{\gamma}$ - kontur so`nishi deyiladi.

Teskari qiymat: $Q = \frac{1}{d} = \frac{\gamma}{g}$ - kontur asilligi deyiladi.

Rezonans holat uchun chastotali xarakteristikalarini tuzishda tok va chastota qiymatlariga nisban olingan tenglamadan foydalaniladi:

$$\frac{I}{I_0} = \sqrt{1 + \left[\left(\frac{1}{h} - h\right) : d\right]^2} \quad (3.11)$$



Keltirilgan xarakteristikadan rezonans chastota so`nish chegaralari d = h_1 – h_2 bilan ifodalaniladi.

Toklar rezonansi paytida xam elektromagnit maydon energiyasining tebranishi kuchlanishlar rezonans xolatiga uxshash va uzgarmas buladi.

$$W = \frac{1}{2}LI^2 = \frac{1}{2}CU^2 = const \qquad (3.12)$$

Tarmoqlangan elektr tok zanjirlarida rezonans

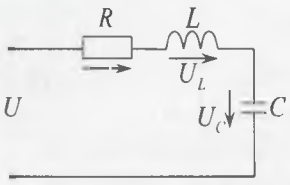
Tarmoqlangan elektr tok zanjirlarida ham rezonans sharti $\varphi = 0$ bo`lib, tok va kuchlanish vektorlari orasidagi burchak nolga teng.

Yoki: x_e=0; v_e= 0

Bir nechta induktivlik va sig`im elementlaridan tuzilgan murakkab elektr zanjirlarida rezonans xodisasi, ba'zi kontur va tarmoqlarda ham hosil bo`lishi mumkin.

Masala yechish namunalari

3.1-masala. Ketma–ket biriktirilgan tok zanjirining parameterlari $L = 150\ \mu Gn = 15 \cdot 10^{-5} Gn$, $C = 470 \mu F = 47 \cdot 10^{-7} F, R = 5\ Om$ bo`lib, U=10 V kuchlanishga ulangan. Rezonans chastotasi $f_0$, reaktiv elementlardagi kuchlanish $U_L$,$U_C$, to`lqin qarshiligi ρ, kontur asilligi Q va so`nish koeffisienti d aniqlansin.



Yechish:

Rezonans chastota:

$$\omega_0 = \frac{1}{\sqrt{LC}} = \frac{1}{\sqrt{705 \cdot 10^{-16}}} = \frac{1}{26{,}6 \cdot 10^{-8}} = 376 \cdot 10^4 (rad/s)$$

Bundan: $$f_0 = \frac{\omega_0}{2\pi} = \frac{376 \cdot 10^4}{6{,}28} = 6 \cdot 10^5 (Gs)$$

Rezonans holat toki: $$I_0 = \frac{U}{R} = \frac{10}{5} = 2(A)$$

Reaktiv qarshiliklari: $$x_L = \omega_0 L = 565 Om$$

$$x_C = \frac{1}{\omega_0 C} = \frac{1 \cdot 10^{11}}{376 \cdot 10^4 \cdot 47} = 565 Om$$

Reaktiv qarshiliklardagi kuchlanishlar:

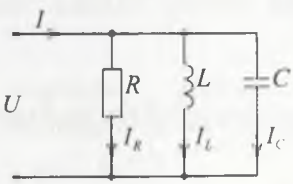
$$U_L = IX_L = 565 \cdot 2 = 1130 \ V, \quad U_C = IX_C = -1130 \ V$$

To`lqin qarshiligi: $$\rho = \sqrt{\frac{L}{C}} = 565$$

Asillik koeffisienti: $$Q = \frac{U_C}{U} = \frac{\rho}{R} = 113$$

So`nish koeffisienti: $$d = \frac{1}{Q} = \frac{1}{113} = 0{,}885 \cdot 10^2$$

3.2-masala. Parallel sxemada ulangan tok zanjirining parametrlari $R = 50 \ Om (g = 0{,}02 \frac{1}{Om})$, $L = 16 mGn = 16 \cdot 10^{-3} Gn$, $C = 40 \mu F =$ $= 40 \cdot 10^{-6} F$ bo'lib, $U = 200V$ kuchlanishga ulangan. Rezonans chastota f_0, toklar I, I_L, I_C so'nish koeffisienti d va to`lqin o`tkazuvchanligi γ aniqlansin.



Yechish:

Rezonans chastota: $\omega_0 = \frac{1}{\sqrt{LC}} = \frac{1}{\sqrt{64 \cdot 10^{-8}}} = \frac{1}{8 \cdot 10^{-4}} = 1250 \ (\frac{rad}{s})$

Yoki: $f_0 = \frac{\omega_0}{2\pi} = 199(Gs)$

Tok: $I = Ug = 200 \cdot 0{,}02 = 4 \ (A)$

Induktiv va sigim reaktiv utkazuvchanliklari:

$$b_L = \frac{1}{\omega_0 L} = \frac{1}{1250 \cdot 16 \cdot 10^{-6}} = 0{,}05 \ (\frac{1}{Om})$$

$$b_C = \omega_0 C = 1250 \cdot 40 \cdot 10^{-6} = 0{,}05 \ (\frac{1}{Om})$$

Induktivlik va sig`imdan oqib o`tuvchi tok:

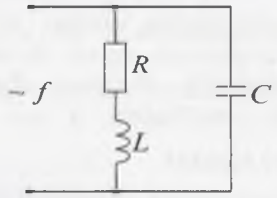
$$I_L = Ub_L = 10 \ (A), \quad I_C = Ub_C = 10 \ (A)$$

To`lqin o`tkazuvchanligi: $\gamma = \sqrt{\frac{C}{L}} = 0{,}05$

Kontur asilligi: $Q = \frac{\gamma}{g} = 2{,}5$

Kontur so`nish koeffisienti: $d = \frac{1}{Q} = 0{,}4$

3.3-masala. Sxemada keltirilgan elektr zanjiri chastotasi *f=400 Gs* o`zgaruvchan tok manbaiga ulangan. Agar aktiv qarshilik *R=5 Om*, sig`im parametr *C=10,5 mkF* bo`lsa, induktivlikning qanday qiymatida rezonans holati yuzaga keladi.



Yechish:

Ushbu zanjir uchun rezonans sharti, reaktiv o`tkazuvchanlikning yigindisi nolga tengligi bo`ladi.

Ya`ni: $y = y_1 + y_2$

Bunda: $y_1 = \frac{1}{z_1} = j\omega c; \quad y_2 = \frac{1}{z_2} = \frac{1}{R + j\omega L} = \frac{R - j\omega L}{R^2 + \omega^2 L^2}$

Yoki: $$y = \frac{R}{R^2 + \omega^2 L^2} + j(\omega c - \frac{\omega L}{R^2 + \omega^2 L^2})$$

"Qavs" ichidagi reaktiv o`tkazuvchanlik tenglamasini nolga tenglaymiz:

$$b = \omega c - \frac{\omega L}{R^2 + \omega^2 L^2} = 0$$

Umumiy maxrajga keltirib ω ga bo`lib yuborilsa:

$$\omega^2 L^2 c^2 - L + cR^2 = 0$$

Induktivlikga nisbatan tenglamani yechimi ildizlari:

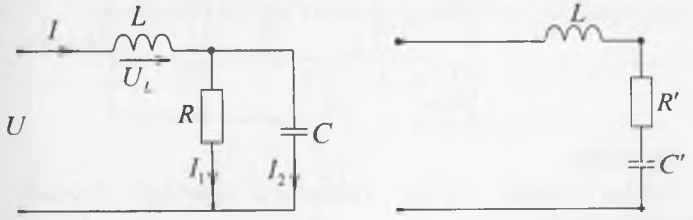
$$L_{1,2} = \frac{1 \pm \sqrt{1 - 4\omega^2 c^2 R^2}}{2\omega^2 c} = \frac{1 \pm 0{,}85}{132}$$

Demak zanjirda rezonans holat yuzaga kelishi mumkin bo`lgan induktivlik qiymatlari:

$$L_1 = 0{,}014Gn = 14mGn$$

$$L_2 = 0{,}00114Gn = 1{,}14mGn$$

3.4-masala. Keltirilgan tok zanjiri uchun rezonans chastota ω_0 tenglamasi va aktiv qarshilikning(Z_0) qanday qiymatida rezonans xolat yuzaga kelishini aniqlansin.



Yechish:

Zanjirning paralell ulangan qismini ekvivalent sxemasi bilan almashtiramiz.

$$R' = \frac{g}{y^2} = \frac{\frac{1}{R}}{\left(\frac{1}{R}\right)^2 + (\omega c)^2} = \frac{R}{1 + \omega^2 C^2 R^2}$$

$$x' = \frac{b}{y^2} = \frac{\omega C}{\left(\frac{1}{R}\right)^2 + (\omega c)^2} = \frac{\omega C R^2}{1 + \omega^2 C^2 R^2}$$

Ketma-ket ulangan ekvivalent sxema uchun rezonans sharti:

$$x = \omega L - \frac{\omega C R^2}{1 + \omega^2 C^2 R^2} = 0$$

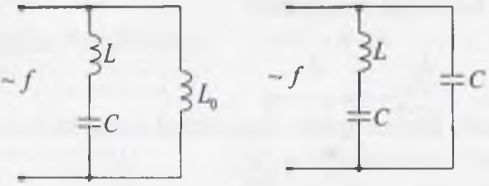
Tenglama umumiy maxraji berilib, ω bo`linsa:

$$L + \omega_0^2 C^2 R^2 L - C R^2 = 0$$

Bundan: $$\omega_0 = \sqrt{\frac{CR^2 - L}{C^2 R^2 L}} = \frac{1}{\sqrt{LC}} \sqrt{1 - \frac{\frac{L}{C}}{R^2}}$$

Demak ushbu zanjirda $R > \sqrt{\frac{L}{C}} = \rho$ bo`lgandagina rezonans hosil bo`ladi.

3.5-masala. Berilgan elektr zanjiri o`zgaruvchan tok chastotasi *f=10-5 Gs* bo'lgan generatorga ulangan. Induktivligi *L=100 mkGn*, sig`imi *C=500 pF*. Zanjirda kuchlanishlar rezonansi hosil qiluvchi induktivlik qiymati L_0 aniqlanib, shu zanjirda toklar rezonansi yuzaga kelishi uchun *f=2 MGs* bo'lganda qanday iste`molchiga ulanishi kerak.



Yechish:

Ushbu zanjir uchun rezonans shartiga asosan reaktiv qarshiliklari nolga teng:

$$в = в_1 + в_0 = 0$$

Bunda: $в_1 = \frac{\omega C}{\omega^2 LC - 1}$ - LC zanjir reaktiv o'tkazuvchanligi

$в_0 = \frac{\omega C}{\omega L_0}$ - L_0 induktivligi reaktiv o'tkazuvchanligi

Demak: $$-\frac{\omega C}{\omega^2 LC - 1} + \frac{1}{\omega L_0} = 0$$

Bundan: $$\omega^2 L_0 C + \omega^2 LC - 1 = 0$$

Tenglamani L_0 ga nisbatan yechish bilan:

$$L_0 = \frac{1-\omega^2 LC}{\omega^2 C} = \frac{1}{\omega^2 C} - L = 0{,}0049Gn = 4{,}9mGn$$

Demak zanjirda kuchlanishlar rezonansi yuzaga kelishi uchun L_0=4,9 *mGn* teng bo'lishi zarur.

Masalaning ikkinchi sharti bo'yicha yana reaktiv o'tqazuvchanliklar tenglamasini nolga tenglaymiz:

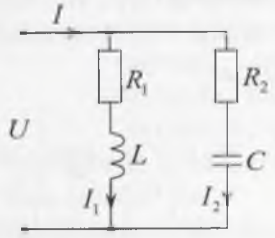
$$в = \frac{\omega C}{\omega^2 LC - 1} + в_0' = 0$$

$\omega = 2\pi f = 4\pi \cdot 10^6 \ \ s^{-1}$-teng bo`lganda, bunda $в_0'$ -zanjir tarmog'ida ulangan reaktiv o'tkazuvchanlik:

$$в_0' = \frac{\omega C}{\omega^2 LC - 1} = -9{,}2 \cdot 10^{-4} < 0 \quad \frac{1}{Om}$$

Demak ushbu elektr zanjirida toklar rezonansi hosil bo'lishi uchun induktivlik L_0 sig'im elementi bilan almashtirilishi zarur. Sig'im parametrlari esa $C_0 = \frac{в_0'}{\omega} = \frac{9{,}2 \cdot 10^{-4}}{4\pi \cdot 10^6} = 73{,}3 \ \ pF$ teng.

3.6-masala. Parallel ulangan tok zanjirining parametrlari: R_1=100 *Om*, R_2=200 *Om*, *L*=0,2*Gn*, *C*=1 *mkF*, manba kuchlanishi $\dot{E}$ =100 *V*. Rezonans chastota, reaktiv qarshiliklar va rezonans holat toklari aniqlansin.



Yechish:

Paralell ulangan elektr zanjirida toklar rezonans sharti $в_L = в_C$ bo'lib, bundan rezonans chastota tenglamasi:

$$\omega_0 = \frac{1}{\sqrt{LC}} \sqrt{\frac{\frac{L}{C} - R_1^2}{\frac{L}{C} - R_2^2}} = 2414 \ \ \frac{1}{s}$$

Reaktiv qarshiliklari:

$$x_L = \omega_0 L = 483 \ (Om), \ x_C = \frac{1}{\omega_0 C} = 414 \ (Om),$$

Tarmoq to'la qarshiliklari:

$$\underline{z}_1 = R_1 + j\omega L = 493 \cdot e^{j78^0} \ (Om)$$

$$\underline{z}_2 = R_2 - j\frac{1}{\omega_0 C} = 460 \cdot e^{-j64^0} \ (Om)$$

Birinchi tarmoq toki: $\dot{I}_1 = \frac{\dot{U}}{\underline{z}_1} = \frac{100e^{j^0}}{493e^{j78^0}} = (0{,}04 - j0{,}19) \ A$

Ikkinchi tarmoq toki: $\dot{I}_2 = \frac{\dot{U}}{\underline{z}_2} = \frac{100e^{j^0}}{493e^{-j64^0}} = (0{,}09 - j0{,}19) \ A$

Umumiy tok: $\dot{I} = \dot{I}_1 + \dot{I}_2 = (0{,}04 - j0{,}19) + (0{,}09 - j0{,}19) = 0{,}13 - j0{,}38 \ A$

Demak rezonans holatda reaktiv qarshiliklar nolga teng.

Mustaqil yechish uchun masalalar

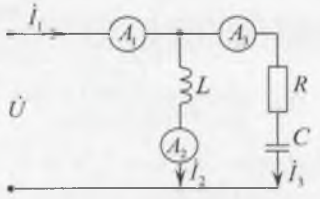
3.7-masala. Ketma – ket ulangan tok zanjirining parametrlari *R=100 Om, L1 =0,2 Gn, C = 1 mkF,* kuchlanishi *U = 100 mV* teng bo`lganda; rezonans chastota ω_0, tok I_0, kuchlanishlar U_{Cmax}, U_{Lmax} qiymatga erishgan holatdagi ω_C va ω_L chastota, U_{Cmax}, U_{Lmax} qiymatlari, kontur asilligi Q, rezonans chastota chegarali $d = (\omega_2 - \omega_1)$ lar aniqlansin.

Javob:

$\omega_0 = 2236\frac{1}{s}$, $I_0 = 1MA$, $\omega_L = 2264\frac{1}{s}$, $\omega_C = 2207\frac{1}{s}$, $U_{C\max} = 0{,}45V$, $U_{L\max} = 0{,}45V$,

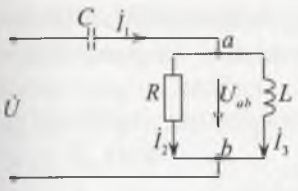
$Q = 4{,}47$, $\omega_2 - \omega_1 = 500$, $\omega_2 = 2500\frac{1}{s}$, $\omega_1 = 2000\frac{1}{s}$, $\Delta f = 79{,}6Gs$

3.8-masala. Keltirilgan sxemada rezonans holatda tarmoq toklari *I1=4 A, I2=3A* teng bo'lib, *I3* tok aniqlansin.



Javob: I3=5A

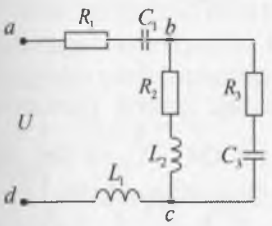
3.9-masala. Rezonans holatdagi zanjir qarshiliklari *R=20 Om*, X_L= *20 Om* va *U=300 V* bo'lganda, sig'im qarshiligi, umumiy ekvivalent qarshiligi kuchlanish va toklari aniqlansin.



Javob:

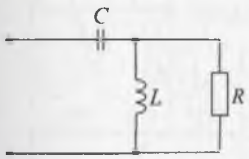
$x_C = 10\ Om,\ z_э = 10\ Om,\ \dot{U}_{aa} = 300\sqrt{2}e^{j45^0}, \dot{I}_1 = 30e^{j0}A,\ \dot{I}_2 = 15 + j15\ (A), \dot{I}_3 = 15 + j15\ A$

3.10-masala. Berilgan zanjir parametrlari $C_3=10\cdot10^{-6}$ *F*, $L_2=18\cdot10^{-3}$ *Gn*, R_2=*40 Om* R_3 =*30 Om* bo'lganda, toklar rezonansini yuzaga keltiruvchi rezonans chastota ω_0 aniqlansin.



Javob: ω_0=*1560 rad/sek*

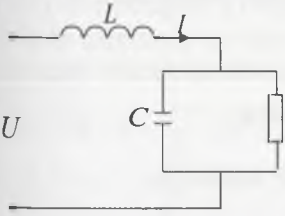
3.11-masala. Induktiv g'altakga, aktiv qarshilik R parallel va sig'im qarshiligiga X_C=*20 Om* ketma - ket ulangan. Chastota *f =50 Gs* qarshiliklar esa *R=40 Om* va *R=80 Om* bo`lganda rezonans hosil qiluvchi induktivlik *L* qiymati aniqlansin va qaysi hollarda umumiy qarshilik z_{min} minimal bo'ladi.



Javob: 1) *R =40 Om* bo'lganda, rezonans induktivlik *L =0,0128 Gn*, umumiy qarshiligi $Z=Z_{min}$, *L=0,052 Gn.*

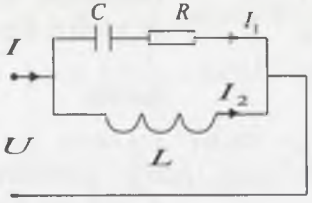
2) R=80 Om bo'lganda rezonans induktivlik *L =0,069Gn va L =0,95 Gn*, $Z=Z_{min}$; *L=0,061 Gn.*

3.12-masala. Elektr zanjiri rezonans holatda bo`lib chastotasi $\omega_0 = 0$ bo`lganda $Z_{кир(0)} = 5Om$ va rezonans chastota $\omega = \omega_0$ da $Z_{ул(ab)} = 2{,}5Om$. Qarshilik parametrlari: R_1, X_L va X_C aniqlansin hamda vektor ifodasi tuzilsin.



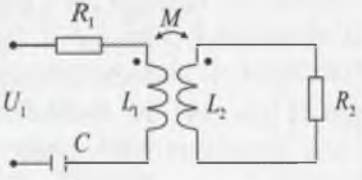
Javob: $R_1 = 5Om, X_L = 2{,}5Om, X_C = 5Om.$

3.13-masala. Elektr zanjirlarning rezonans holati toklari I_1 = *7A, I=3,6 A* teng. Induktivlikdan oqib o`tivchi I_2 tok aniqlanib vektor ifodasi tuzilsin.



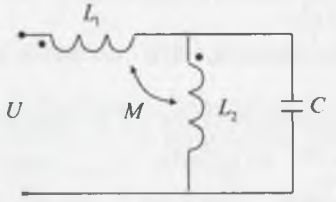
Javob: $I_2 = 6$ A.

3.14-masala. Induktiv bog'langan tok zanjiri parametrlari: $R_1 = 2\ Om$, $X_{L_1} = 10\ Om$, $X_C = 8\ Om$, $X_{L_2} = 9\ Om$, $X_M = 6\ Om$ bo`lib, *U=100 V* kuchlanish ulangan. R_2 ning qaysi qiymatida zanjirda rezonans holat yuzaga keladi.



Javob: R_2*=9 Om.*

3.15-masala. Elektr zanjiri parametrlari: L_1*=4 Gn,* L_2*=2 Gn, C=1 F* va bog'lanish koeffisienti $k = \frac{1}{\sqrt{2}}$ bo`lganda kuchlanishlar(ketma-ket) va toklar(parallel) rezonans chastotasi aniqlansin.



Javob: $\omega_0 = 0{,}71\frac{1}{s}$ - toklar rezonansi

$\omega_0 = 1{,}58\frac{1}{s}$ - kuchlanishlar rezonansi.

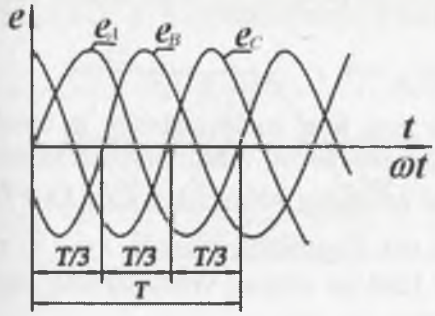
4 -BOB. UCH FAZALI O`ZGARUVCHAN TOK ZANJIRLARI

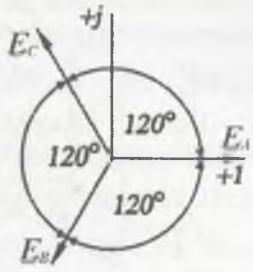
Elektromagnit induksiya qonuniga ko'ra bu chulg'amlarda qiymatlari teng va fazalari bo'yicha o'zaro 120^0(davrning uchdan bir bo'lagi)ga siljigan sinusoidal EYK lar tizimi hosil bo'ladi, ya'ni

$$e_A = E_m \sin \omega t$$
$$e_B = E_m \sin(\omega t - 120^0) \qquad (4.1)$$
$$e_C = E_m \sin(\omega t - 240^0)$$

Hosil bo'lgan EYK larning vaqtga bog'liqlik grafigi va kompleks tekislikdagi tasviri quyida keltirilgan. EYK lar kompleks qiymatlarini quyidagicha yozish mumkin:

$$\underline{E}_A = E; \underline{E}_B = Ee^{-j120^0}; \underline{E}_C = Ee^{-j240^0} = Ee^{j120^0}. \qquad (4.2)$$





Bir xil chastotali, amplitudali va fazalari bo'yicha o'zaro 120^0 ga siljigan sinusoidal EYK lar tizimi uch fazali simmetrik EYK lar tizimi deb ataladi. Bu tizimning asosiy xususiyati shundan iboratki, vaqtning istalgan paytida EYK lar oniy qiymatlarining algebraik yig'indisi nolga teng bo'ladi, ya'ni

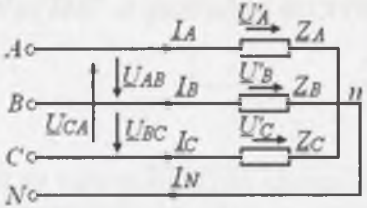
$$e_A + e_B + e_C = 0. \qquad (4.3)$$

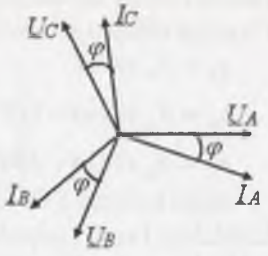
(4.3) ifodaning to'g'riligiga EYK lar oniy qiymatlarini istalgan vaqt uchun algebraik qo'shib yoki $\underline{E}_A + \underline{E}_B + +\underline{E}_C = 0$ tenglik orqali ishonch hosil qilish mumkin, ya'ni

$$\underline{E}_A + \underline{E}_B + \underline{E}_C = E + Ee^{-j120^0} + Ee^{j120^0} =$$
$$= E\left(1 - 0{,}5 - j\frac{\sqrt{3}}{2} - 0{,}5 + j\frac{\sqrt{3}}{2}\right) = 0. \qquad (4.4)$$

Yuklama yulduz usulda ulangan zanjirda simmetrik rejim

Yulduz usulda ulangan simmetrik zanjirda $\underline{Z}_A = \underline{Z}_B = \underline{Z}_C = ze^{j\varphi}$.

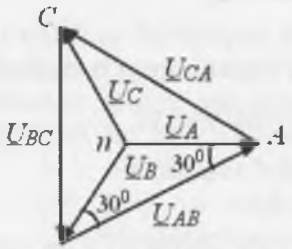




Yuklama qarshiliklari induktiv xarakterga ($\varphi>0$) ega deb hisoblab, kuchlanishlar va toklar vektor diagrammasini quramiz. Simmetrik rejimda $\underline{U}_A$, $\underline{U}_B$, $\underline{U}_C$ faza kuchlanishlari simmetrik vektorlar sistemasini hosil qiladi:

$$\underline{U}_A = \underline{U}_A^{\cdot} = U_f, \underline{U}_B = \underline{U}_B^{\cdot} = U_f e^{-j120^0}, \underline{U}_C = \underline{U}_C^{\cdot} = U_f e^{j120^0}. \qquad (4.5)$$

Har bir fazadagi tok mos faza kuchlanishidan φ burchakka orqada qoladi va toklar ham simmetrik vektorlar sistemasini hosil qiladi. Kirxgofning birinchi qonuniga ko'ra $\underline{I}_N = \underline{I}_A + \underline{I}_B + \underline{I}_C$, bu yerda $\underline{I}_N$-neytral simdagi tok. Simmetrik rejimda $\underline{I}_N = 0$, chunki modullari teng va o'zaro 120^0 ga siljigan vektorlarning yig'indisi nolga teng.



Kuchlanishlar topografik diagrammasidan ko'rinib turibdiki, liniya kuchlanishlari vektorlari faza kuchlanishlari vektorlari uchlarini birlashtiruvchi vektorlar ko'rinishida bo'ladi. Simmetrik rejimda liniya kuchlanishlarining qiymatlari teng bo'lib, bir-biridan o'zaro 120^0 ga siljigan bo'ladi. Topografik diagrammadan:

$$\underline{U}_{AB} = \underline{U}_A - \underline{U}_B, \underline{U}_{BC} = \underline{U}_B - \underline{U}_C, \underline{U}_{CA} = \underline{U}_C - \underline{U}_A, \qquad (4.6)$$

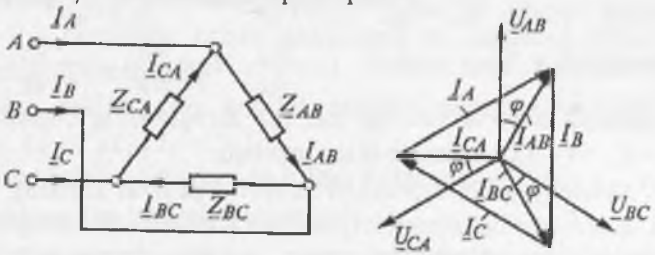
Yuklama uchburchak usulda ulangan zanjirda simmetrik rejim

Yuklama uchburchak ulangan uch fazali zanjirda $\underline{Z}_A = \underline{Z}_B = \underline{Z}_C = ze^{j\varphi}$ shart bajarilganida va u simmetrik EYK (kuchlanish)lar sistemasidan ta'minlanganida zanjirda simmetrik rejim yuzaga keladi. Kuchlanishlar topografik diagrammasi quyida keltirilgan. Unga ko'ra kuchlanishlar simmetrik yulduz hosil qiladi.

Kirxgoffning birinchi qonuniga ko'ra liniya toklari faza toklari orqali quyidagicha ifodalanadi:

$$\underline{I}_A = \underline{I}_{AB} - \underline{I}_{CA}, \underline{I}_B = \underline{I}_{BC} - \underline{I}_{AB}, \underline{I}_C = \underline{I}_{CA} - \underline{I}_{BC}. \qquad (4.7)$$

Bundan $\underline{I}_A + \underline{I}_B + \underline{I}_C = 0$ ekanligi kelib chiqadi, ya'ni liniya toklari simmetrik vektorlar sistemasini hosil qiladi. Yuklama induktiv(φ>0) xarakterli bo'lganida faza toki mos faza kuchlanishidan φ burchakka orqada qoladi.



$\underline{I}_A$ liniya tokini faza toklari orqali ifodalaymiz:

$$\underline{I}_A = \underline{I}_{AB} - \underline{I}_{CA} = I_f - I_f e^{j120^0} = I_f(1 - e^{j120^0}) = \sqrt{3} I_f e^{-j30^0} \qquad (4.8)$$

boshqa liniya toklari uchun

$$\underline{I}_B = \underline{I}_{BC} - \underline{I}_{AB} = \sqrt{3} I_f e^{-j150^0}, \underline{I}_C = \sqrt{3} I_f e^{j90^0}. \qquad (4.9)$$

Shunday qilib, yuklama uchburchak ulangan simmetrik uch fazali zanjirda liniya kuchlanishi faza kuchlanishiga teng bo'lib, liniya toki faza tokidan $\sqrt{3}$ marta katta bo'ladi, ya'ni $U_l = U_f$, $I_l = \sqrt{3} I_f$.

Uch fazali zanjir aktiv quvvati har bir faza aktiv quvvatlarining yig'indisiga teng, ya'ni:

$$P = P_A + P_B + P_C = 3P_f = 3U_f I_f \cos\varphi. \qquad (4.10)$$

Uch fazali zanjirlarni hisoblashda liniya kuchlanishi va toklaridan foydalanish qulayroq. Yulduz ulangan sxema uchun

$U_f = U_l/\sqrt{3}$, $I_f = I_l$, uchburchak ulangan sxema uchun esa $U_f = U_l$, $I_f = I_l/\sqrt{3}$ bo'lganligi sababli ulanish sxemasidan qat'i nazar simmetrik uch fazali zanjirning aktiv quvvati $P = \sqrt{3}U_l I_l \cos\varphi$ ifoda bilan aniqlanadi.

Simmetrik uch fazali zanjirning reaktiv va to'la quvvatlari quyidagicha topiladi:

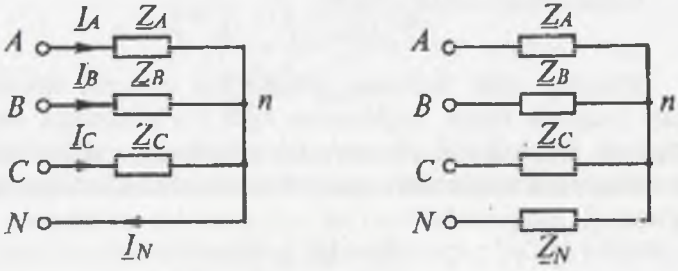
$$Q = \sqrt{3}U_l I_l \sin\varphi,\ S = \sqrt{3}U_l I_l. \qquad (4.11)$$

Yulduz usulda ulangan neytral simli zanjir

Yuklama qarshiliklari ($\underline{Z}_A \neq \underline{Z}_B \neq \underline{Z}_C$) yulduz usulda ulangan to'rt simli ($Z_N = 0$) zanjir simmetrik kuchlanishlar sistemasidan ta'minlanayotgan bo'lsin. Qarshiligi nolga teng bo'lgan neytral simning mavjudligi fazalarning o'zaro bog'liqsizligini ta'minlaydi va shuning uchun $\underline{U}_A = U_\Phi$; $\underline{U}_B = U_\Phi e^{-j120^0}$; $\underline{U}_C = U_\Phi e^{j120^0}$ bo'lganda iste'molchilar faza toklari $\underline{I}_A = \frac{\underline{U}_A}{\underline{Z}_A}$, $\underline{I}_B = \frac{\underline{U}_B}{\underline{Z}_B}$, $\underline{I}_C = \frac{\underline{U}_C}{\underline{Z}_C}$ tengliklar yordamida, neytral simdagi tok esa Kirxgoffning 1-qonuniga ko'ra $\underline{I}_N = \underline{I}_A + \underline{I}_B + \underline{I}_C$ formula bilan topiladi.

Shunday qilib, uch fazali zanjirda neytral simning mavjudligi faza kuchlanishlar simmetriyasini ta'minlaydi. Shuning uchun ham iste'molchilar(yoritgich lampalar, maishiy xizmat yuklamalari va boshqalar) to'rt simli tarmoqqa ulanadi.

Agar neytral simning qarshiligini hisobga olish lozim bo'lsa, u holda neytralning siljish kuchlanishi aniqlanadi:



$$\underline{U}_N = \underline{I}_N \underline{Z}_N = \frac{\underline{U}_A \underline{Y}_A + \underline{U}_B \underline{Y}_B + \underline{U}_C \underline{Y}_C}{\underline{Y}_A + \underline{Y}_B + \underline{Y}_C + \underline{Y}_N} \qquad (4.12)$$

bu yerda $\underline{Y}_A = \frac{1}{\underline{Z}_A}$, $\underline{Y}_B = \frac{1}{\underline{Z}_B}$, $\underline{Y}_C = \frac{1}{\underline{Z}_C}$, $\underline{Y}_N = \frac{1}{\underline{Z}_N}$ - fazalar va neytral sim kompleks o'tkazuvchanliklari.

Quyida generator chulg'amlari va iste'molchi fazalari "yulduz-yulduz" sxemasida ulangan uch fazali zanjirni hisoblash va uning vektor diagrammasini qurish tartibini ko'rib chiqamiz. Hisoblash va qurish tartibi quyidagicha:

1. Kompleks tekislikda $\underline{E}_A$, $\underline{E}_B$, $\underline{E}_C$ EYK lar vektorlari quriladi.

2. Neytralning siljish kuchlanishi $\underline{U}_N$ hisoblanadi va uning vektori diagrammaga joylashtiriladi.

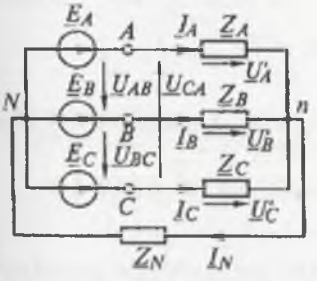
3. Iste'molchilar faza kuchlanishlarini $\underline{U}'_A = \underline{E}_A - \underline{U}_N$, $\underline{U}'_B = \underline{E}_B - \underline{U}_N$, $\underline{U}'_C = \underline{E}_C - \underline{U}_N$ tengliklar orqali aniqlanadi va ularning vektorlari diagrammada aks ettiriladi.

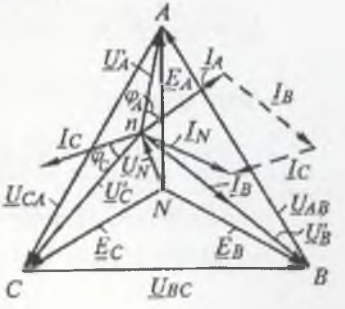
4. Faza toklari Om qonuni asosida quyidagicha topiladi: $\underline{I}_A = \underline{U}'_A \underline{Y}_A$, $\underline{I}_B = \underline{U}'_B \underline{Y}_B$, $\underline{I}_C = \underline{U}'_C \underline{Y}_C$.

5. Faza toklari vektorlari mos faza kuchlanishlaridan φ_A, φ_B va φ_C burchakka siljigan holatda quriladi.

6. Neytral simdagi tok Kirxgoffning 1-qonuni ($\underline{I}_N = \underline{I}_A + \underline{I}_B + \underline{I}_C$) yoki Om qonuni ($\underline{I}_N = \underline{U}_N \underline{Y}_N$) asosida aniqlanadi va vektor diagrammada aks ettiriladi.

7. Liniya kuchlanishlar vektorlari $\underline{U}_{AB} = \underline{U}'_A - \underline{U}'_B$, $\underline{U}_{BC} = \underline{U}'_B - \underline{U}'_C$, $\underline{U}_{CA} = \underline{U}'_C - \underline{U}'_A$ tengliklar asosida quriladi.





Masala yechish namunalari

4.1-masala. Uch fazali asinxron motor stator chulg'amlari nosimmetrik kuchlanishlar sistemasi $\underline{U}_A = 400\,V$, $\underline{U}_B = -j300\,V$, $\underline{U}_C = j300\,V$ ga ulangan. Motor neytral nuqtasi izolyasiyalangan. Motor fazalarining to'g'ri va teskari ketma-ketlikli toklarga qarshiliklari $\underline{Z}_1 = 6 + j6\,Om$, $\underline{Z}_2 = 0{,}3 + j1{,}1\,Om$. Liniya toklari, motor iste'mol qilayotgan aktiv, reaktiv va to'la quvvatlar topilsin.

Yechish. Faza kuchlanishlarining simmetrik tashkil etuvchilari quyidagicha topiladi:

$$\underline{U}_0 = \frac{1}{3}(\underline{U}_A + \underline{U}_B + \underline{U}_C) = \frac{400 - j300 + j300}{3} \approx 133\ V,$$

$$\underline{U}_1 = \frac{1}{3}(\underline{U}_A + a\underline{U}_B + a^2\underline{U}_C) = \frac{1}{3}\left[400 + e^{j120^0}(-j300) + e^{j240^0} j300\right] = 307\ V,$$

$$\underline{U}_2 = \frac{1}{3}(\underline{U}_A + a^2\underline{U}_B + a\underline{U}_C) = \frac{1}{3}\left[400 + e^{j240^0}(-j300) + e^{j120^0} j300\right] = -40{,}7\ V.$$

Toklar simmetrik tashkil etuvchilari Om qonuni yordamida quyidagicha aniqlanadi:

$$\underline{I}_0 = \frac{\underline{U}_0}{\underline{Z}_0} = \frac{133}{\infty} = 0,\quad \underline{I}_1 = \frac{\underline{U}_1}{\underline{Z}_1} = \frac{307}{6 + j6} = 36{,}2e^{-j45^0}\ A,$$

$$\underline{I}_2 = \frac{\underline{U}_2}{\underline{Z}_2} = \frac{-40{,}7}{0{,}3 + j1{,}1} = -35{,}7e^{-j75^0}\ A.$$

Liniya toklari:

$$\underline{I}_A = \underline{I}_1 + \underline{I}_2 = 36{,}2e^{-j45^0} - 35{,}7e^{-j75^0} = 19{,}2e^{-j29^0}\ A,$$

$$\underline{I}_B = a^2\underline{I}_1 + a\underline{I}_2 = 36{,}2e^{-j45^0}e^{j240^0} - 35{,}7e^{-j75^0}e^{j120^0} = 69e^{-j160^0}\ A,$$

$$\underline{I}_C = a\underline{I}_1 + a^2\underline{I}_2 = 36{,}2e^{-j45^0}e^{j120^0} + 35{,}7e^{-j75^0}e^{j240^0} = 51e^{j29^0}\ A.$$

Aktiv quvvat:

$$P = \mathrm{Re}\left|3\underline{U}_0\overset{\cdot}{\underline{I}}_0 + 3\underline{U}_1\overset{\cdot}{\underline{I}}_1 + 3\underline{U}_2\overset{\cdot}{\underline{I}}_2\right| = 3\underline{U}_1\underline{I}_1\cos\varphi_1 + 3\underline{U}_2\underline{I}_2\cos\varphi_2 =$$

$$= 3 \cdot 307 \cdot 36{,}2\cos 45^0 + 3 \cdot 40{,}7 \cdot 35{,}7\cos 75^0 = 24{,}7\ kW.$$

Reaktiv quvvat:

$$Q = \mathrm{Im}\left|3\underline{U}_1\overset{*}{\underline{I}}_1 + 3\underline{U}_2\overset{*}{\underline{I}}_2\right| = 3\underline{U}_1\underline{I}_1\sin\varphi_1 + 3\underline{U}_2\underline{I}_2\sin\varphi_2 =$$

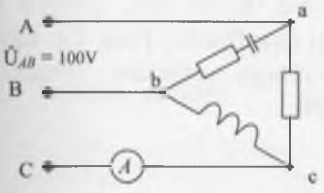
$$= 3\cdot 307\cdot 36{,}2\sin 45^0 + 3\cdot 40{,}7\cdot 35{,}7\sin 75^0 = 27{,}8\ kVar.$$

To'la quvvat va quvvat koeffitsiyenti:

$$S = \sqrt{P^2 + Q^2} = \sqrt{24{,}7^2 + 27{,}8^2} = 37{,}2\ kVA,$$

$$\cos\varphi = \frac{P}{S} = \frac{24{,}7}{37{,}2} = 0{,}68.$$

4.2-masala. Uchburchak shaklida biriktirilgan uch Z_{CA} fazali tok zanjiri iste`molchi qarshilik $Z_{AB}$ lari $\underline{Z}_{av}=(3-j4)$ *Om* $\underline{Z}_{vs}=j100$*m:* $\underline{Z}_{sa}=10$ *Om* teng bo'lib, liniya kuchlanish $U_l=100V$ bo'lgan generatorga ulangan. Sxemaga ulangan ampermetr qiymati va sarf bo`ladigan quvvat aniqlansin.



Yechish. Liniya kuchlanishlarini aniqlaymiz:

$$\dot{U}_{ab} = 100(V)$$

$$\dot{U}_{bc} = 100\cdot a^2 = (-50 - j\cdot 87)\cdot(V)$$

$$\dot{U}_{ca} = 100\cdot a = (-50 + j\cdot 87)(V)$$

Iste`molchilardagi faza toklari:

$$\dot{I}_{ab} = \frac{\dot{U}_{ab}}{\underline{Z}_{ab}} = \frac{100}{3-j4} = \frac{100\cdot(3+j4)}{9+16} = (12+j16)A$$

$$\dot{I}_{bc} = \frac{\dot{U}_{bc}}{\underline{Z}_{bc}} = \frac{(-50-j87)\cdot(-j10)}{100} = (-8{,}7+j5)A$$

$$\dot{I}_{ca} = \frac{\dot{U}_{ca}}{\underline{Z}_{ca}} = \frac{-50+j87}{10} = (-5+j8{,}7)A$$

Liniya toklari:

$$\dot{I}_a = \dot{I}_{ab} - \dot{I}_{bc} = 12 + j16 + 5 - j8{,}7 = (17+j7{,}3)A$$

$$\dot{I}_b = \dot{I}_{bc} - \dot{I}_{ab} = -8{,}7 + j5 - 12 - j16 = (-20{,}7-j11)A$$

$$\dot{I}_c = \dot{I}_{ca} - \dot{I}_{bc} = -5 + j8{,}7 - j5 + 8{,}7 = (3{,}7+j3{,}7)A$$

Toklaning algebraik yig`indisi $\sum I = 0$

Ampermetr ko`rsatish qiymati:

$$\dot{I}_c = \sqrt{(3,7)^2 + (3,7)^2} = 5,2A$$

Iste`molchilar to'la quvvatlari:

$$\widetilde{S}_{ab} = \dot{U}_{ab} \cdot \dot{I}_{ab} = 100(12 - j16) = (1200 - j1600)(VA)$$

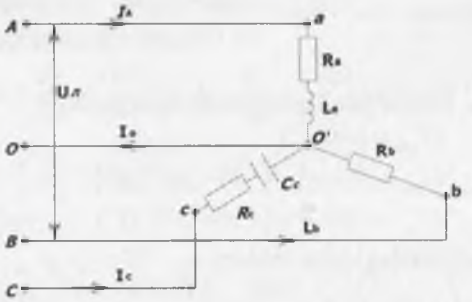
$$\widetilde{S}_{bc} = \dot{U}_{bc} \cdot \dot{I}_{bc} = (-50 - j87)(-8,7 - j5) = j1000(VA)$$

$$\widetilde{S}_{ca} = \dot{U}_{ca} \cdot \dot{I}_{ca} = (-50 + j87)(-5 - j8,7) = 1000(VA)$$

Iste`molchilarning o`rtacha aktiv quvvati:

$$P = 1200 + 1000 = 2200W$$

4.3-masala. To`rt simli yulduzcha shaklida ulangan uch fazali tok zanjirining iste`molchi parametrlari: R_a=80 Sm, L_a=0,18 Gn, R_b=70 Sm, R_c=40 Sm, C_c=30mkF bo'lib, chastotasi f=50 Gs, Liniya kuchlanishi U_l=380 V bo'lgan generatorga ulangan. Toklar va iste`molchilardagi to'la quvvat aniqlansin.



Yechish:

Faza kuchlanishini topamiz: $U_f = \frac{380}{\sqrt{3}} = 220\ V$

Fazalardagi to'la qarshiliklar:

$$Z_a = \sqrt{R_a^2 + x_{i_a}} = \sqrt{80^2 + (314 \cdot 0,18)^2} = 100\ Om$$

$$Z_b = R_b = 70\ Om$$

$$Z_c = \sqrt{R_c^2 + x_{c_c}^2} = \sqrt{(40)^2 + \left(\frac{1 \cdot 10^6}{314 \cdot 30}\right)^2} = 110\ Om$$

Faza toklari:

$$I_a = I_a = \frac{U_a}{Z_a} = \frac{220}{100} = 2{,}2 \ \ A$$

$$I_b = \frac{U_b}{Z_b} = \frac{220}{70} = 315 \ \ A$$

$$I_c = \frac{U_c}{Z_c} = \frac{220}{110} = 2 \ \ A$$

Aktiv quvvat: $P_a = I_a^2 \cdot R_a = (2{,}2)^2 \cdot 80 = 400 \ \ W$

$$P_b = I_b^2 \cdot R_b = (3{,}15)^2 \cdot 70 = 700 \ \ W$$

$$P_c = I_c^2 \cdot R_c = (2)^2 \cdot 40 = 160 \ \ W$$

$$P = P_a + P_b + P_c = 400 + 700 + 160 = 1260 \ W$$

Reaktiv quvvat: $Q_a = I_a^2 \cdot x_{i_c} = (2{,}2)^2 \cdot 56{,}6 = 285 \ \ Var$

$$Q_b = 0$$

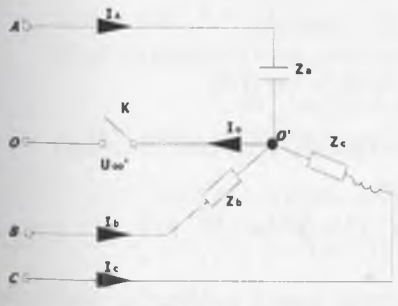
$$Q_c = -I_c^2 \cdot x_c = -(2^2 \cdot 106) = 425 \ \ Var$$

$$Q = Q_a + Q_c = 285 - 425 = -140 \ \ Var$$

Iste`molchilarda sarf bo'ladigan quvvat:

$$S = \sqrt{P^2 + Q^2} = \sqrt{(1260)^2 + (140)^2} = 1280 \ \ BA = 1{,}28 \ \ kVa$$

4.4-masala. Yulduzcha shaklida biriktirilgan neytral simli uch fazali tok zanjirning parametrlari: $Z_1 = -j8$ *Om*; $Z_2 = 10$ *Om*; $Z_3 = (3+j4)$ *Om* va liniya kuchlanishlari simmetrik bo'lib $U_{ab} = U_{bc} = U_{ca} = 173$ *(V)*. Neytral sim ulangan va uzilgan holatlar uchun toklari, neytral sim toki I_0, neytral sim uzilgandagi potensiallar kuchlanishi U_{oo}, va iste`molchi quvvatlari aniqlansin.



Yechish:

1) Kalit ***K*** ulangan holda neytral simli yulduzcha sxema bo'lib, faza kuchlanishlar kompleks ifodasi: $U_f = \frac{U_l}{\sqrt{3}} = 100\ (V)$

$$\dot{U}_A = \dot{U}_f = 100\ (V)$$

$$\dot{U}_B = \dot{U}_A \cdot a^2 = (50 - j87)\ (V)$$

$$\dot{U}_C = \dot{U}_A \cdot a = (-50 - j87)\ (V)$$

Faza toklari:

$$\dot{I}_a = \frac{\dot{U}_a}{Z_a} = \frac{100}{-j8} = j1.25\ \ A$$

$$\dot{I}_b = \frac{\dot{U}_b}{Z_b} = \frac{-50 - j87}{10} = (-5 - j8{,}7)\ \ A$$

$$\dot{I}_c = \frac{\dot{U}_c}{Z_c} = \frac{-50 - j87}{3 + j4} = (7{,}9 + j18{,}4)\ \ A$$

Neytral sim toki:

$$\dot{I}_o = \dot{I}_a + \dot{I}_b + \dot{I}_c = (2{,}9 + j22{,}2)\ \ A$$

Effektiv yoki haqiqiy qiymat:

$$I_o = \sqrt{(2{,}9)^2 + (22{,}2)^2} = 22{,}4\ \ A$$

Potensiallar orasidagi kuchlanish: $U_{oo'} = 0$.

Istemolchilar to'la quvvati:

$$\tilde{S}_a = \dot{U}_a \cdot \overset{\bullet}{I}_a = 100 \cdot (-j12{,}5) = -j1250\ \ (VA)$$

$$\tilde{S}_b = \dot{U}_b \cdot \overset{\bullet}{I}_b = (50 - j87) \cdot (-5 + j8{,}7) = 100\ \ (VA)$$

$$\tilde{S}_c = \dot{U}_c \cdot \overset{\bullet}{I}_c = (-50 - j87) \cdot (7{,}9 - j18{,}4) = (1220 + j1600)\ \ (VA)$$

Istemolchilar o`rtacha quvvati:

$$P = 100 + 1220 = 1320\ \ (W) = 1{,}32\ \ kW$$

2) Kalit ***K*** uzilgan holda, neytral simsiz yulduzcha shaklidagi sxema.

Iste`molchilar o`tkazuvchanligi:

$$\underline{y}_a = \frac{1}{\underline{Z}_a} = \frac{1}{-j8} = j0{,}125 \ \frac{1}{Om}$$

$$\underline{y}_e = \frac{1}{\underline{Z}_e} = \frac{1}{10} = 0{,}1 \ \frac{1}{Om}$$

$$\underline{y}_c = \frac{1}{\underline{Z}_c} = \frac{3-j4}{9+16} = (0{,}12 - j0{,}16) \ \frac{1}{Om}$$

Generator bilan iste`molchi o`rtasidagi potensial kuchlanish:

$$U'_{oo} = \frac{\dot{U}_a \underline{y}_a + \dot{U}_b \underline{y}_b + \dot{U}_c \underline{y}_c}{\underline{y}_a + \underline{y}_b + \underline{y}_e} = (-2{,}8 + j100) \ V.$$

Iste`molchi faza kuchlanishlari:

$$\dot{U}_a = \dot{U}_A - \dot{U}_{oo}' = 100 - (-2{,}8j + 100) = (102{,}8 - j100) \ V$$

$$\dot{U}_b = \dot{U}_B - \dot{U}_{oo}' = -50 - j87 - (-2{,}8 + j100) = (-47{,}8 - j187) \ V$$

$$\dot{U}_c = \dot{U}_C - \dot{U}_{oo}' = -50 + j87 - (-2{,}8 + j100) = (-47{,}8 - j13) \ V$$

Faza toklari. ($\dot{I}_f = \dot{I}_A$)

$$\dot{I}_a = \dot{U}_a \underline{y}_a = (102{,}8 - j100) \cdot j0{,}125 = (12{,}5 + j12{,}8) \ A$$

$$\dot{I}_b = \dot{U}_b \underline{y}_b = (-47{,}8 - j187) \cdot 0{,}1 = (-4{,}78 - j18{,}7) \ A$$

$$\dot{I}_c = \dot{U}_c \underline{y}_c = (-47{,}8 - j13) \cdot (0{,}12 - j0{,}16) = (-7{,}82 + j6{,}1) \ A$$

Toklarning algebraik yigindisi $\sum \dot{I}_q = 0$;

Liniya toki $I_l = \sqrt{(12{,}5)^2 + (12{,}8)^2} = 17{,}8 \ A.$

Neytral nuqtalardagi potensiallarning effektiv qiymati:

$$\dot{U}_{oo}' = \sqrt{(-2{,}8)^2 + 100^2} = 100 \ V$$

Iste`molchilar to'la quvvatlari:

$$\widetilde{S}_a = \dot{U}_a \dot{I}_a^* = (102{,}8 - j100)(12{,}5 - j12{,}84) = -j2560 \ VA$$

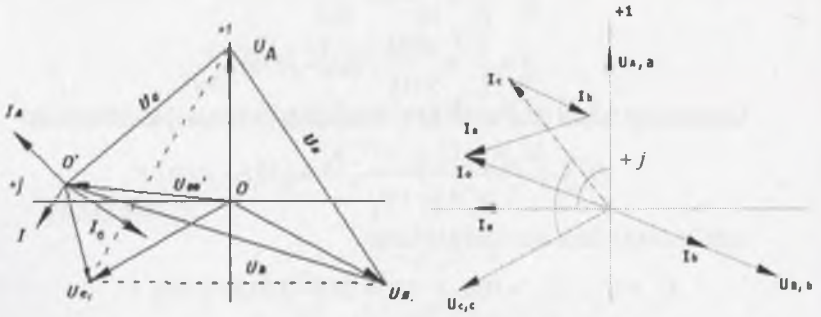
$$\widetilde{S}_b = \dot{U}_b \dot{I}_b^* = (-47{,}8 - j187)(4{,}78 + j18{,}7) = 3720 \ VA$$

$$\widetilde{S}_c = \dot{U}_c \dot{I}_c^* = (-47{,}8 - j13)(-7{,}8 - j6{,}1) = (293 + j393{,}5) \ VA$$

Iste`molchilardagi sarf buladigan aktiv quvvatning o`rtacha qiymati:

$$P=3720+293=4013\ (W)$$

Vektor ifodasini tuzamiz:



4.5-masala. Uch fazali tok generatorning simmetrik tashkil etuvchilari $\dot{E}_1=100\ V$; $\dot{E}_2=25\cdot e^{j120}\ V$; $\dot{E}_0=100\cdot e^{-j\frac{\pi}{3}}\ V$; ga teng bo'lganda nosimmetrik EYK analitik va vektor ifodalari aniqlansin.

Yechish:

$$\dot{E}_1=100\ (V),\ \dot{E}_2=25e^{j\frac{\pi}{3}}=(12{,}5+j21{,}7)\ (V),$$

$$\dot{E}_0=100^{-j\frac{\pi}{3}}=(50-j86)\ (V)$$

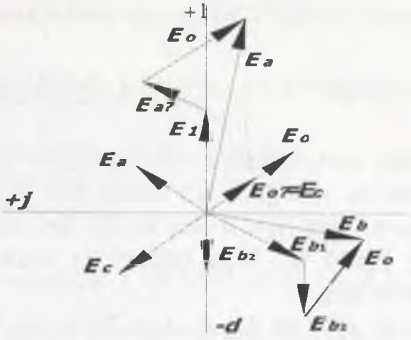
Nosimmetrik uch fazali tok sistemalarining simmetrik tashkil etuvchilarga ajratish tenglamasiga asosan:

$$\dot{E}_a=\dot{E}_o+\dot{E}_1+\dot{E}_2=(50-j86)+100+(12{,}5+j21{,}7)=(162{,}5-j65)\ V$$

$$\dot{E}_b=\dot{E}_0+a^2\dot{E}_1+a\dot{E}_2=(50-j86{,}7)-50+(-j86{,}7+25)=(-25-j173{,}4)\ V$$

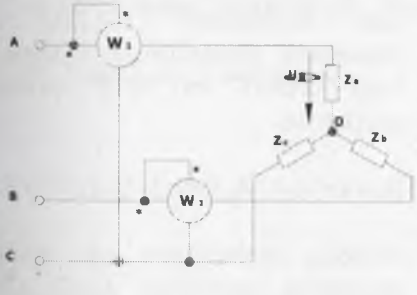
$$\dot{E}_c=\dot{E}_0+a\dot{E}_1+a^2\dot{E}_2=(50-j86{,}7)+(-50+j86{,}7)+25=(12{,}5+j21{,}7)\ V$$

Vektor ifodasini tuzamiz:



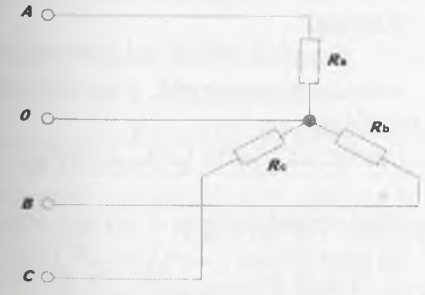
Mustaqil yechish uchun masalalar

4.6-masala. Yulduzcha shaklida ulangan uch fazali tok zanjirining faza kuchlanishi $U_\varphi=127\ V$ bo'lib, kompleks qarshiligi $Z_a=Z\varphi=10+j10\ Om$ bo'lgan simmetrik iste`molchiga ulangan. Sxemada ko'rsatilgan ulanish bo'yicha vattmetr qiymatlari va uch fazali tok quvvati aniqlanib vektor ifodasi tuzilsin.



Javob: $P_1=805,8\ W;\ P_2=805,8\ W;\ P=2417,4\ W.$

4.7-masala. To'rt simli yulduzcha shaklida ulangan uch fazali tok zanjirining liniya kuchlanishi $U_l=380\ V$, istemolchi aktiv qarshiligi $R=100\ Om$. Faza toklari va sarf bo'ladigan quvvat aniqlansin.



Javob: $I=2,2\ A;\ P=1452\ W.$

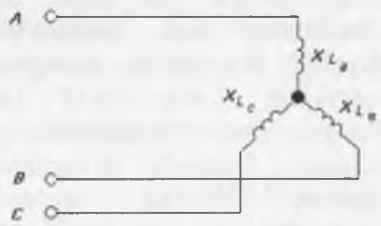
4.8-masala. Turt simli yulduzcha sxemaning fazalariga $P_a=40$ *W*, $P_b=100$ *W*, $P_c=60$ *W* quvvatga ega bo'lgan lampochkalar ulangan. Liniya kuchlanishi $U_L=220$ *V* bo'lganda toklar aniqlanib vektor ifodasi tuzilsin.

Javob: $I_a=40/127=0,3$ *A*; $I_b=0,75$ *A*; $I_c=0,45$ *A*; $\overline{I_0}=\overline{I_a}+\overline{I_b}+\overline{I_c}\approx 0.38$ *A*

4.9-masala. Liniya kuchlanishi $U_L=220$ *V* bo'lgan neytral simsiz yulduzcha shaklida ulangan uch fazali tok zanjirining iste`molchi qarshiliklari $R_a=40$ *Om*; $R_b=50$ *Om*; $R_c=20$ *Om*. Aktiv quvvatlari $R_a=40$ *W*; $P_b=100$ *W*; $P_c=60$ *W*. Faza toklari va kuchlanishlari aniqlanib, vektor ifodasi tuzilsin.

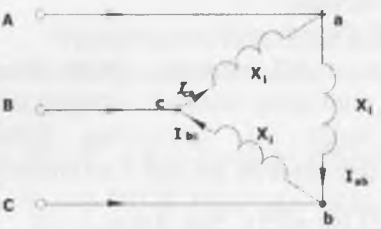
Javob: $I_a=1$ *A*; $i_b=1.41$ *A*; $I_c=1.73$ *A*. $U_a'=401$ *V*; $U_b'=70.5$ *V*; $U_c'=34.6$ *V*.

4.10-masala. Induktivligi $L_1=L_2=L_3=126$ *mGn* bo'lgan uch fazali asinxron motor chastotasi $f=50$ *Gs*, faza kuchlanishi $U_A=120$ *V* simmetrik generatorga ulangan. Faza toklari va to'la quvvat aniqlansin.



Javob: $I_\varphi=3$ *A*; *P=0*; *S=Q=1076 VA*.

4.11-masala. Uchburchak shaklida biriktirilgan tok zanjiri istemolchi karshiligi $X_i=22$ *Om* bo'lib, $\dot{U}_A=220e^{j45^\circ}$ *B* kuchlanishga ulangan.

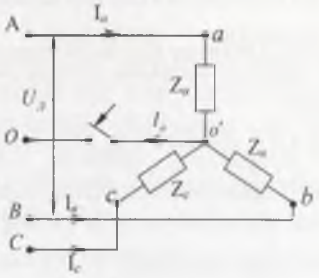


Faza va liniya toklari topilib kompleks topografik diagrammasi tuzilsin.

Javob: $I_F=10e^{-j45}$; $I_L=17,3\ ye^{-j45}$.

4.12-masala. Yulduzcha shaklida birlashtirilgan 4 ta simli uch fazali tok zanjir istemolchi kompleks qarshiliklari: $Z_a=(40+j30)$ *Om*; $Z_b=50$ *Om*, $Z_c=(25-j25)$*Om* teng bo'lib, $U=380$ *V* liniya kuchlanishi

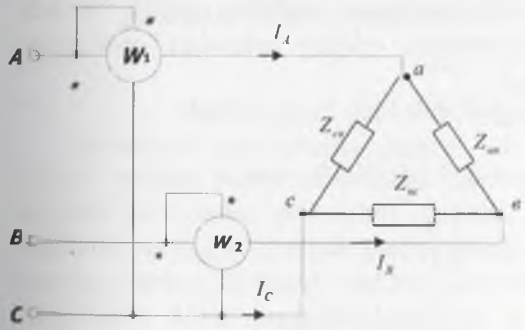
ulangan. Kalit ulangan yoki uzilgan holatlar uchun liniya va neytral sim toklari hamda neytral nuqtalar orasidagi $\dot{U}_{00'}$ kuchlanish aniqlanib vektor ifodasi tuzilsin.



Javob: a) kalit ulanganda: $\dot{I}_a$=3,52-j2,64 A, $\dot{I}_b$=-2,2-j3,78 A; $\dot{I}_c$=-2,75-j0,56 A; $\dot{I}_0 = \dot{I}_a + \dot{I}_b + \dot{I}_c = -2{,}71 - j0{,}56$ A. $\dot{U}_{00'}$=0

b) kalit uzilganda: $\dot{U}_0$=-35-j175 V, $\dot{I}_a$=6,18-j0,26 A, $\dot{I}_b$=-1,5-j0,3 A; $\dot{I}_c$=-4,68-j0,56 A;

4.13-masala. Uchburchak shaklida ulangan uch fazali tok zanjiri istemolchilari: Z_{av}=20+j20 Om; Z_{vs}=50 Om, Z_{ca}=-j40 Om teng bo'lib, U_L =200 V liniya kuchlanishiga ulangan. Liniya toklari va istemolchilarda sarf bo'ladigan quvvat aniqlansin.



Javob: $\dot{I}_a$=9,33-j2,5 A, $\dot{I}_b$=-7+j1,54 A;

$\dot{I}_c$=-2,33+j0,96 A;

$P=P_1 + P_2 = 1366+434=1800$ W.

4.14-masala. Uchburchak shaklida biriktirilgan uch fazali tok zanjirining istemolchilari simmetrik bo'lib I=1 A tok oqib o'tadi. Liniya simi va A faza simi ab uzilgan holda liniya toklari qiymatini aniqlang. **Javob:** $I_{\Pi} = \sqrt{3}$ A; $I_{\Phi} = \sqrt{3}$ A; $I_a = \sqrt{3}$ A; $I_c = \sqrt{3}$ A.

5- BOB. DAVRIY NOSINUSOIDAL TOK ZANJIRLARI

Davriy o'zgaruvchan funksiyalarni garmonik qatorga yoyish

Matematika kursidan ma'lumki, Dirixle shartini qanoatlantiruvchi har qanday uzluksiz davriy funksiya $f(t)$ni Fure qatoriga yoyish mumkin:

$$f(t) = A_0 + A_1 Sin(\omega t + \varphi_1) + A_2 Sin(2\omega t + \varphi_2) + ... + A_k Sin(k\omega t + \varphi_k) \quad (5.1)$$

bunda: A_0 – o'zgarmas tashkil etuvchi, $A_1 Sin(\omega t + \varphi_1)$-asosiy yoki birinchi garmonika, $A_k Sin(k\omega t + \varphi_k)$-"k"tartibli yuqori garmonika, A_k va φ_k - yuqori garmonika amplituda va boshlang'ich fazasi.

Amalda elektrotexnika, elektronika, elektromagnit zanjirlarida uchraydigan nosinusoidal signallar miqdori (funksiyalar) Dirixle shartini qanoatlantiradi.

Fur`e qatorining koeffisientlarini aniqlash uchun $f(t)$ funksiyani quyidagicha yozamiz:

$$f(\omega t) = A_0 + B_1 Sin\omega t + B_2 Sin2\omega t + ... + B_k Sink\omega t + ... + C_1 Cos\omega t + \\ + C_2 Cos2\omega t + ... C_k Cosk\omega t \quad (5.2)$$

Bu shartlarning koeffisientlarini analitik, grafik usulda hisoblash bilan yoki elektrotexnik o'lchov asboblari yordamida aniqlanadi.

Analitik usulda quyidagi ifodalardan foydalaniladi:

$$A_0 = \frac{1}{T}\int_0^T f(\alpha)d\alpha$$

$$B_k = \frac{1}{T}\int_0^T f(\alpha)Sink\alpha\, d\alpha$$

$$C_k = \frac{1}{T}\int_0^T f(\alpha)Cosk\alpha\, d\alpha$$

Ushbu koeffisientlarning qiymatini bilgach «k» yuqori garmonika amplitudasi va fazasini aniqlash mumkin:

$$A_k = \sqrt{B_k^2 + C_k^2}; \qquad tg\varphi_k = \frac{C_k}{B_k}; \qquad \varphi_k = arctg\frac{B_k}{C_k}; \quad (5.2)$$

yoki: $B_k = A_k Cos\varphi_k$

$C_k = A_k Sin\varphi_k$.

Agar davriy o'zgaruvchan nosinusoidal funksiya grafik ko'rinishda berilgan bo'lsa koeffisientlarni aniqlashda grafik usuldan (Chebishev usuli) foydalaniladi.

Nosinusoidal tok zanjirlarini hisoblash

Chiziqli nosinusoidal tok zanjirlarini hisoblashda ustma-ustlik (superpozisiya) usuli tatbik etilib, har bir garmonikaning zanjir parametrlariga ta'siri alohida aniqlanadi va bularning oniy qiymatlarining yig'indisi aniqlanadi. Masalan, kuchlanish ifodasi:

$$u = u_0 + u_1 + u_2 + ... + u_k \qquad (5.3)$$

bunda: $u_k = U_{km} Sin(k\omega t + \varphi_k)$

tok ham: $i = I_0 + i_1 + i_2 + ... + i_k$

$i_k = I_{km} \sin(k\omega t + \varphi_{ik} - \varphi_{uk})$

Ketma – ket ulangan oddiy R,L,C zanjir uchun "k"-garmonika tok amplutudasi:

$$I_{km} = \frac{U_{km}}{\sqrt{R^2 + \left(k\omega L - \frac{1}{k\omega C}\right)^2}}$$

"k" garmonika faza burchagi esa:

$$tg\varphi_k = \frac{k\omega L - \frac{1}{k\omega C}}{R}$$

Murakkab nosinusoidal elektr tok zanjirlarini hisoblashda mavjud bo'lgan elektr zanjirlarini hisoblash usullari tadbiq etilib, har bir garmonika qiymatlari alohida hisoblab topiladi. Shuni takidlash kerak: "k"- yuqori garmonikaga induktivlik qarshiligi "k" martaga katta ($X_L = k\omega L$), sig'im qarshiligi "k" marta kamayadi ($X_S = 1/k\omega C$). Aktiv qarshilik chastotaga bog'liq emas va o'zgarmas bo'ladi (Zanjir chastotasi juda ham yuqori bo'lganda inobatga olinadi).

Nosinusoidal, tok, kuchlanish va quvvatning haqiqiy yoki effektiv qiymatlari

Nosinusoidal funksiya f(ωt) effektiv qiymati:

$$A = \sqrt{1/T \int_0^T f^2(\omega t)dt} \qquad (5.4)$$

Bunda tokning effektiv qiymatlari:

$$I = \sqrt{I_0^2 + I_1^2 + I_2^2 + ... + I_k^2}$$

Kuchlanish effektiv qiymati:

$$U = \sqrt{U_0^2 + U_1^2 + U_2^2 + ...U_k^2}$$

E.Yu.K effektiv qiymati:

$$E = \sqrt{E_0^2 + E_1^2 + E_2^2 + ... + E_k^2}$$

Nosinusoidal tok quvvati har bir yuqori garmonika uchun aniqlangan o'rtacha quvvatlar yig'indisiga teng. Nosinusoidal tok aktiv quvvati (o'rtacha quvvat).

$$P = P_0 + P_1 + ... + P_k = U_0I_0 + U_1I_1\cos\varphi_1 + U_2I_2\cos\varphi_2 + ... + U_kI_k\cos\varphi_k$$

Reaktiv quvvat :

$$Q = Q_1 + Q_2 + ... + Q_k = U_1I_1\sin\varphi_1 + U_2I_2\sin\varphi_2 + ... + U_kI_k\sin\varphi_k$$

To'la quvvat :

$$S = UI = S_0 + S_1 + S_2 + ... + S_k$$

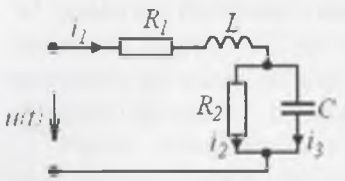
Nosinusoidal tok aktiv quvvatning to'la quvvatga nisbati, quvvat koeffisienti deyiladi:

$$\alpha = \frac{P}{S} = \frac{P_0 + P_1 + P_2 + ... + P_k}{\sqrt{U_0^2 + U_1^2 + U_2^2 + ... + U_k^2 + ... + U_k^2} \cdot \sqrt{I_0^2 + I_1^2 + I_2^2 + ... + I_k^2}} \qquad (5.5)$$

Nosinusoidal elektr zanjirlarida quvvat koeffisienti $\alpha = \frac{P}{UI} < 1$.

Masala yechish namunalari

5.1-masala. Elektr zanjiri $u(t) = 50 + 141\sin(\omega t + 30^0) + 70{,}7\sin(3\omega t - 60^0)V$ kuchlanish manbaiga ulangan.



Zanjir shoxobchalaridagi oniy toklar ifodalarini va ularning effektiv qiymatlarini aniqlang.

$$R_1 = 20\,Om;\ R_2 = 5\,Om;$$

$$\omega L = 3\,Om;\ \frac{1}{\omega C} = 9\,Om.$$

Yechish: Manba kuchlanishining doimiy tashkil etuvchisidan zanjirda hosil bo'lgan toklarni hisoblaymiz $U_{(0)} = 50\,V$.

$$I_{1(0)} = I_{2(0)} = \frac{U_{(0)}}{R_1 + R_2} = \frac{50}{20 + 5} = 2,\ A,\ I_{3(0)} = 0.$$

Zanjirni birinchi garmonika uchun hisoblaymiz:

$$u(t) = 141\sin(\omega t + 30^0), V,\ \underline{U}_{(1)} = 100e^{j30^0}\ V.$$

Parallel uchastkaning kompleks qarshiligi:

$$Z_{23(1)} = \frac{\underline{Z}_2\underline{Z}_{3(1)}}{\underline{Z}_2 + \underline{Z}_{3(1)}} = \frac{R_2\left(-j\dfrac{1}{\omega C}\right)}{R_2 - j\dfrac{1}{\omega C}} = \frac{5\cdot(-j9)}{5-j9} = 4{,}37e^{-j29^0} = 3{,}83 - j2{,}12\ Om.$$

Birinchi garmonika uchun zanjirning ekvivalent qarshiligi:

$$\underline{Z}_{(1)} = \underline{Z}_{1(1)} + \underline{Z}_{23(1)} = R_1 + j\omega L + \underline{Z}_{23(1)} = 20 + j3 + 3{,}83 - j2{,}12 =$$

$$= 23{,}83 + j0{,}88 = 23{,}9e^{j2^0}\ Om.$$

Umumiy tok birinchi garmonikasi effektiv qiymatining kompleksi:

$$\underline{I}_{1(1)} = \frac{\underline{U}_{(1)}}{\underline{Z}_{(1)}} = \frac{100e^{j30^0}}{23{,}9e^{j2{,}12^0}} = 4{,}184e^{j28^0}\ A.$$

Parallel uchastkadagi kuchlanish:

$$\underline{U}_{23(1)} = \underline{I}_{1(1)}\underline{Z}_{23(1)} = 4{,}184e^{j28^0}\cdot 4{,}37e^{-j29^0} = 18{,}28e^{j1^0}\ V.$$

Ikkinchi va uchinchi shoxobchadagi toklar:

$$\underline{I}_{2(1)} = \frac{\underline{U}_{23(1)}}{R_2} = \frac{18{,}28e^{-j1^0}}{5} = 3{,}66e^{-j1^0}\ A,$$

$$\underline{I}_{3(1)} = \frac{\underline{U}_{23(1)}}{-j\dfrac{1}{\omega C}} = \frac{18{,}28e^{-j1^0}}{-j9} = 2{,}03e^{j89^0}\ A.$$

Birinchi garmonika toklarining oniy qiymati:

$$i_{1(1)} = 4{,}184\sqrt{2}\sin(\omega t + 28^0),\ A;$$

$$i_{2(1)} = 3{,}66\sqrt{2}\sin(\omega t - 1^0)\ A;$$

$$i_{3(1)} = 2{,}03\sqrt{2}\sin(\omega t + 89^0)\ A.$$

Manba kuchlanishining uchinchi garmonikasidan zanjirda hosil bo'lgan toklarni topamiz. Uchinchi garmonika kuchlanishi:

$$u_{(3)} = 70{,}7\sin(3\omega t - 60^0)\ B,\ \underline{U}_{(3)} = 50e^{-j60^0}V.$$

Uchinchi garmonika kuchlanishi: Uchinchi garmonika uchun zanjirning kompleks qarshiliklari:

$$\underline{Z}_{23(3)} = \frac{\underline{Z}_2 \underline{Z}_{3(3)}}{\underline{Z}_2 + \underline{Z}_{3(3)}} = \frac{R_2\left(-j\dfrac{1}{3\omega C}\right)}{R_2 - j\dfrac{1}{3\omega C}} = \frac{5\cdot(-j3)}{5-j3} = 2{,}57e^{-j59^0} =$$

$$= 1{,}32 - j2{,}2 \ Om,$$

$$\underline{Z}_{(3)} = R_1 + j3\omega L + \underline{Z}_{23(3)} = 20 + j9 + 1{,}32 - j2{,}2 = 21{,}32 + j6{,}8 =$$

$$= 22{,}38e^{j18^0} \ Om.$$

Tok va kuchlanishlar:

$$\underline{I}_{1(3)} = \frac{\underline{U}_{(3)}}{\underline{Z}_{(3)}} = \frac{50e^{-j60^0}}{22{,}38e^{j18^0}} = 2{,}23e^{-j78^0} \ A,$$

$$\underline{U}_{23(3)} = \underline{I}_{1(3)} \cdot \underline{Z}_{23(3)} = 2{,}23e^{-j78^0} \cdot 2{,}57e^{-j59^0} = 5{,}73e^{-j137^0} \ V,$$

$$\underline{I}_{2(3)} = \frac{\underline{U}_{2(3)}}{R_2} = \frac{5{,}73e^{-j137^0}}{5} = 1{,}14e^{-j137^0} \ A,$$

$$\underline{I}_{3(3)} = \frac{\underline{U}_{23(3)}}{-j\dfrac{1}{3\omega C}} = \frac{5{,}73e^{-j137^0}}{-j3} = 1{,}91e^{-j47^0} \ A.$$

Uchinchi garmonika toklarining oniy qiymatlari:

$$i_{1(3)} = 2{,}23\sqrt{2}\sin(3\omega t - 78^0) \ A,$$

$$i_{2(3)} = 1{,}14\sqrt{2}\sin(3\omega t - 137^0) \ A,$$

$$i_{3(3)} = 1{,}91\sqrt{2}\sin(3\omega t - 47^0) \ A.$$

Shoxobchadagi oniy toklar:

$$i_1 = I_{1(0)} + i_{1(1)} + i_{1(3)} = 2 + 4{,}184\sqrt{2}\sin(\omega t + 28^0) +$$

$$+ 2{,}23\sqrt{2}\sin(3\omega t - 78^0) \ A,$$

$$i_2 = I_{2(0)} + i_{2(1)} + i_{2(3)} = 2 + 3{,}66\sqrt{2}\sin(\omega t - 1^0) +$$

$$+ 1{,}14\sqrt{2}\sin(3\omega t - 137^0) \ A,$$

$$i_3 = I_{3(0)} + i_{3(1)} + i_{3(3)} = 2{,}03\sqrt{2}\sin(\omega t + 89^0) +$$

$$+ 1{,}91\sqrt{2}\sin(3\omega t - 47^0) \ A.$$

Toklarning effektiv qiymatlari:

$$I_1 = \sqrt{I_{1(0)}^2 + I_{1(1)}^2 + I_{3(3)}^2} = \sqrt{2^2 + 4{,}184^2 + 2{,}23^2} = 5{,}146\ A,$$

$$I_2 = \sqrt{I_{2(0)}^2 + I_{2(1)}^2 + I_{2(3)}^2} = \sqrt{2^2 + 3{,}66^2 + 1{,}146^2} = 4{,}32\ A,$$

$$I_3 = \sqrt{I_{3(1)}^2 + I_{3(3)}^2} = \sqrt{2{,}03^2 + 1{,}91^2} = 2{,}79\ A.$$

5.2-masala. Berilgan nosinusoidal tok va kuchlanish ekvivalent sinusoidalar bilan almashtirilsin va ular orasidagi $\varphi_э$ faza siljish burchagi topilsin.

$U = 25{,}9\sin(\omega t - 11^0 40') + 6\sin(3\omega t + 53^0 50')$ V,

$i = 3\sin(\omega t - 40^0) + 0{,}9\sqrt{2}\sin(3\omega t + 125^0)$ A.

Yechish:

$$U_1 = \frac{25{,}9}{\sqrt{2}} = 18{,}3\ B, \quad U_3 = \frac{6}{\sqrt{2}} = 4{,}26\ V,$$

$$I_1 = \frac{3}{\sqrt{2}} = 2{,}13\ A, \quad I_3 = 0{,}9\ A,$$

$$\varphi_1 = -11^0 40' - (-40^0) = 28^0 20', \quad \varphi_3 = -71^0 10'.$$

$$P = 18{,}3 \cdot 2{,}13\cos 28^0 20' + 4{,}26 \cdot 0{,}9\cos(-71^0 10') = 35{,}5\ W,$$

$$U = \sqrt{U_1^2 + U_3^2} = \sqrt{18{,}3^2 + 4{,}26^2} = 18{,}55\ W,$$

$$I = \sqrt{2{,}13^2 + 0{,}9^2} = 2{,}31\ A,$$

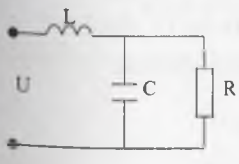
$$S = UI = 18{,}55 \cdot 2{,}31 = 42{,}8\ VA.$$

Kuchlanish ekvivalent sinusoidasining effektiv qiymati *U=18,55 M*. Tok ekvivalent sinusoidasining effektiv qiymati esa *I=2,31 A*.

Quvvat koeffitsiyenti $\cos\varphi_э = \dfrac{35{,}5}{18{,}55 \cdot 2{,}31} = 0{,}828.$

Faza siljish burchagi $\varphi_э = \arccos 0{,}828 = 34^0$.

5.3-masala. Sxemada keltirilgan tok zanjirlari parametrlari: *L=0,5 Gn, C=4 mkF, R=300 Om* ga teng, hamda chastotasi *f= 100 Gs* bo'lib *U=100 sin³ωt* nosinusoidal kuchlanishga ulangan. Tarmoq toklari oniy qiymatlari aniqlanib, buzilish koeffisienti aniqlansin.



Yechish: Kuchlanish ifodasini Fur`e qatoriga yoyamiz:

$$\sin^2 \omega t = \sin \omega t \cdot \frac{1-\cos 2\omega t}{2} = \frac{1}{2}(\sin \omega t - \sin \omega t \cos 2\omega t) = \frac{3}{4}\sin \omega t - \frac{1}{4}\sin 3\omega t ;$$

Bunda zanjir kuchlanishi oniy qiymati:

$$U = 75\sin \omega t - 25\sin 3\omega t = 75\sin \omega t + 25\sin(3\omega t + \pi)$$

Birinchi garmonika uchun zanjir qarshiligi:

$$\underline{Z}_{L_1} = j\omega L_1 = j628 \cdot 0.05 = j3.14\ Om \qquad \underline{Z}_{C_1} = \frac{1}{j\omega C} = -j398\ Om$$

Bunda: $\omega = 2\pi f = 628\frac{1}{s}$

Zanjirning kompleks to'la qarshiligi:

$$\underline{Z}_1 = \underline{Z}_{L_1} + \frac{R \cdot \underline{Z}_{C_1}}{R + \underline{Z}_{C_1}} = j31.4 + \frac{300(-j398)}{300 - j398} = 192 - j112.6 = 220e^{-j30^0}$$

Tarmoq toklari kompleks ifodasi:

$$\dot{I}_{L_1} = \frac{75}{\sqrt{2} \cdot 220e^{-j30^0}} = 0{,}24e^{j30^0}$$

$$\dot{I}_{C_1} = \frac{\dot{I}_{L_1} R}{R + \underline{Z}_{C_1}} = \frac{0{,}24e^{j30^0} \cdot 300}{300 - j398} = 0{,}145e^{j83^0}$$

$$\dot{I}_{R_1} = \frac{\dot{I}_{L_1} \underline{Z}_{C_1}}{R + \underline{Z}_{C_1}} = \frac{0{,}24e^{j30} \cdot 398e^{-j90^0}}{300 + j398} = 0{,}19e^{-j6^0 40'}$$

Bu toklarning oniy qiymatlari:

$$i_{L_1} = 0.24\sqrt{2}\sin(\omega t + 30^0) \qquad (A)$$

$$i_{C_1} = 0.145\sqrt{2}\sin(\omega t + 83^0 20') \qquad (A)$$

$$i_{R_1} = 0.19\sqrt{2}\sin(\omega t - 6^0 40') \qquad (A)$$

Uchinchi yuqori garmonika uchun reaktiv qarshiliklar:

$$\underline{Z}_{L_3} = j3\omega L = j94\ Om$$

$$\underline{Z}_{C_3} = -j\frac{10^6}{3 \cdot 628 \cdot 4} = -j133\ Om$$

To'la kompleks qarshilik:

$$\underline{Z}_3 = \underline{Z}_{L_3} + \frac{R\underline{Z}_{C_3}}{R + \underline{Z}_{C_3}} = j94 + \frac{300(-j133)}{300 - j133} = 49.6e^{-j19^0}$$

Uchinchi garmonika tarmoq toklar kompleks ifodasi:

$$\dot{I}_{L_3} = \frac{25e^{j150^0}}{\sqrt{2}49{,}6e^{-j19^0}} = 0{,}36e^{j19^0}$$

$$\dot{I}_{C_3} = \frac{0{,}356e^{j199^0}}{300 - j179} = 0{,}144e^{j133^0}$$

$$\dot{I}_{R_3} = \frac{0{,}356e^{j199^0}}{300 - j179} = 0{,}144e^{j133^0}$$

Toklarning oniy qiymatlari :

$$i_{L_3} = 0{,}356\sqrt{2}\sin(3\omega t + 199^0) \quad (A)$$

$$i_{C_3} = 0{,}325\sqrt{2}\sin(3\omega t + 223^0) \quad (A)$$

$$i_{R_3} = 0{,}144\sqrt{2}\sin(3\omega t + 132^0) \quad (A)$$

Tarmoq toklarining effektiv qiymatlari:

$$I_L = \sqrt{I_{L_1}^2 + I_{L_3}^2} = \sqrt{0{,}24^2 + 0{,}356^2} = 0{,}43\ A$$

$$I_C = \sqrt{I_{C_1}^2 + I_{C_3}^2} = 0{,}373\ A$$

$$I_R = \sqrt{I_{R_1} + I_{R_3}} = 0{,}24\ A$$

Buzilish koeffisienti:

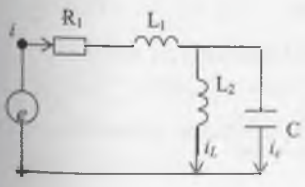
$$k_L = \frac{I_{L_1}}{I_{L_3}} = \frac{0{,}356}{0{,}43} = 0{,}83$$

$$k_C = \frac{I_{C_1}}{I_{C_3}} = \frac{0{,}325}{0{,}373} = 0{,}87$$

$$k_R = \frac{I_{R_1}}{I_{R_3}} = \frac{0{,}144}{0{,}240} = 0{,}33$$

Demak sig'imdan oqib o'tuvchi tok shakli ko'proq buzilar ekan.

5.4-masala. Nosinusoidal tok zanjirining parametrlari *R=300 Om, L_1=0.25 Gn, L_2=0.1 Gn, S=3,3 mkF* va chastota *ω=1000 rad/sek* bo'lib, *e=60+250sinωt+100sin3ωt* garmonikalardan tarkib topgan manbaaga ulangan. Birinchi tarmoq tokining oniy, effektiv qiymatlari va aktiv quvvati aniqlansin.



Yechish: O'zgarmas tok kondensatordan oqib o'tmasligi *(I_C=0)* va induktiv qarshiliklar nolga tengligini *(L=0)* hisobga olsak:

$$I_0 = \frac{E_0}{R_1} = \frac{60}{300} = 0{,}2\ A$$

Masalani kompleks usul bilan yechamiz.Bunda birinchi garmonika uchun kompleks tok amplitudasi:

$$\dot{I}_{m_1} = \frac{\dot{E}_{m_1} e^{j0^0}}{\underline{Z}_1}$$

Reaktiv qarshiliklarni aniqlaymiz:

$$X_1 = \omega L_1 = 1000 \cdot 0{,}25 = 250\ Om$$

$$X_2 = \omega L_2 = 1000 \cdot 0{,}1 = 100\ Om$$

Sig'imdagi qarshilik: $X_C = \frac{1}{\omega C} = \frac{1}{1000 \cdot 3{,}3 \cdot 10^{-6}} = 300\ Om$

Birinchi garmonika kompleks to'la qarshilik:

$$\underline{Z}_1 = R_1 + j\,\omega L_1 + \frac{j\,\omega L_2 \left(-j\,\frac{1}{\omega C}\right)}{j\,\omega L_2 - j\,\frac{1}{\omega C}} = 300 + j\,400 = 500 e^{j53^0}$$

Tok amplituda qiymati:

$$\dot{I}_{m_1} = \frac{250 e^{j0^0}}{500 \cdot e^{j53^0}} = 0{,}5 e^{-j53^0} \quad (A)$$

Tokning oniy qiymati:

$$i_1 = 0.5 \sin(\omega t - 53^0) \qquad (A)$$

Uchinchi garmonika tokini aniqlaymiz.
Manba kuchlanishi:

$$e_3 = 100 \sin \omega t = \dot{E}_{m_3} \cdot 100 e^{j0^0}$$

Uchinchi garmonika uchun reaktiv qarshiliklar:

$$X_{L1} = 3\omega L_1 = 250\ Om, \qquad X_{L_2} = 3\omega L_2 = 300\ Om, \qquad X_C = \frac{1}{3\omega C_3} = 100\ Om$$

Umumiy kompleks qarshilik:

$$\underline{Z}_{(3)} = R_1 + j\,X_{L_1} + \frac{j\,X_{L_2} \cdot \frac{1}{j\,X_C}}{j\,X_{L_2} + \frac{1}{j\,X_C}} = 300 + j\,750 + \frac{j\,300(-j\,100)}{j\,300 - j\,100} = 300 + j\,600 = 675 e^{j63^0}\ Om$$

Uchinchi garmonika tok amplitudasining kompleks ifodasi:

$$\dot{I}_{m_3} = \frac{\dot{E}_{m_3}}{\underline{Z}_{(3)}} = \frac{100}{671 \cdot e^{j63^0}} = 0{,}15 \cdot e^{-j63^0}$$

Tokning oniy qiymati:

$$i_3 = 0{,}15\sin(3\omega t - 63^0)$$

Zanjirga kiruvchi tok oniy qiymati :

$$i_1 = 0{,}2 + 0{,}5\sin(\omega t - 53^0) + 0{,}15\sin(3\omega t - 63^0) \quad A$$

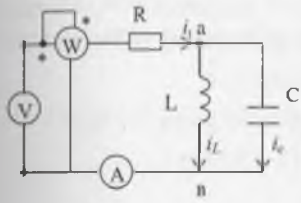
Bu tokning effektiv qiymati esa:

$$I = \sqrt{0{,}2^2 + \left(\frac{0{,}5}{\sqrt{2}}\right)^2 + \left(\frac{0{,}15}{\sqrt{2}}\right)^2} = 0{,}42 \quad A$$

Zanjir aktiv quvvati har bir garmonikalar tok va kuchlanish oniy qiymatlari ifodasidan:

$$P = P_0 + P_1 + P_3 = 60 \cdot 0.2 + \frac{250}{\sqrt{2}} \cdot \frac{0.5}{\sqrt{2}} \cos 53^0 + \frac{100}{\sqrt{2}} \cdot \frac{0.15}{\sqrt{2}} \cos 63^0 = 52.8\,W$$

5.5-masala. Berilgan elektr tok zanjirining induktivlikdan oqib o'tuvchi nosinusoidal tok $i_L = 4 + 8\sin\omega t + 6\sin(2\omega t + 90^0)$ bo'lib, qarshilik parametrlari $R=\omega L=5$ *Om*, $\frac{1}{\omega C} = 20\,Om$ga teng. Elektr o'lchov asboblari: ampermetr, voltmetr va vattmetrlarning ko'rsatish qiymatlari aniqlansin.



Yechish: Induktivlikdan oqib o'tuvchi tok ma'lum bo'lganligi uchun har bir garmonika uchun parallel ulangan tarmoq kuchlanishlarini aniqlaymiz.

$$U_{Lm_1} = I_{Lm_1} \cdot X_{L_1} = 8 \cdot 5 = 40\,V$$

$$U_{Lm_2} = I_{Lm_2} \cdot X_{L_2} = 6 \cdot 10 = 60\,V$$

Sig'im va induktivlikdagi kuchlanish oniy qiymati:

$$U_C = U_L = 40\sin(\omega t + 90^0) + 60\sin(2\omega t + 180^0) = 40\sin(\omega t + 90^0) - 60\sin 2\omega t$$

Birinchi garmonika uchun paralell ulangan *L,C* kompleks reaktiv qarshilik:

$$\underline{Z}_{ab_1} = X_{ab_1} = \frac{jX_{L_1} \cdot jX_{C_1}}{jX_{L_1} + jX_{C_1}} = -j\frac{20 \cdot 5}{5 - 20} = j6{,}67 \quad Om$$

Birinchi garmonika tok amplitudasi:

$$I_{m_1} = \frac{U_{Lm_1}}{Z_{ab_1}} = \frac{40}{6.67} = 6\,A$$

Ikkinchi garmonika uchun:

$$\underline{Z}_{ab_2} = \frac{j2\omega L \cdot \frac{1}{j2\omega C}}{j\left(2\omega L - \frac{1}{2\omega C}\right)} = \infty$$

Demak parallel ulangan reaktiv elementlarda toklar rezonansi yuzaga kelib birinchi tarmoqda ikkinchi garmonika toki ($I_{2m}=0$) nolga teng.

Tokning oniy qiymati:

$$i = I_0 + I_{m_1}\sin(\omega t + \varphi_u - \varphi) = 4 + 6\sin(\omega t + 90^0 - 90^0) = 4 + 6\sin\omega t$$

Ampermetrdagi tok: $I = \sqrt{4^2 + \left(\frac{6}{\sqrt{2}}\right)^2} = 5{,}8\ A$

Har bir yuqori garmonika uchun zanjirning umumiy qarshiligini aniqlaymiz. Nolinchi va birinchi garmonika uchun aktiv qarshilik: $R_0 = R = 5\ Om$

Birinchi garmonika to'la qarshiligi :

$$Z_1 = \sqrt{R^2 + (X_{ab_1})^2} = \sqrt{5^2 + (6.7)^2} = 8{,}3\ Om$$

Ikkinchi garmonikada $Z_2=\infty$

Garmonikalar kuchlanishini topamiz:

$$U_0 = I_0 R_0 = 4 \cdot 5 = 20\ V$$

$$U_{m_1} = I_{m_1} \cdot Z_1 = 6 \cdot 8{,}3 = 50\ V$$

$$U_{m_2} = U_{Lm_2} = 60\ V$$

Faza burchagi $\varphi_1 = arctg\frac{X_{ab_1}}{R} = \frac{6.67}{5} = 53^0$

Zanjirni umumiy kuchlanish oniy qiymati:

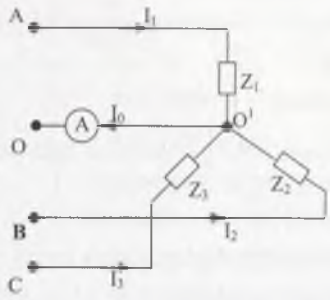
$$U = U_0 + U_1 + U_2 = U_0 + Um_1 \sin(\omega t + \varphi_1) + Um_2 \sin 2\omega t =$$
$$= 20 + 50\sin(\omega t + 53^0) - 60\sin 2\omega t\ (V)$$

Voltmetr ko'rsatishi:

$$U = \sqrt{U_0^2 + U_1^2 + U_2^{-2}} = \sqrt{20^2 + (\frac{50}{\sqrt{2}})^2 + (\frac{60}{\sqrt{2}})^2} = 58{,}6V$$

O'rtacha quvvat yoki volmetr ko'rsatishi: $P = U_0 I_0 + U_1 I_1 \cos\varphi_1 + U_2 I_2 \cos\varphi_2 = 170\ W.$

5.6-masala. Yulduzcha shaklida ulangan tok zanjirining iste`molchilar kompleks qarshiliklari: $\underline{Z}_1 = \underline{Z}_2 = \underline{Z}_3 = (3 + j6)Om$ bo'lib, faza kuchlanishi $141\sin\omega t + 42{,}5\sin 3\omega t + 5\sin 2\omega t(V)$ generatorga ulangan. Neytral sim toki I_0 faza toklar oniy qiymatlari va uch fazali tok quvvati aniqlansin.



Yechish:

Birinchi garmonika uchun istemolchi faza kuchlanishlari

$$\dot{U}_1 = 100\,V;\quad \dot{U}_2 = 100e^{-j120^0}\,V;\quad \dot{U}_3 = 100e^{j120^0}\,V$$

Faza tokining effektiv qiymati:

$$U_{\phi_1} = \frac{U}{\underline{Z}} = \frac{100}{\sqrt{3^2+6^2}} = 15\,A$$

Faza burchagi: $\varphi = arctg\dfrac{X_L}{R} = 63^0 30'$

Neytral simda birinchi garmonika bo'lmaydi. ($I_0=0$)

Uchinchi garmonika faza kuchlanishlari :

$$\dot{U}_1 = 30\,V,\qquad \dot{U}_2 = 30e^{-j3120^0} = 30\,V,\qquad \dot{U}_3 = 30^{j3120^0} = 30\,V.$$

Kuchlanish effektiv qiymati: $U=30\ V$

Faza toki effektiv qiymati: $I_{\phi_3} = \dfrac{U}{Z} = \dfrac{30}{\sqrt{3^2+18^2}} = 1{,}65\,A$

Faza farqi: $\varphi_3 = arctg\dfrac{X_{L_3}}{R} = \dfrac{3\omega L}{R} = 80^0 30'$

Neytral simda uchinchi garmonika toki faza tokidan 3 barobar katta bo'lib:

$$I_0 = 3I_{\phi_3} = 3\cdot 1.65 = 5\,A$$

Liniya kuchlanishlari tarkibida uchinchi garmonika yo'q. ($U_{l(3)}=0$).

Beshinchi garmonika uchun faza kuchlanishlari:

$\dot{U}_1 = 3{,}54\,V;\quad \dot{U}_2 = 3{,}54e^{-j5(120^0)} = 3{,}54e^{j120^0}\,V;\quad \dot{U}_3 = 3{,}54e^{j5(120^0)} = 3{,}54e^{-j120^0}\,V$

Kuchlanish effektiv qiymati: *U=3,54 V*

Faza toki: $I_{\phi_5} = \dfrac{U}{\sqrt{R^2 + (5\omega L)^2}} = \dfrac{3{,}54}{\sqrt{3^2 + 30^2}} = 0{,}117\ A$

Faza farqi: $\varphi_5 = arctg\,\dfrac{5\omega L}{R} = 84^0$

Neytral simda beshinchi garmonika toki nolga teng. ($I_{0(5)}=0$)

Birinchi faza tokining oniy qiymati:

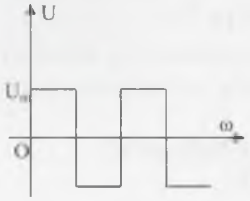
$i_1 = i_\phi = 15\sqrt{2}\sin(\omega t - 63^0 30') + 1.65\sqrt{2}\sin(3\omega t - 80^0 30') + 0.117\sqrt{2}\sin(5\omega t - 84^0 15')\ A$

Iste'molchilarda sarf bo'ladigan uch fazali tok o'rtacha quvvati:

$$P = 3(U_1 I_1 \cos\varphi_1 + U_3 I_3 \cos\varphi_3 + U_5 I_5 \cos\varphi_5) \approx 9980\ W$$

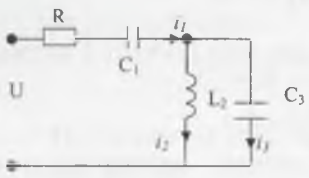
Mustaqil yechish uchun masalalar

5.7-masala. Kuchlanish amplituda qiymati $U_m=100\ V$ bo'lgan funksiyani Fure qatoriga yoyish bilan 1,2,3 garmonikalar ifodasi yoki kuchlanish oniy qiymati aniqlansin.



Javob: $U = 127.3\sin\omega t + 42.4\sin 3\omega t + 25.5\sin 5\omega t\ (V)$

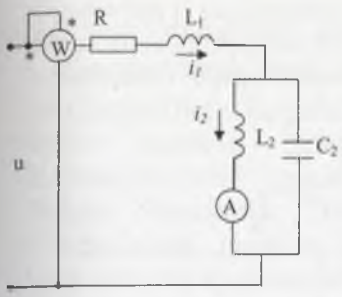
5.8-masala. Berilgan sxemaning qarshilik parametrlari: $R_1=100$ Om, $X_{L_2} = 100\ Om$, $X_{C_3} = 200\ Om$ bo'lib, nosinusoidal manba $U = 100 + 500\sin\omega t + 200\sin\omega t$ kuchlanishga ulangan. Tarmoq toklarini oniy qiymati aniqlansin.



Javob: $i_1 = 3.54\sin(\omega t - 45^0) + 0.743\sin(2\omega t + 68^0)\quad A$

$i_2 = 7.08\sin(\omega t - 45^0) + 0.743\sin(2\omega t - 112^0)$ A

$i_3 = 3.54\sin(\omega t + 135^0) + 1.5\sin(2\omega t + 68^0)$ A

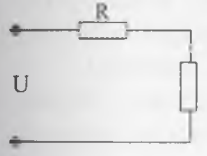


5.9-masala. Berilgan sxemani parametrlari *R=20 Om, L_1=20 mGn, L_2=60 mGn, C=16.6 mkF, ω=1000 rad/sek* bo'lib, nosinusoidal kuchlanishga $U = 40 + 120\sin\omega t + 60\sin 2\omega t$ ulangan. Birinchi tarmoq toki i_1 va elektr o'lchov asboblarining ko'rsatish qiymatlari topilsin.

Javob: $i_1 = 2 + 1.06\sin(2\omega t + 45^0)$ A

$I_2 = 2.47$ A, $P = 102.5$ W

5.10-masala. Elektr zanjiri qarshilik parametrlari $R_1 = 10\ Om$,



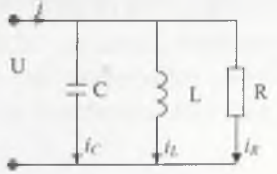
$X_C = \frac{1}{\omega C} = 270\ Om$ bo'lib, nosinusoidal kuchlanish $U = 100 + 200\sin\omega t + 30\sin(\omega t - 90^0) + 50\sin(5\omega t + 45^0)$ ulangan. Tokning oniy qiymati, kuchlanishi va quvvatlari aniqlansin.**Javob:**

$i = 0.74\sin(\omega t + 88^0) + 0.33\sin(3\omega t - 6^0 30') + 0.97\sin(5\omega t + 124^0 30')$ (A)

$U = 178\ V, I = 0.863\ A, P = 7.47\ W$

5.11-masala. Berilgan sxema parametrlari: $R = \frac{1}{\omega C} = 10\ Om$ bo'lib,

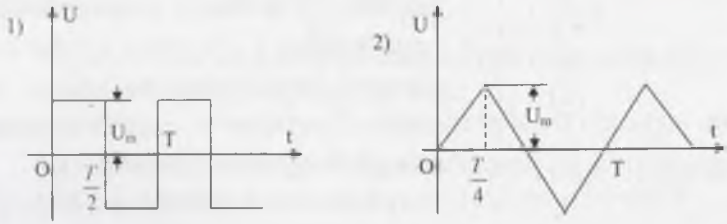
$U = (200\sin\omega t + 60\sin 3\omega t + 30\sin 5\omega t)$ (V) kuchlanish ulangan. Tok i ning oniy qiymati ifodasi effektiv qiymati I va quvvati P aniqlansin.



Javob: $i = 20\sin\omega t + 17.4\sin\left(3\omega t + 67^0\right) + 14.7\sin\left(5\omega t + 178^0\right)$

$I = 32\ A, P = 4450\ W$

5.12-masala. Grafikda keltirilgan kuchlanish funksiyalari uchun amplituda k_a, forma k_f va siljish k_{sil} koeffisienti aniqlansin.



Javob: 1) $k_a = k_\phi = 1;\quad k_{sin} = \dfrac{2\sqrt{2}}{\pi}$

2) $k_a = \sqrt{3};\quad k_\phi = \dfrac{2}{\sqrt{3}};\quad k_{sin} = \dfrac{4\sqrt{6}}{\pi^2}$

6-BOB. NOCHIZIQLI ZANJIRLAR

Chiziqli elektr zanjirlarini tahlil qilishda shu paytgacha ular elementlarining parametrlari - rezistor qarshiligi R, g'altak induktivligi L, kondensator sig'imi C o'zgarmas bo'lib, zanjirdagi tok va kuchlanishlarga bog'liq emas, ya'ni ular chiziqli VAX ga ega deb hisoblandi. Lekin bu holat zanjirdagi haqiqiy jarayonni ideallashtirishdir. Ko'pchilik hollarda elektr zanjirlardagi elementlar VAXsi nochiziq bo'lib, ularning parametrlari tok va kuchlanishlarning qiymatlari va yo'nalishlariga bog'liq bo'ladi. Bunday elementlar, kitobning birinchi bobida qayd etib o'tganimizdek, nochiziq elementlar, tarkibida hech bo'lmaganda bitta nochiziq elementi bo'lgan zanjirlar esa nochiziq zanjirlar deb ataladi.

Nochiziq zanjirlar energetika, avtomatika, radiotexnika, elektronika, elektr aloqa va boshqa sohalarda keng qo'llaniladi. Bunday zanjirlardagi jarayonlarni tahlil qilish chiziqli zanjirlardagi jarayonlarni tahlilidan ancha murakkabdir. Chunki, nochiziq zanjirlar o'zgaruvchan koeffitsiyentli tenglamalar bilan ifodalanadi.

Qarshilik, induktivlik va sig'im tegishli elementdagi elektr va magnit maydonlarining element yasalgan material bilan o'zaro ta'sirini miqdor jihatdan tavsiflaydi. Masalan, l_E uzunlikdagi va S_E kesimli to'g'ri chiziqli o'tkazgichning qarshiligi $R = \rho \frac{l_E}{S_E}$, S_μ kesimli va l_μ uzunlikli toroidal magnit o'tkazgichga o'ralgan va o'ramlar soni w ga teng bo'lgan g'altakning induktivligi $L = \mu \frac{w^2 S_\mu}{l_\mu}$, yupqa plastinalarining yuzasi S, ular orasidagi masofa d bo'lgan kondensator sig'imi $C = \varepsilon \frac{S}{d}$ formulalar bilan aniqlanadi.

Ko'pchilik elektrotexnika materiallarida $\rho = f(\delta), \mu = f(H)$ va $\varepsilon = f(E)$ bog'lanishlar nochiziq funksiya ko'rinishida bo'ladi va shuning uchun ham bu materiallar asosida yasalgan rezistorlar, induktiv g'altaklar va kondensatorlar nochiziqlik xossalariga ega bo'ladi.

Nochiziq elementlar nochiziqli rezistor, nochiziq induktiv g'altak va nochiziq kondensatorlarga bo'linadi.

Odatda nochiziqli elementlar ikkita katta guruhga ajratiladi: *boshqarilmaydigan* (nochiziq ikkiqutbliklar) va *boshqariladigan* (nochiziq ikki-, uch-, to'rt- yoki ko'pqutbliklar). Birinchi guruh nochiziq elementlarga rezistor, diod, cho'g'lanma lampa, termoqarshilik, elektr yoyi, ferromagnit o'zakli induktiv g'altak, baretter, gazotron, stabilitron va boshqalar kiradi. Ikkinchi guruh nochiziq elementlarga bir nechta kirish qismalari bo'lgan va ulardan kamida bittasi boshqarish maqsadida foydalaniladigan elementlar kiradi. Bularga tranzistor, tiristor, radiolampa va boshqalar misol bo'la oladi.

Nochiziq elementlar xossalarini ularning VAXlari yordamida tahlil etish qulay hisoblanadi. VAX bir qiymatli va ko'p qiymatli bo'lishi mumkin. Bir qiymatli VAXlarda argument (masalan, tok) ning har bir qiymatiga funksiya (masalan, kuchlanish) ning faqat bitta qiymati mos keladi. Ko'p qiymatli VAXlarda esa argumentning bir qiymatiga funksiyaning bir nechta qiymatlari mos keladi. Masalan, gisterezis sirtmog'i ko'p qiymatli VAX lar guruhiga kiradi.

Nochiziqli rezistordagi kuchlanishni undan o'tayotgan tokka nisbati statik qarshilik deb ataladi:

$$R_{st} = \frac{U}{I} = m_R tg\alpha, \qquad (6.1)$$

bu yerda m_R - qarshilik masshtabi.

Nochiziqli rezistordagi kuchlanish orttirmasini undan o'tayotgan tok orttirmasiga nisbatining tok orttirmasi nolga intilgandagi limiti *dinamik qarshilik* deb ataladi, ya'ni:

$$R_d = \lim_{\Delta I \to 0} \frac{\Delta U}{\Delta I} = \frac{dU}{dI} = m_R tg\beta. \qquad (6.2)$$

Magnit zanjirlar uchun Om qonuni magnit zanjirlardan o`tuvchi oqim bilan magnit kuchlanishni bir-biri bilan bog`laydi.

$$\Phi = \frac{U_M}{R_M} \qquad (6.3)$$

Bu yerda, Φ – magnit oqim $[Vb]$, U_M – magnit kuchlanish $[A]$, R_M – magnit qarshilik $[Gn^{-1}]$

Magnit zanjirlar uchun Kirxgoffning 1 - qonuni magnit zanjirning o`tuvchi oqim bilan magnit kuchlanishni bir-biri bilan bog`laydi.

$$\sum_i^n \Phi_i = 0 \qquad (6.4)$$

Magnit zanjirlar uchun Kirxgoffning 2 – qonuni bo`yicha ketma-ket magnit zanjirdagi m.y.k.(magnit yurituvchi kuch) larning yig`indisi uning ayrim uchastkalaridagi magnit kuchlanishlarining yig`indisiga teng, yani

$$\sum_i^n F_i = \sum_i^n U_{M_i} \qquad (6.5)$$

Bu tenglamada, $F = I \cdot \omega$ – magnit yurituvchi kuch, A; $U_M = \Phi \cdot R_M$ yoki $U_M = H \cdot l$,A ; ω – induktiv g`altakning o`ramlari soni; H – magnit maydon kuchlanganligi, A/m ; l – magnit o`tkazgichning uzunligi, m.

Masala yechish namunalari

6.1-masala. Zanjirdagi nochiziq elementdan o'tayotgan tok topilsin. Bunda $R_1 = 30\ Om$, $R_2 = 60\ Om$, $R_3 = 20\ Om$, $R_4 = 20\ Om$, $E = 360\ V$ bo'lib, NE VAXsi quyidagi rasmda berilgan.

Yechish: $U_{ab\ s.i.}$ kuchlanishni topish uchun sxemadan foydalanamiz.

$$I_{1s.i.} = \frac{E}{R_1 + R_2} = \frac{360}{30 + 60} = 4\ A,$$

$$I_{2s.i.} = \frac{E}{R_3 + R_4} = \frac{360}{20 + 20} = 9\ A,$$

$$U_{ab\ s.i.} = I_{2s.i.} R_3 - I_{1s.i.} R_1 = 9 \cdot 20 - 4 \cdot 30 = 60\ V.$$

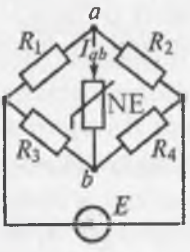
Ekvivalent generator ichki qarshiligini topish uchun sxemadan foydalanamiz:

$$R_e = R_{ich.} = \frac{R_1 R_2}{R_1 + R_2} + \frac{R_3 R_4}{R_3 + R_4} = 30\ Om.$$

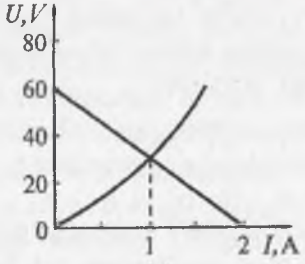
Ekvivalent generator tashqi xarakteristikasini qurish uchun zanjirdagi qisqa tutashish tokini quyidagicha aniqlaymiz:

$$I_{q.t.} = \frac{E_e}{R_e} = \frac{U_{ab\ s.i.}}{R_{ich}} = \frac{60}{30} = 2\ A.$$

Ekvivalent generator tashqi xarakteristikasi $E_e = 60\,V$ da $I = 0$ va $U = 0$ da $I_{q.t} = 2A$ ($I_{q.t}$- qisqa tutashish rejimidagi tok) nuqtalar asosida qurilgan. Bu xaratkeristikani NE VAX bilan kesishgan nuqtasining absissasi izlanayotgan tok qiymatiga teng bo'ladi, ya'ni $I_{ab} = 1\,A$.



a)



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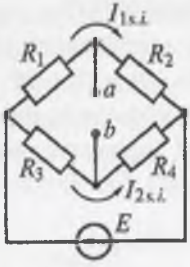

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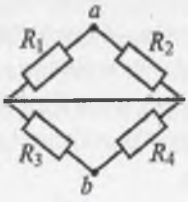


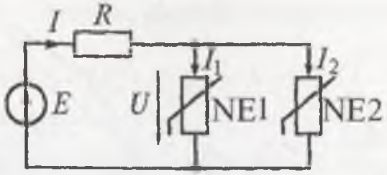
g)

6.2-masala. Keltirilgan zanjirda quyidagilar berilgan: $E = 30\,V$; $R = 20\ Om$; NE1 va NE2 larning VAXlari mos ravishda $I_1(U) = a_1U + a_2U^2$ va $I_2(U) = b_1U + b_2U^2$ tenglamalar ko'rinishda berilgan, bu yerda $a_1 = 0{,}1\,A/V$; $a_2 = 0{,}003\,A/V^2$; $b_1 = 0{,}04\,A/V$; $b_2 = 0{,}002\,A/V^2$.

Nochiziq elementlardagi kuchlanish va toklar topilsin.

Yechish: Berilgan zanjir uchun Kirxgoffning birinchi va Om qonunlari asosida quyidagilarni yozamiz:

$$I = I_1 + I_2,\ I = \frac{E - U}{R}.$$



Yuqoridagi 1- tenglamaga $I_1(U)$ va $I_2(U)$ lar ifodalarini qo'yib va ikkala tenglama o'ng tomonlarini o'zaro tenglashtirib quyidagini hosil qilamiz:

$$[(E-U/R)]=(a_2+b_2)U^2+(a_1+b_1)U$$

yoki berilgan qiymatlarni qo'ysak:

$$0{,}005U^2+0{,}1U-1{,}5=0.$$

Bundan $U=10\ V$.

O'zaro parallel ulangan nochiziq elementlardagi kuchlanishning topilgan qiymatini ularning VAXlari tenglamalariga qo'yib, toklarni topamiz:

$$I_1=0{,}1\cdot 10+0{,}003\cdot 10^2=0{,}4\ A,$$

$$I_2=0{,}04\cdot 10+0{,}002\cdot 10^2=0{,}6\ A.$$

6.3-masala. Berilgan sxema uchun nochiziqli element va chiziqli qarshilikdagi kuchlanish pasayishlari va zanjirdan o'tayotgan tok topilsin. Quyidagilar berilgan: $U=230\ V$; $R_1=190\ Om$, NE VAXsi quyidagi rasmda keltirilgan.

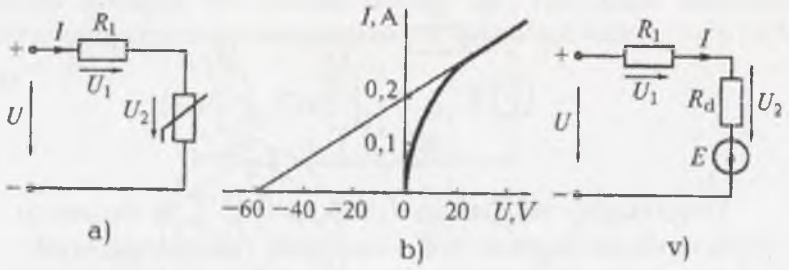
Yechish: NE VAX ishchi qismini to'g'ri chiziq bilan almashtiramiz. Natijada quyidagini hosil qilamiz:

$$U_2=E+IR_d$$

bu yerda, $E=-60\ V$; $R_d=\dfrac{\Delta U}{\Delta I}=\dfrac{60}{0{,}2}=300\ Om.$

Yuqoridagi almashtirish natijasida ko'rsatilgan chiziqli zanjirni hosil qilamiz. Kirxgofning 2 - qonuniga ko'ra

$$U=U_1+U_2=IR_1+E+IR_d=190I-60+300I=490I-60.$$

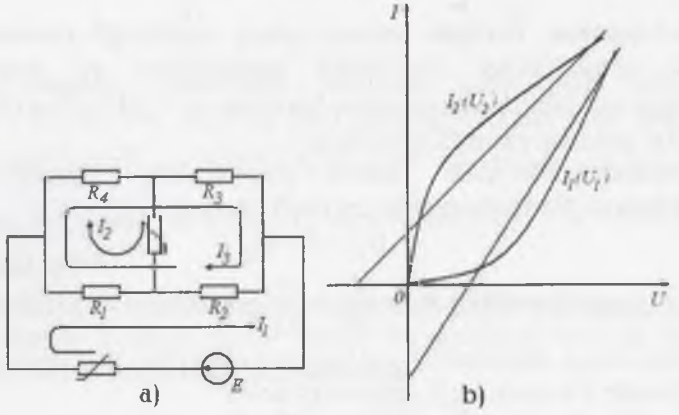


Bundan

$$I = \frac{U+60}{490} = \frac{230+60}{490} \approx 0{,}6;\ U_1 = IR_1 = 0{,}6 \cdot 190 = 110\ V;$$

$$U_2 = -60 + I \cdot 300 = -60 + 0{,}6 \cdot 300 = 120\ V.$$

6.4-masala. Berilgan sxemadagi ikkita nochiziq elementning VAXlari keltirilgan. Ulardagi tok masshtabi $m_I = 0{,}1\ A/mm$, kuchlanish masshtabi esa $m_U = 0{,}5\ \text{V}/mm$. Agar $E = 20\ V$, $R_1 = 4\ Om$, $R_2 = 1\ Om$, $R_3 = 3\ Om$, $R_4 = 2\ Om$ bo'lsa, nochiziq elementlardagi tok va kuchlanishlarni iteratsiya usuli yordamida aniqlang.



Yechish: Zanjirdagi kontur toklar shunday tanlanganki, nochiziq elementlardagi toklar bevosita kontur toklarga teng. Sxema uchun Kirxgoffning 2 - qonuni asosida tenglamalar sistemasini quyidagicha tuzamiz:

$$(R_1 + R_2)I_1 - R_1I_2 - (R_1 + R_2)I_3 = E - U_1,$$
$$-R_1I_1 + (R_1 + R_4)I_2 + (R_1 + R_4)I_3 = -U_2,$$
$$-(R_1 + R_2)I_1 + (R_1 + R_4)I_2 + (R_1 + R_2 + R_3 + R_4)I_3 = 0,$$

bu yerda I_1, I_2, I_3 - kontur toklar.

Oxirgi tenglamadan I_3 tokni topib, uni 1- va 2- tenglamalarga qo'yamiz va natijada quyidagi 2 ta tenglamani hosil qilamiz:

$$\frac{(R_1 + R_2)(R_3 + R_4)}{R_\Sigma} I_1 - \frac{R_1R_3 - R_2R_4}{R_\Sigma} I_2 = E - U,$$
$$-\frac{R_1R_3 - R_2R_4}{R_\Sigma} I_1 + \frac{(R_1 + R_4)(R_2 + R_3)}{R_\Sigma} I_2 = -U_2.$$

Chiziqli qarshiliklar va EYK qiymatlarini qo'yamiz:

$$2{,}5I_1 - I_2 = 20 - U_1, \; -I_1 + 2{,}4I_2 = -U_2.$$

Iteratsiya usuliga ko'ra yechimga birinchi yaqinlashishni topish uchun nochiziq elementlar VAXlarini chiziqli qarshiliklar va EYuK lar bilan almashtiramiz va grafiklardan $E_1 = 6\,V$ va $R_{d1} = 3\,Om$, $E_2 = 2{,}5\,V$, $R_{d2} = 4\,Om$ ekanligiga ishonch hosil qilamiz. Linearizatsiyalangan NElarda tok va kuchlanishlar quyidagi tenglamalar bilan bog'langan:

$$U_1 = 3I_1 + 6;$$
$$U_2 = 4I_2 - 2{,}5.$$

Bu ifodalarni Kirxgoffning 2 - qonuni asosida tuzilgan tenglamalarga qo'yib toklarning 1- taqribiy qiymatlarini topamiz:

$$I_1 = 2{,}7\,A, \; I_2 = 0{,}81\,A.$$

Toklarning topilgan qiymatlariga VAXlardan $U_1 = 60\,V$ va $U_2 = 0{,}8\,V$ kuchlanishlar mos keladi. Ularni yana tenglamalar sistemasiga qo'yib I_1 va I_2 toklarning yangi qiymatlarini topamiz va h.k. Ketma-ket yaqinlashish natijalari quyidagi jadval ko'rinishida berilgan:

Yaqinlashish tartibi	I_1	U_1	I_2	U_2
1	2,7	16	0,81	0,8
2	2,46	15,4	0,8	0,722
3	2,37	15,2	0,78	0,646
4	2,31	15	0,72	0,593
5	2,3	14,9	0,712	0,588

Jadvaldagi toklar va kuchlanishlar qiymatlaridan ko'rinib turibdiki, 4 – yaqinlashishdan keyin ularning qiymatlari qaytirila boshladi. Shunday qilib, berilgan zanjir nochiziq elementlaridagi tok va kuchlanishlar quyidagiga teng:

$$U_1 = 14{,}9\,V,\quad I_1 = 2{,}3\,A,$$
$$U_2 = 0{,}588\,V,\quad I_2 = 0{,}715\,A.$$

6.5-masala. Berilgan magnit zanjiri shoxobchalaridagi magnit oqimlarining qiymatlari aniqlansin. Quyidagilar berilgan:

$I_1 = 2$ A, $W_1 = 500$ o'ram, $l_1 = 30$ sm, $S_1 = 4$ mm^2,

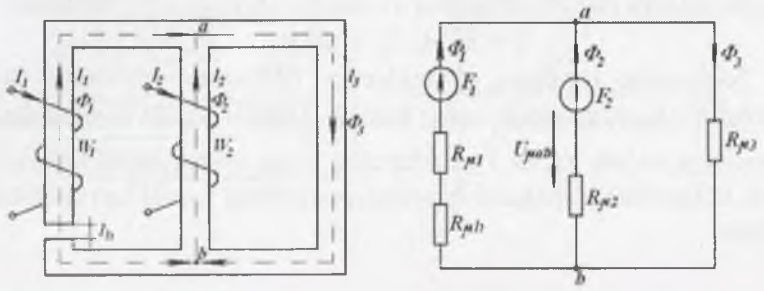
$I_2 = 5$ A, $W_2 = 150$ o'ram, $l_2 = 20$ sm, $S_2 = 6$ mm^2,

$l_3 = 30$ sm, $S_3 = 4$ mm^2, $l_h = 1$ mm.

Ferromagnit o'zakning magnit xossasi quyidagi jadval ko'rinishda berilgan magnitlanish egri chizig'i bilan ifodalanadi:

B, Tl	0	0,22	0,75	0,93	1,02	1,14	1,28	1,47	1,53	1,57
N, A/м	0	20	40	60	80	120	200	400	600	800

Berilgan zanjirni quyidagi ekvivalent sxema ko'rinishda tasvirlaymiz.



$U_{\mu ab}$ kuchlanishni o'zak qismlaridagi MYuK va magnit qarshiligi orqali aniqlaymiz:

$U_{\mu ab} = F_1 - H_1 l_1 - H_h l_h$ - o'zakning chap qismi uchun,

$U_{\mu ab} = F_2 - H_2 l_2$ - o'zakning o'rtadagi qismi uchun,

$U_{\mu ab} = H_3 l_3$ - o'zakning o'ng qismi uchun.

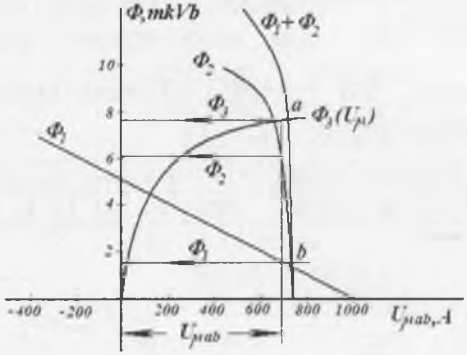
Har bir o'zak qismi uchun magnit induksiyasiga ixtiyoriy qiymatlar berib $\Phi = BS$ formula yordamida o'zak qismlaridagi magnit oqimlarini hisoblaymiz.

Magnitlanish egri chizig'idan zanjirning ferromagnit qismidagi kuchlanganliklarni aniqlaymiz. Havo oralig'idagi kuchlanganlikni $H_h = 8 \cdot 10^3$ V formula yordamida hisoblaymiz.

O'zakning har bir qismi uchun magnit kuchlanishlarni 2-bandda keltirilgan formulalardan foydalanib topamiz.

Hisoblash natijalarini jadval ko'rinishida yozamiz.

Bitta koordinatalar sistemasiga $\Phi_1 = f(U_{\mu ab})$, $\Phi_2 = f(U_{\mu ab})$, $\Phi_3 = f(U_{\mu ab})$ egri chiziqlar grafiklarini quramiz va Φ_1 va Φ_2 grafiklar ordinatalarini o'zaro qo'shish natijasida $\Phi_1 + \Phi_2 = f(U_{\mu ab})$ ni hosil qilamiz.



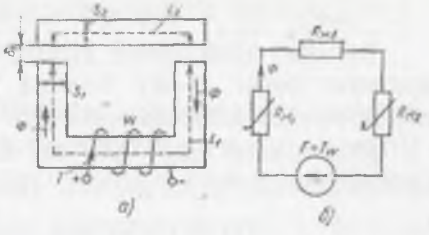
Magnit zanjir uchun Kirxgoffning 1-qonuni bajariladigan $\Phi_1 + \Phi_2 = \Phi_3$ a nuqtani topamiz va undan abssissa o'qiga ab perpendikular tushiramiz. Bu perpendikularning abssissa o'qi bilan kesishgan nuqtasi berilgan zanjir uchun $U_{\mu ab}$ kuchlanishning haqiqiy qiymatiga teng bo'ladi. To'g'ri chiziqning magnit oqimlari

grafiklari bilan kesishgan nuqtalari esa magnit oqimlarining haqiqiy qiymatlarini beradi:

$$\Phi_1 = 1{,}3 \text{ mkVb}, \Phi_2 = 6 \text{ mkVb}, \Phi_3 = 7{,}3 \text{ mkVb}.$$

Mustaqil yechish uchun masalalar

6.6-masala. Quyidagi uchta xarakterli uchastkadan iborat magnit zanjir berilgan. O`rtacha uzunligi $l_1 = 20$ sm bo`lgan po`lat o`zak, uzunligi $l_h = 2 \cdot \delta = 0{,}1\ sm$ bo`lgan havo oralig`i va uzunligi $l_2 = 6$ sm bo`lgan yakor.

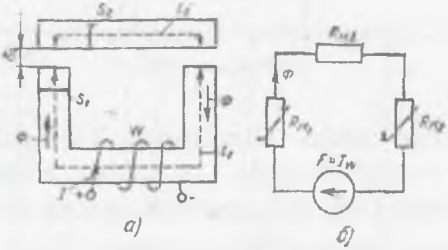


Po`lat o`zakning ko`ndalang kesim yuzasi $S_1$= 10 sm$^2$, yakorning kesim yuzasini $S_2$= 5 sm$^2$(havo oralig`ining kesim yuzasi S_h= S_1). Magnit o`tkazgichning materiali E41 markali po`lat va uning magnitlanish egri chizig`i (magnit induksiyaning magnit kuchlanganlikka bog`liqligi) quyidagi jadvalga berilgan. Magnit o`tkazgichdan o`tuvchi magnit oqimning qiymati $\Phi = 6 \cdot 10^{-4}$Vb bo`lsa $\omega = 200$ ta o`ramdan iborat induktiv chulg`amdan o`tuvchi tokning qiymatini aniqlash kerak.

Javob: I=239 A.

6.7-masala. E41 markali po`latdan tayyorlangan magnit zanjirdagi tokni aniqlang?

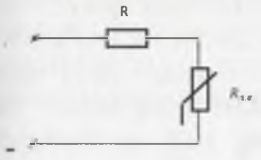
№	l_1, sm	l_2, sm	l_3, sm	δ, sm	ω	S_1, sm^2	S_2, sm^2	Φ, Vb
1	18	5	18	0,05	100	10	4	$6 \cdot 10^{-4}$



E41 markali po`latning magnitlanish egri chizig`i (magnit induksiyaning magnit kuchlanganlikka bog`liqligi) jadvali.

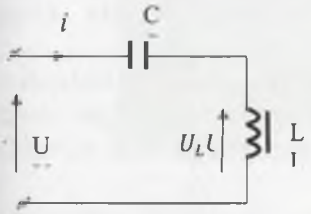
B,Tl	H, A/m	B,Tl	H, A/m	B,Tl	H, $10^2 A/m$	B,Tl	H, $10^3 A/m$
0,25	50	1,0	210	1,4	15	1,65	10
0,4	64	1,1	250	1,42	20	1,7	13
0,6	88	1,2	390	1,45	28	1,75	18
0,7	113	1.25	530	1,5	42	1,8	23
0,8	138	1,3	700	1,56	60	1,9	34
0,9	170	1,35	1000	1,6	78	2,0	70

6.8-masala. Volt-amper xarakteristikasi I_{ne}=0,06 U_{ne} + 0,001U_{ne}^2 aktiv qarshiligi R=20 Om bo`lgan ketma-ket zanjir o`zgarmas kuchlanish 120 V ga ulangan. Quyidagilar aniqlansin.1) zanjir uchastkalaridagi tok va kuchlanish. 2) zanjirdagi nochizig`iy elementning statikaviy va dinamikaviy qarshiliklari.



Javob: $U_{ne} = 40\ V, U_R = U_o - U_{ne}$= 80 V, I_{ne}= 4 A, R_{st}=10 Om, $R_{st}=\frac{500}{30+U_{ne}}$ Om.

6.9-masala. Ketma-ket ulangan C sig`im va L(i) nochiziqli induktivlikdan ω chastotali sinusoidal o`zgaruvchan tok o`tmoqda. Nochiqli induktivlikkda oqim tutashuvi va tok orasidagi bog`liqlik tenglamasi quyidagicha: $\psi = ai + bi^3$



Zanjirda kuchlanishlar rezonansi sodir bo`lganda birinchi garmonika bo`yicha tokning maksimal qiymati I_m aniqlansin.

Javob: I_m=9 A

7-BOB. TRANSFORMATORLAR

Transformatorning pasport parametrlari

Transformatorlar nominal kuchlanish va nominal tok bilan uzoq muddat ishlashga moslanib tayyorlanadi. Transformatorning pasportida ko'rsatilgan birlamchi chulg'am kuchlanishi uning birlamchi nominal kuchlanishi deyiladi. Salt ishlaganda va birlamchi kuchlanish nominal qiymatga teng bo'lgandagi ikkilamchi chulg'am kuchlanishi transformatorning ikkilamchi nominal kuchlanishi deyiladi. Transformatorning pasportida yozilgan quvvat uning nominal quvvati deyiladi. Transformatorning nominal quvvati va nominal kuchlanishi orqali aniqlanadigan birlamchi va ikkilamchi chulg'amlarning toklari uning nominal toklari deyiladi. Uzoq vaqt nominal tok bilan ishlaganda transformator chulg'amlari va chulg'amlar izolyatsiyasining temperaturasi yo'l qo'yiladigan qiymatdan oshmaydi.

Uch fazali transformatorlar amalda bir necha xil sharoitlarda, ya`ni turli rejimlarda ishlaydi.

1) salt ishlashi

2) normal sharoitda yuklama bilan ishlashi;

3) ishlab turgan transformatorning chulg'amlari qisqa tutashib qolganda yoki elektr tarmogi qisqa tutashganda, laboratoriya sharoitida qisqa tutashish tajribasi o'tkazilayotganda qisqa tutashish rejimida ishlashi mumkin.

Amalda kuch transformatorlari doimo yuklama bilan ishlaydi.

Har bir transformatorning baki devorida o'rnatilgan temir taxtachada uning texnik ko'rsatkichlari yozilgan bo'ladi va unda quyidagilar ko'rsatiladi:

1) transformatorning tipi, nomeri va ishlab chiqargan zavodning nomi va manzili;

2) nominal quvvati (kVA);

3) yuqori va past nominal kuchlanishi (V yoki kV);

4) yuqori va past kuchlanishli chulg'amlarining nominal toki (A);

5) o'zgaruvchan tok chastotasi;

6) fazalar soni;

7) yuqori va past chulg'amlarining ulanish sxemalari va guruhi;

8) qisqa tutashish kuchlanishi (U_k %);

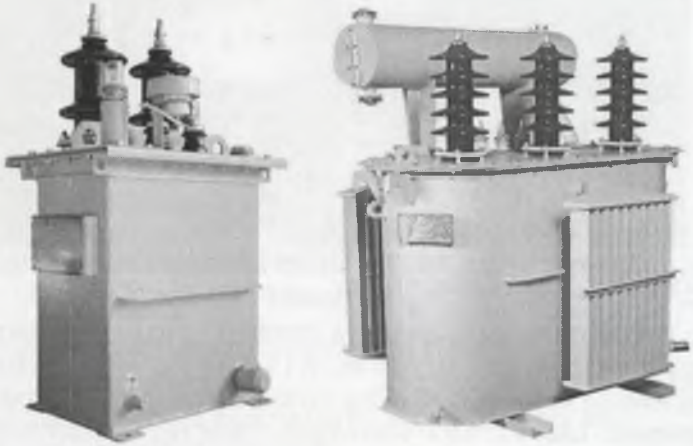
9) sovitilish usuli;

10) transformatorning massasi (kg yoki t);

11) moyning massasi (kg yoki t);

12) kuchlanishni o'zgartiruvchi ulagichning vaziyati va hokazo.

Transformatorlarning markasi tipi va raqamlar bilan ko'rsatiladi. Masalan: Т – uch fazali, О – bir fazali, М – moy bilan sovutiladigan, Д – moyni tashqaridan shamol bilan yoki majburiy xarakatlantirib sovutiladigan, Ц – moyni sovuq suvli sovitgichdan o'tkazib sovutiladigan; ДЦ – yuqoridagi ikkala usul bilan sovitiladigan, Г – yashinga chidamli, Н – kuchlanishi yuklamani uzmasdan rostlanadigan.



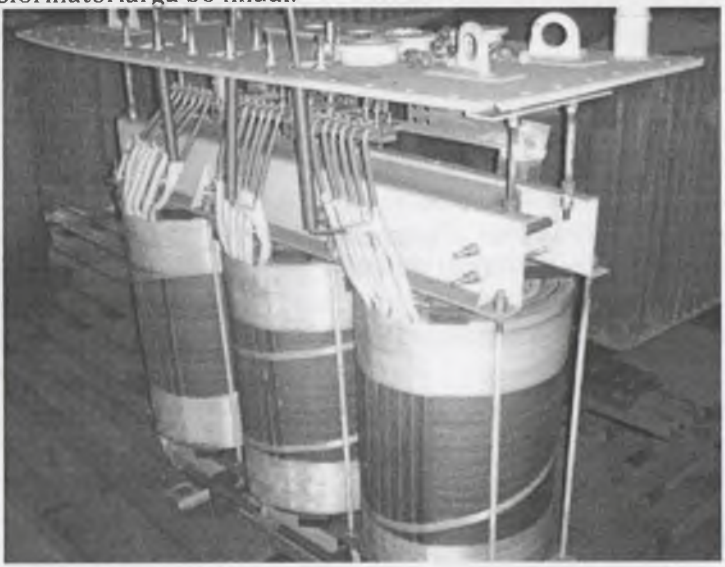
a) b)

7.1-rasm. Transformatorni umumiy ko'rinishi: a) bir fazali, b) uch fazali

O'zgaruvchan tok kuchlanishini bir qiymatidan chastotasini o'zgartirmasdan boshqa qiymatiga o'zgartiruvchi elektromagnit apparat transformator deyiladi. Transformatorlar kuchlanishni o'zgartirgich uchun ko'p sohalarda, har xil maqsadlarda foydalaniladi. Xususan, elektr energiyasining uzoq masofalarga uzatishda va iste`molchilarga taqsimlashda transformatorlarning

ahamiyati katta. Elektr tarmoqlarida istemolchilarni elektr energiyasi bilan ta`minlash uchun ishlatiladigan transformatorlar kuch transformatorlari deb ataladi.

Kuch transformatorlari asosan bir fazali yoki uch fazali kuch transformatorlarga bo'linadi.



7.2 -rasm. Uch fazali transformatorni aktiv qismining ko'rinishi

Transformatorning energiya manbaiga yoki elektr tarmogiga ulanadigan chulg'ami *birlamchi chulg'am* deyiladi. Bu chulg'amning bosh qismasi A harfi bilan, oxirgi qismasi *x* harfi bilan belgilanadi. Iste`molchiga ulanadigan chulg'am transformatorning *ikkilamchi chulg'ami* deyiladi. Ikkilamchi chulg'amning bosh qismasi *a* harfi bilan, ozirgi qismasi *x* xarfi bilan belgilanadi. Transformatorlar kuchlanishni pasaytirishga yoki oshirishga mo'ljallab tayyorlanadi. Ikkilamchi chulg'amdan olinadigan kuchlanish uning birlamchi chulg'amiga berilayotgan kuchlanishdan kichik bo'lsa, kuchlanishni *pasaytiruvchi* transformator va aksincha, ikkilamchi chulg'amning kuchlanishi birlamchi chulg'amga berilayotgan kuchlanishdan katta bo'lsa, kuchlanishni *oshiruvchi* transformator deyiladi.

Transformatorning chulg'amlari ikkita bo'lsa, ikki chulg'amli, uchta va undan ortiq bo'lsa, uch chulg'amli va mos holda ko'p chulg'amli transformator deyiladi. Uch fazali transformatorlar ham ikki yoki uch chulg'amli bo'lishi mumkin.

Transformatorni ekspluatatsiyalash rejimlari

Transformatorning to'la quvvati qo'yidagicha topiladi

$$S = m \cdot U \cdot I, \tag{7.1}$$

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

To'la quvvatning reaktiv tashkil etuvchisi

$$Q = m \cdot U \cdot I \cdot \sin\varphi, \tag{7.2}$$

bu yerda: φ-tok va kuchlanish orasidagi burchak.

To'la quvvatning aktiv tashkil etuvchisi

$$P = m \cdot U \cdot I \cdot \cos\varphi. \tag{7.3}$$

Ma`lumki magnit oqimi F birlamchi va ikkilamchi chulg'amlarda EYK E_1 va E_2 larni hosil qiladi:

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

$$E_2 = 4{,}44 \cdot f \cdot \omega_2 \cdot \Phi, \tag{7.4}$$

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

Transformatorning transformatsiyalash koeffisienti

$$k_{\ddot{u}} = \frac{E_1}{E_2} = \frac{\omega_1}{\omega_2} = \frac{U_1}{U_2} = \frac{I_1}{I_2}. \tag{7.5}$$

Birlamchi va ikkilamchi chulg'amdagi MYuK lar

$$F_2 = I_1\omega_1; \quad F_2 = I_2\omega_2 \tag{7.6}$$

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

Keltirilgan tok

$$I' = I_2 / k_T \tag{7.7}$$

Keltirilgan kuchlanish

$$U'_2 = k_T \cdot U_2 \tag{7.8}$$

Keltirilgan aktiv va induktiv qarshiliklar

$$R'_2 = k^2_T \cdot R_2; \quad x'_2 = k^2_T \cdot x_2 \tag{7.9}$$

Transformatorning FIK va quvvat isroflari

Transformatorlarda asosin chulg'amlardagi quvvat isrofi P va pulatdagi isrof P_t lar bo'ladi.

Po'latdagi isrof

$$P_n \approx k_{ir} P_{1.0} (B_m)^2 m_n, \qquad (7.10)$$

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 boo'lgan doimiy. Bu doimiyning o'rtacha qiymati $k_{ir} = 1{,}2$ ga teng.

Chulg`amlardagi elektr isroflar

$$P_{..} = m_1 I^2_{1\delta} R_1 + m_2 I^2_{2\delta} R_2, \qquad (7.11)$$

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

$$\eta = \frac{P_2}{P_2 + P_n + P_r} \cdot 100 = \frac{P_1 - P_n - P_r}{P_1} \cdot 100, \qquad (7.12)$$

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

$$\eta = \frac{S_2 \cos\varphi_2}{S_2 \cos\varphi_2 + P_n + P_r} \cdot 100 \qquad (7.13)$$

Yuqoridagi tenglamaning surati va maxrajini $S_2 \cos\varphi_2$ ga bo'lib, hamda $P_{..} = P_{..t}(\frac{S_2}{S_{jh}}) = P_{..t} x^2$ ni kiritib

$$\eta = \frac{1}{1 + \frac{P_n + P_{..}}{S_2 \cos\varphi_2}} \cdot 100 = \frac{1}{1 + \frac{P_n + x^2 P_{..t}}{S_2 \cos\varphi_2}} \cdot 100 \qquad (7.14)$$

Masala yechish namunalari

7.1-masala. TM-100/6.3 uch fazali tarnsformatorning nominal toklari va faza kuchlanishlarini hisoblang?

S, kVA	YuK, kV	PK, kV	P_o, kW	P_k, kW	u_k, %	i_o, %	Ulanish usuli
100	6.3	0.4	0.310	1.97	4.5	2.6	Y/Y-0

Yechish: Transformatorning asosiy elektr kattaliklarini hisoblash.

$$S^{\text{ф}} = \frac{S}{m} = \frac{100}{3} = 33.33\ kVA,$$

bu yerda, m-fazalar soni va u m=3 ga teng.

Transformatorni nominal toklari:

yuqori kuchlanish tomonida

$$I_1 = \frac{S}{\sqrt{3}\cdot U_{YuK}} = \frac{100}{1.73\cdot 6.3} = 9.2\ A,$$

past kuchlanish tomonida

$$I_2 = \frac{S}{\sqrt{3}\cdot U_{PK}} = \frac{100}{1.73\cdot 0.4} = 145\ A,$$

Faza kuchlanishlar:

yuqori kuchlanish tomonida

$$U_{f1} = \frac{U_{YuK}}{\sqrt{3}} = \frac{6.3}{1.73} = 3.64\ kV,$$

past kuchlanish tomonida

$$U_{f2} = \frac{U_{PK}}{\sqrt{3}} = \frac{400}{1.73} = 231\ V,$$

faza toklari chulg'amlar yulduzcha ulanganda

$$I_f = I_{nom}.$$

7.2-masala. 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 $U_c = 4{,}26$ V, chastota f =50 Gs bo'lsa, transformatorning ikkala chulg'amlarining o'ramlari soni ω_1 va ω_2 lar aniqlansin; tok zichligi $j = 3{,}2\ A/mm^2$ bo'lganda chulg'am simlarining kesim yuzalari A_1 va A_2 lar aniqlansin, induksiya $B_0 = 1{,}4$ Tl bo'lgan magnit o'tkazgichning kundalang 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

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

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

Magnit oqim

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

7.3-masala. 7.2-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 $P_{}$, salt ishlashdagi quvvat isrofi $\cos\varphi_0$, qisqa tutashuvdagi quvvat koeffisienti $\cos\varphi_{KT}$ va qisqa tutashuv kuchlanishining foizdagi qiymati topilsin.

Yechish: Po'latdagi isrof

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

Chulg'amdagi quvvat isrofi

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

Quvvat koeffisientlari

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

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

Nominal tokdagi qisqa tutashuv kuchlanishi

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

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

bu yerda: $U_1 = 5000$ V.

7.4-masala. 7.2.- masalada keltirilgan transformatorning past kuchlanish chulg'ami to'la qarshilik $z_{yuk} = 1{,}2 + j1{,}5$ Om yuklama bilan yuklangan.

a) Transformatorning FIK o'sha yuklama uchun aniqlansin.

b) Qarshilik $R_{yuk} = 1{,}2$ Om transformatorni naminal tok bilan yuklagan vaqtdagi induktiv qarshilik $x_{yuk1min}$ va quvvat koeffisienti $\cos\varphi_{max}$ topilsin.

v) Punkitdagi asosan FIK η , aniqlansin.

g) Ikkala yuklama uchun transformatorning ikkilamchi chulg'amidagi kuchlanish topilsin.

Yechish: a) Berilgan yuklama uchun transformatorning toki:

$$I_{yuk} = \frac{U_2}{z_{yuk}} = \frac{400}{1{,}2 + j1{,}5} = 130 - j162{,}6\ A$$

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

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

Istemol qilinayotgan va chulg'amlardagi quvvat isrofi

$$P_2 = I^2{}_{yuk} R_{yuk} = 208^2 \cdot 1{,}2 = 51920W = 51{,}92kW.$$

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

bu yerda: $P_{yH} = 2956W; I_{2H} = 250A$ (7.2 va 7.3- 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

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

$$x_{yuk.nom} = \sqrt{z^{*2}_{yuk} - R^{*2}_{yuk}} = \sqrt{2,56 - 1,44} = 1,061 \text{ Om}$$

Nominal tokdagi quvvat koeffisienti

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

v) Nominal tokdagi FIK

$$\eta_1 = \frac{P^{*}_2}{P^{*}_2 + P_{po} + P_{mis}} \cdot 100 = 94,5\%,$$

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

g) Ikkilamchi chulg'amdagi kuchlanishni xisoblashda ulchovchi shaxobchalarni xisobga olmaymiz

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

Elektr zanjirning qisqa tutashuv rejimdagi to'la qarshiligi

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

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

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

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

$$U_{21} = \frac{U_{KT1}}{n} = \frac{4704}{12,5} = 376,3V;$$

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

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

7.5-masala. 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 $P_{mis} = 0,048 \cdot S_1$, po'latdagi quvvat isrofi $P_{po} = 0,036 \cdot S_1$. Transformatorning magnit o'tkazgichi qalinligi 0,5 mm bo'lgan plastinkalardan yig'ilib, solishtirma quvvat isrofi $P_{1,0} = 2,3$ W/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 koeffisienti $\kappa_3 = 0,94$ va past kuchlanish chulg'amining o'ramlar soni $\omega_2 = 31$ bo'lsa, sterjenning ko'ndalang kesim yuzasi;

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

g) Qisqa tutashuv quvvat koeffisienti $\cos\varphi_{KT}$, aktiv R va induktiv x qarshiliklar;

d) Qisqa tutashuv rejimida 75% nominal tok bilan yuklangan vaqtdagi sig'im xarakteriga ega bo'lgan to'la qarshilik z_{yuk} va uning siljish burchagi φ_{yuk} 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

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

Po'latdagi to'la isrof

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

$$T_t = \frac{P_t}{P} = \frac{576}{5,037} = 114 \text{ kg.}$$

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

$$U_y = \frac{U_2}{\omega_2} = \frac{110}{31} = 3,548\text{V}$$

$$U_y = 4,44\phi f,$$

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

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

$$A_{on} = \frac{A_n}{K_3} = \frac{107}{0,94} = 113,8sm^2$$

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

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

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

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

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

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

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

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

g) Qisqa tutashuv rejimidagi elektr zanjirining to'la qarshiligi

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

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

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

d) Ikkilamchi chulg'amdagi kuchlanish

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

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

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

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

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

To'la yuklama qarshilik moduli

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

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

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

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

7.6-masala. Ulanish sxemasi va guruhi $\Delta/Y - 11$ bo'lgan uch fazali transformatorning nominal quvvati $S_i = 40$ kW, nominal kuchlanishi $U_1/U_2 = 10/0{,}4$ kV, salt ishlash toki $I_0 = 0{,}04 \cdot I_1$ 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 koeffisientlari, yani $\cos\varphi_0$ va $\cos\varphi_{KT}$;

b) Chulg'amning aktev R va induktiv x qarshiliklari;

v) agarda po'lat sterjenning kesim yuzasi $A_n = 654 sm^2$ bo'lsa, bitta o'ramdagi kuchlanish U_e;

g) chulg'amdagi o'ramlar soni ω_1 va ω_2;

d) agarda o'ramnmng o'rtacha uzunligi $l_1 = 0{,}576$ m, o'tkazgichning (simning) kesim yuzasi $A_1 = 0{,}503 mm^2$, solishtirma qarshilik $\rho = 0{,}024$ mkOmm bo'lsa, birlamchi chulg'amning aktiv qarshiligi R_1;

e) transformatorning ikkala chulg'amlarining tok zichliklari bir xil bo'lsa, ikkilamchi chulg'amning simini kesim yuzasi A_2 aniqlansin.

Yechish: Nominal toklar

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

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

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

Quvvat koeffisientlari

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

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

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

b) aktiv qarshilikni qisqa tutashuv quvvat isrofi orqali hisoblash mumkin

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

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

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

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

v,g) o'ramdagi kuchlanish va chulg'amlardagi o'ramlar soni

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

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

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

d) birlamchi chulg'am fazasining aktiv qarshiligi

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

e) simning ko'ndalang kesim yuzasi va past kuchlanish chulg'amining aktiv qarshiligi

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

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

$$R'_2 = n^2 R_2, bunda$$

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

7.7-masala. Uch fazali transformatorning nominal quvvati ulanishi va guruhi $\Delta / Y - 5$; qisqa tutashuv kuchlanishning qiymati U_{K7} 4,8%, aktiv tashkil etuvchisi $U_a = 1{,}8\%$. Transformatorning ikkilamchi chulg'ami quvvat koeffisienti $\cos\varphi = 0{,}9$ 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;

v) nominal toklar I_{1H}, I_{2H} va tansformatsiyalash koeffisienti;

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

d) qisqa tutashuv rejimida chulg'amlardagi nominal quvvat isrofi P_r va quvvat koeffisienti $\cos\varphi_{KT}$.

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

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

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

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

v) nominal toklar va transformatsiyalash koeffisienti

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

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

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

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

g) qisqa tutashuv kuchlanishining aktiv tashkel etuvchisi U_a orqali yig'indi aktiv qarshilikni topamiz

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

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

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

yuklama uchun chulg'amdagi quvvat isrofi va FIK.

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

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

$R_1 = R'_2$, bo'lgani uchun

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

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

d) nominal yuklama uchun chulg'amdagi quvvat isrofi va qisqa tutashuv rejimidagi quvvat koeffisienti $\cos\varphi_{KT}$

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

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

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

bu yerda:

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

7.8-masala. Uch fazali transformatorning to'la quvvati $S_t = 63$ kW, kuchlanishlari $U_1/U_2 = 21/0{,}4$ kV; salt ishlash toki $I_0 = 0{,}035 \cdot I_t$, salt ishlash quvvat isrofi $P_0 = 0{,}29$ kW, qisqa tutashuv rejimidagi isrof $P_{r.t} = 1{,}65$ kW, qisqa tutashuv kuchlanishi U_{KT} 4,5%, ulanish va guruhi $Y/Z-11$.

Quyidagilar topilsin.

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

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

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

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

d) $\cos\varphi = 1$ 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 koeffisientlari

$$I_{1H} = \frac{S_H}{\sqrt{3}U_1} = \frac{63\cdot10^3}{\sqrt{3}\cdot21\cdot10^3} = 1,734A;$$

$$I_{2H} = \frac{U_1}{U_2}\cdot I_{1H} = \frac{21\cdot10^3}{400}\cdot1,734 = 91,03A;$$

$$\cos\varphi_0 = \frac{P_0}{\sqrt{3}I_0U_0} = \frac{290}{\sqrt{3}\cdot0,035\cdot1,734\cdot21\cdot10^3} = 0,1315;$$

$$\cos\varphi_{KT} = \frac{P_{r.i}}{\sqrt{3}U_{KT}I_{1H}} = \frac{P_{r.i}}{\sqrt{3}\frac{U_{KT}U_1}{100}I_{1H}} = \frac{1650}{\sqrt{3}\frac{4,5\cdot21\cdot10^3}{100}\cdot1,734} = 0,592.$$

b) yig'indi aktiv va induktiv qarshiliklar

$$P_{r.i} = 3I^2_{r.i}R, \text{ bundan}$$

$$R = \frac{P_{r.i}}{I^2_{r.i}} = \frac{1650}{3\cdot1,734^2} = 183 \text{ Om.}$$

$$x = \frac{U_{2ph}}{I_{1H}} = \frac{U_pU_{1H}}{\sqrt{3}\cdot100I_{1H}} = \frac{\sqrt{U^2_k - U^2_a}\cdot U_{1H}}{\sqrt{3}\cdot100I_{1H}} = \frac{\sqrt{4,5^2-2,54^2}\cdot21\cdot10^3}{\sqrt{3}\cdot100\cdot1,734} = 260 \text{ Om}$$

v) nominal yuklamadagi FIK

$$\eta_1 = \frac{S_H\cos\varphi}{S_H\cos\varphi + P_0 + P_{KT}}\cdot100 = \frac{63\cdot1}{63\cdot1+0,29+1,65}\cdot100 = 97,01\%$$

$$\eta_{0,8} = \frac{63\cdot0,8}{63\cdot0,8+0,29+1,65}\cdot100 = 96,29\%$$

g) tok maksimum η uchun tok

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

$$I_1 = \sqrt{\frac{P_0}{3R}} = \sqrt{\frac{290}{3\cdot183}} = 0,727A$$

$$I_2 = nI_1 = \frac{21}{0,4}\cdot0,727 = 38,17A$$

$$P = \sqrt{3}U_2I_2\cos\varphi = \sqrt{3}\cdot400\cdot38,17 = 21,1 \text{ kW.}$$

d) nominal yuklama uchun ikkilamchi chulg'amdagi kuchlanish

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

$$U'_{2(1)} = \frac{21\cdot10^3}{\sqrt{3}} - 1,734\cdot183 = 11,82\cdot10^3 \text{ V}$$

$$U_{2(1)} = \frac{\sqrt{3}U'_{2(1)}}{U_1/U_2} = \frac{\sqrt{3}\cdot11,82\cdot10^3}{21/0,4} = 389,5 \text{ V}$$

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

$$U'_{2(0,8)} = \frac{21\cdot10^3}{\sqrt{3}} - 1,734\cdot(183\cdot0,8+260\cdot0,6) = 11,63\cdot10^3 \text{ V}$$

$$U_{2(0,8)} = \frac{\sqrt{3}U'_{2(0,8)}}{U_1/U_2} = \frac{\sqrt{3}\cdot11,63\cdot10^3}{21/0,4} = 383,2 \text{ V}$$

Mustaqil yechish uchun masalalar

7.9-masala. Chulg'amlarning ulanish sxemasi Y/Y bo'lgan uch fazali transformator birlamchi chulg'amining liniya kuchlanishi $U_{2e} = 220$ V, transformator chulg'amlarining ulanish sxemalari Δ/Δ, Y/Δ va Δ/Y bo'lganda, ikkilamchi chulg'amning liniya kuchlanishlari aniqlansin.

Javob: Hamma holda 380/220 V bo'ladi.

7.10-masala. 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.

Javob: $\omega_2 = 30$; $\omega_3 = 600$

7.11-masala. 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 $P = 5,1$ kW bo'lsa, birinchi transformatorning kirish tomonidagi aktiv quvvat aniqlansin.

Javob: $P_1 = 10$ kVt.

7.12-masala. 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 $l_{y1} 0,734m$, $A_2 = 404,5mm^2$, nominal quvvat $S_H = 630$ kVa; salt ishlash toki $I_0 = 0,021I_H$; salt ishlash quvvat

isrofi $P_0 = 1{,}49$ kW; qisqa tutashuv quvvat isrofi $P_{KT} = 9{,}25$ kW; 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;

v) birlamchi va ikkilamchi chulg'amlarning naminal toklari I_{1i}, I_{2i};

g) magnit oqimining maksimal qiymati;

d) qisqa tutashuv va salt ishlash rejimlaridagi quvvat koeffisientlari $\cos\varphi_0, \cos\varphi_{Ki}$;

e) barcha induktiv sochilma qarshiliklar x_s.

Javob: a) $R_1 = 15{,}75$ Om, $R_2 = 0{,}0015$ Om, b) $P_1 = 1488$ W; v) $I_{1H} = 17{,}34$ A, $I_{2H} = 910$ A; g) $\hat{o} = 4{,}33 \cdot 10^{-2}$ Vb; d) $\cos\varphi_0 = 0{,}1126$, $\cos\varphi_{KT} = 0{,}3263$; e) $x_s = 89{,}4$ Om.

7.13-masala. Kuchlanishlar $U_1/U_2 = 550/380$ V bo'lgan uchta parallel transformatordan bir fazali istmolchi kuchlanish olmoqda. Transformatorning quyidagi parametlari berilgan:
$S_{H1} = 15k$VA; $S_{HII} = 20k$VA; $S_{HIII} = 18k$VA; $U_{K1} = 4{,}2\%$; $U_{KH} = 4{,}8\%$; $U_{KIII} = 5{,}2\%$.
Yuklamaning parametrlari:

$$U_{yuk} = U_2 = 380V; P_{yuk} = 50kW;\ \cos\varphi_{yuk} = 0{,}8 \text{ (ind.)}$$

Quyidagilar aniqlansin

a) har bir transformatorning nominal toklari

b) yuklama toki

v) berilgan yuklama uchun hamma transformatorning toklari

g) transformatorlarning yuklanish koeffisientlari

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

d) $U_{KT1} = U_{KT11} = U_{KT111} = 6\%$ bo'lsa transformatorning yuklanish koeffisientlari $\frac{I'_1}{I_{21H}} \cdot 100$; $\frac{I'_{11}}{I_{211H}} \cdot 100$; $\frac{I'_{111}}{I_{211H}} \cdot 100$.

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

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

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

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

7.14-masala. Chulg'amlari $Y/Y-0$ ulangan transformatorning nominal quvvati $S_H = 63$ kW, 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 $P_{r.i}$.

b) aktiv R vainduktiv x qarshiliklar;

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

Javob: a) $I_{1H} = 6{,}621A$; $I_{2H} = 91{,}04A$; $P_{r.i} = 1500$ W.

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

7.15-masala. Chulg'amlari $\Delta/Y-11$ ulangan transformatorning nominal quvvati $S_t = 250$ kW, kuchlanish $U_1/U_2 = 21/0{,}4$ kV. Nominal yuklamada chulg'amdagi isrof $P_{r.i} = 4{,}6$ kW, po'latdagi isrof $P_n = 0{,}75$ kVt. Bir yillik uzatiladigan elektr energiyasi $W_{ekv} = 185000$ kWs. Eng katta quvvat $P_{max} = 120$ kW, $\cos\varphi = 0{,}68$ (aktiv-induktiv yuklama).

Quyidagilar topilsin:

a) transformatorning yillik FIK η_y;

b) agarda elektr energiyasi narxi $e = 0{,}2$ so'm/(kWs) bo'lsa transformatordagi isroflarga ketgan yillik xarajatlar k;

v) $U_{KT} = 4{,}5\%$ bo'lsa, maksimal yuklama uchun U_2.

Javob: a) $\eta_e = 95{,}63\%$; b) $\kappa = 43$ so'm; v) $U_2 = 338$ V.

7.16-masala. Chulg'amlari $Y/Z-11$ ulangan transformatorning nominal quvvati $S_t = 160$ kW, kuchlanishlari $U_1/U_2 = 35000/400$ V, bitta o'ramdagi kuchlanishi $U_v = 8{,}75$ V.

Quyidagilar aniqlansin:

a) nominal toklar I_{1f}, I_{2f};

b) ikkala chulg'amdagi o'ramlar soni ω_1, $\omega_2 = 2\omega_2$;

v) $U_{KT} = 6\%$, $U_{KTa} = 2{,}4\%$ bo'lsa, aktiv R, induktiv x va to'la qisqa tutashuv qarshiliklari;

g) nomial yuklamada chulg'amdagi isrof $P_{r.i}$ va qisqa tutashuv xolatidagi quvvat koeffisienti $\cos\varphi_{KT}$;

d) $R_1 = R_2$ shart uchun ikkilamchi chulg'amning aktiv qarshiligi R_2;

e) agarda $\rho_{75} = 0{,}216$ mkOmm va tok zichligi $j = 3{,}8$ A/mm^2 bo'lsa, chulg'am simlarining uzunligi l_1, l_2;

j) induksiyaning maksimal qiymati 1,62 Tl bo'lsa, magnit o'tkazgichning (po'latning) ko'ndalang kesim yuzasi A_n.

Javob: 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) $P_{r.i} = 3850$ 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.)

7.17-masala. Chulg'amlari $Y/Z-11$ ulangan, kuchlanishlari $U_1/U_2 = 21000/400$ V, o'ramdagi kuchlanish $U_y = 7{,}48$ V, nominal quvvati $S_1 = 160$ 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;

v) asosiy magnit oqimiga mos keluvchi induktiv qarshilik x_μ va po'latdagi isroflarga mos keluvchi aktev qarshilik R_n;

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

d) sterjen atrofida chizilgan aylananing diametri D_0 (kesim yuzasi to`ldirish koeffisienti $\kappa_{\partial\partial E} = 0{,}86$).

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

8-BOB. O'ZGARMAS TOK ELEKTR MASHINALARI

EYK, 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 qo'yidagicha bo'ladi:

$$E = U + I_{ya} R_{ya} \qquad (8.1)$$

Bu yerda: U- yakordagi kuchlanish; R- yakordagi EYK; I_{ya} - yakor toki; R_{ya} - yakor chulg'amining aktiv qarshiligi.

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

$$U = E + I_{ya} R_{ya} \qquad (8.2)$$

Yakor chulg'amidagi moment quyidagicha topiladi:

$$M = C_M \Phi I_{ya} \qquad (8.3)$$

Bu yerda: C_M – moment doimiysi; $C_M = C_e / 2\pi$, Φ- magnit oqim.

Yakor chulg'amidagi EYK quyidagiga teng:

$$E = zn\Phi n / a = C_n n \Phi \qquad (8.4)$$

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:

$$n = U \cdot 60 / C_e \Phi - I_{ya} \cdot R \cdot 60 / C_e \Phi = U \cdot 60 / C_e \Phi - R \cdot M \cdot 60 / C_e \cdot K_M \cdot \Phi^2 \qquad (8.5)$$

O'zgarmas tok mashinalarida quvvat isroflari va FIK

O'zgarmas tok mashinalarida quyidagi quvvat isroflari mavjud:

Po'latdagi isrof

$$P = \kappa \cdot \left[P_{1.or} \cdot f \cdot B^2 / 50 + P_{1/oy} \cdot (f \cdot B / 50)^2 \right] \cdot m_n \qquad (8.6)$$

Bu yerda: κ - o'zakdagi isrof koeffisienti($\kappa \approx 2 \div 2{,}5$); $P_{1or}, P_{1/oy}$ plastinkalardan yig'ilgan o'zak uchun xarakterli bo'lgan uyurma toklar hosil qilgan solishtirma isrof va gisterezis solishtirma

isrofi (bunda f =50 Gs va B = 1 Tl); B - induksiyaning maksimum qiymati; $m_{po'}$ - po'lat massasi:

Cho'tkalardagi isrof

$$P_{ч} = 9{,}81\vartheta_{к} A_{к} p\mu \qquad (8.7)$$

Bu yerda: $\vartheta_{к}$ - kollektorning aylanma tezligi; $A_{к}$ - cho'tkalarning kollektorga tegib turgan yuzasi; p - prujinalarning bosimi; μ - titrash koeffisienti.

Cho'tka kontaktlaridagi isrof

$$P_{к} = \Delta U_{k} I_{ya} \qquad (8.8)$$

Bu yerda: $\Delta U_{к}$ - cho'tkalardagi kuchlanish pasayishi (elektrografit cho'tkalar uchun 2 V.).

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

Yakor cho'lg'amidagi isrof

$$P_{я} = I_{я}^{2} R_{я} \qquad (8.9)$$

Qo`shimcha isroflar

$$P_{y.ш} = (0{,}005 \div 0{,}01) P_{н} \qquad (8.10)$$

Bu yerda: $P_{н}$ - mashinaning nominal quvvati.

Qo'zg'atish chulg'amidagi isrof

$$P_{к} = U_{к} I_{к} = U_{к} I / R_{к}, \qquad (8.11)$$

Yig'indi quvvat isrofi

$$\Sigma P = P_{ч} + P_{к} + P_{мех} + P_{я.ч} + P_{y.ш} + P_{г} \qquad (8.12)$$

Mashinaning FIK

$$\eta = P_{н} / (P_{н} + \Sigma P) \qquad (8.13)$$

Masala yechish namunalari

8.1-masala. Chiqish klemmalarida U=220V bo'lgan parallel qo'zg'atishli o'zgarmas tok generatori nominal yuklama $P_{н}$=120 kW va n=1440 ayl/min tezlik bilan ishlamoqda. Agarda generatorni motor rejimida P=60 kW yuklama bilan ishlatilsa, motorning aylanish chastotasini toping. Yakor chulg'amining ichki qarshiligi $R_{я}$=38 Om, cho'tkalardagi kuchlanish pasayishi $\Delta U_{к}$ =2 V.

Yechish:

Generator rejimidagi EYK $E = U + I_{нок} R_{я} + \Delta U_{к}$

Bu yerda

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

EYK ni topamiz:

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

Bu yerda

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

Motor rejimida EYK quyidagicha topiladi:

$E = U - I_г R_г - \Delta U_ж$

bunda

$I_г = I_{юк} - I = P / U - U / R_г = 60 \cdot 10^3 / 220 - 220 / 38 = 267$ 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.

8.2-masala. Mustaqil qo'zg'atishli generatorning texnik malumotlari quyidagicha: nominal quvvati $P_к = 16$ kW, 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 tashkel etadi. Generatorning EYK, FIK aniqlansin.

Yechish:

Generatorning EYK

$$E = U + I_я R_я$$

Mustaqil qo`zg'atishli generatorda

$$I_я = I_к$$

Generatorning nominal toki

$$I_i = P_i / U_i = 16 \cdot 10^3 / 230 = 69{,}57 \text{ A},$$

u holda

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

Generatorning nominal rejimdagi FIK

$$\eta = \frac{P_i}{P + \sum P}.$$

Qo'zg'atish chulg'amidagi quvvat isrofi

$$P_к = \frac{U^2{}_к}{R_к} = \frac{110^2}{18} = 672 \text{ W} = 0{,}672 \text{ kW}$$

Yakor chulg'amidagi quvvat isrofi

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

Shart bo'yicha

$$P_{mex} + P_{maz} = 0.045 P_н = 0.045 \cdot 16 \cdot 10^3 = 720 \text{W} = 0{,}72 \text{ kW}$$

FIK

$$\eta = \frac{P_н}{P_н + P_к + R_я + P_{mex} + P_{maz}} = \frac{16}{16 + 0{,}672 + 0{,}581 + 0{,}72} = 0{,}89$$

8.3-masala. To'lqinsimon chulg'amli o'zgarmas tok mashinasining quyidagi parametlari berilgan: yakor pazlari soni z=25; juft qutblar soni p=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

$$P_{э.м} = EI_я$$

EYK

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

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.

EYKni aniqlaymiz

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

Elektromagnit quvvat

$$P_{эй} = EI_y = 195 \cdot 27 = 5265 \text{ W}$$

8.4-masala. 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 $R_я = 0{,}19$ Om. Yuklama 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 EYK

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

Salt ishlaganda EYK

$$E_0 = Cn_0\Phi.$$

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

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

8.5-masala. Uchlarida kuchlanishi $U = 110$ V bo'lgan mustaqil qo'zg'atishli o'zgarmas tok generatorining yuklamasi 3 kW dan 1,5 kW gacha kamaysa, magnit oqimini necha foizga kamaytirish kerak. Bunda kuchlanish o'zgarmas, ya`ni $U = 110V = const$ bo'lsin. Cho'tkalardagi kuchlanish pasayishi $\Delta U_k = 2$ V, quvvat isroflari hisobga olinmasin, yakor reaksiyasi ta`siri va yakor chulg'amidagi quvvat isrofi hisobga olinsin. Yakor chulg'ami qarshiligi $R_a = 0{,}5$ Om.

Yechish: Yuklamaning ikki qiymati uchun kuchlanishlar muvozanat tenglamasi

$$U = E_1 - I_{y1}R_y - \Delta U_c;$$

$$U = E_2 - I_{y2}R_y - \Delta U_c;$$

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

$$I_{y1} = \frac{P_1}{U} = \frac{3000}{110} = 27{,}3 \text{ A};$$

$$I_{y2} = \frac{P_2}{U} = \frac{1500}{110} = 13{,}65 \text{ A}.$$

Quyidagi nisbatni yozish mumkin.

$$\frac{E_2}{E_1}=\frac{\kappa\Phi_2}{\kappa\Phi_1}=\frac{U+I_{a2}R_a+\Delta U_k}{U+I_{a1}R_a+\Delta U_k}-1=\frac{110=13{,}65\cdot 0{,}5+2}{110+27{,}3\cdot 0{,}5+2}-1=0{,}055.$$

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

8.6-masala. Parallel qo'zg'atishli generatorning nominal kuchlanishi $U_n=230$ V, yuklama toki $I=160$ A. Yakor chulg'amining qarshiligi $R_a=0{,}11$ Om.

Yakor chulg'amidagi EYK E va tok I_a, generator berayotgan quvvat P_2 va yakor chulg'amidagi quvvat isrofi P_z aniqlansin.

Yechish: Qo'zg'atish zanjiridagi tok

$$I_k=\frac{U}{R_k}=\frac{230}{72}=3{,}2 \text{ A}.$$

Yakor chulg'amidagi tok

$$I_a=I+I_k=160+3{,}2=163{,}2 \text{ A}.$$

Yakordagi EYK

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

Foydali quvvat

$$P_2=UI=230\cdot 160=36800 \text{ W}=36{,}8 \text{ kW}$$

Yakor chulg'amidagi quvvat isrofi

$$P_y=I^2_yR_y=163{,}2\cdot 0{,}11=2930 \text{ W}=2{,}93 \text{ kW}$$

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

Yechish: Bu ikki hol uchun momentlar tenglamasi

$$M_1=C_M\Phi I_{a1}\ ; M_2=2C_M\Phi I_{a1}$$

Bunda, $I_{y2}=2I_{y1}=2\cdot 74=148$ 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:

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

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

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

8.8-masala. 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 EYK

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

Bu yerda: p-juft qutblar soni. Generator ikki qutbli bo'lgani uchun p=1.

Generator uchlaridagi kuchlanish

$$U_г = E - I_я R_я = 300 - 60 \cdot 0{,}2 = 288 \text{ V},$$

Bu yerda: $I_я = I + I_к = 56 + 4 = 60$ 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 holda

$$M = 47{,}8 \cdot 0{,}03 \cdot 60 = 86 \quad N \cdot m$$

8.9-masala. 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 $A_{см} = 2mm^2$. Uchlaridagi kuchlanish $U = 110$ V bo'lganda generator tarmoqga $P = 3{,}5$ kVt quvvat beradi. Generatorning yakor

chulg'ami qarshiligi $R_я = 20^0 C$ da aniqlansin va $75^0 C$ da yakor chulg'amidagi quvvat isrofi topilsin. Mustaqil qo'zg'atishli generator yakor chulg'ami misdan tayyorlangan bo'lib, $20^0 C$ da misning solishtirma qarshiligi $p = 0{,}0172\ \mu Om \cdot m$.

Yechish: Bitta parallel shaxobchadagi yakor chulg'amining qarshiligi

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

Cho'tkalar orasidagi yakorning qarshiligi

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

Yakor toki

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

Yakor chulg'amidagi kuchlanish pasayishi

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

$75^0 C$ dagi yakor qarshiligi

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

$75^0 C$ dagi yakor chulg'amining isrofi

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

8.10-masala. Aylanish chastotasi $n = 1000$ ayl/min bo'lgan o'zgarmas tok motori yuksiz ishlamoqda; undagi gisterezis isrofi $P_г = 2500$ W, uyurma toklar hosil qilgan quvvat isrofi $P_у = 1000$ W. 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

$$P_г = P_{1.0г} \frac{f}{50} B^2 \cdot G_{пўл} = \kappa_1 \cdot f = \kappa^*_1 \cdot n$$

Bunda

$$\kappa^*_1 = \frac{P_г}{n} = \frac{2500}{1000} \cdot 60 = 150 W \cdot s$$

Uyurma toklar hosil qilgan isrof

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

$$\kappa^*_2 = \frac{P_y}{n^2} = \frac{1000}{1000^2}\cdot 60^2 = 3{,}6W\cdot s^2$$

Po'latdagi isrof($n = 1000$ ayl/min tezlikda)

$$P_{nyo} = P_r + P_y = 2500 + 1000 = 3500 \text{ W}$$

Quyidagi tezlikda n, po'latdagi isrof ikki martaga kamayadi

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

Bu hol uchun ikkinchi darajali tenglama

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

Bu tenglamaning yechimi:

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

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

Mustaqil yechish uchun masalalar

8.11-masala. 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 $R_a = 0{,}8$ Om, magnit oqim $\Phi = 0{,}63\cdot 10^{-2}$ Vb, yakor toki $I_a = 27$ A bo'lganda motorning aylanish chastotasi aniqlansin. Cho'tkalardagi kuchlanishning pasayishi $\Delta U_k = 2$ V. Yakor reaksiyasining tasiri hisobga olinmasin.

Javob: $n = 2878$ ayl/min.

8.12-masala. Mustaqil qo'zg'atish o'zgarmas tok motori kuchmanishi $U = 220$ V bo'lgan tarmoqqa ulangan. Motorning yuklama momenti nominal momentiga teng, aylanish chastotasi $n = 1440$ ayl/min, yakor toki $I_a = 50$ A, yakor chug'ami qarshiligi $R_a = 0{,}4$ Om. Agarda yuklama motenti ikki martaga kamaysa, motorning tezligi qancha bo'ladi? Cho'tkalardagi kuchlanish pasayishi $\Delta U_k = 2$ V.

Javob: $n = 1513$ ayl/min.

8.13-masala. O'zgarmas tok motorining kuchlanish $U = 440$ V. nominal quvvati $P_1 = 120$ kW, FIK $\eta = 92\%$ bo'lsa, motor tarmoqdan tokni istemol qiladi?

Javob: $I_a = 296$ A.

8.14-masala. Mustaqil qo'zg'atishli generator salt ishlayotganda kuchlanish $U_0 = E_{\Gamma} = 150$ 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.

Javob: $C_e = 2$.

8.15-masala. To'rt qutbli o'zgarmas tok generatorni chulg'amlarini kesib o'tayotgan magnit oqimi $\Phi = 1 \cdot 10^{-2}$ 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 EYK ni toping.

Javob: $E = 75$ V

8.16-masala. O'zgarmas tok generatorning yakor chulg'amlarini kesib o'tayotgan magnit oqimi 0,02 Vb, mashina doimiysi 10. Yakorning aylanish chastotasi 1000, 1500, va 2000 ayl/min bo'lganda yakor chulg'amidagi inuktivlangan EYK lar aniqlansin.

Javob: 200 V, 300 V, 400 V

8.17-masala. Parallel qo'zg'atili 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?

Javob: $r_p = 48$ Om

8.18-masala. Parallel qo'zg'atishli generator nominal kuchlanishi $U_t = 120$ V, yakorning naminal aylanish chastotasi $n_t = 1000$ ayl/min, nominal toki $I_{y.t} = 80$ A va yakor chulg'amining qarshiligi $R_y = 0{,}15$ Om. Generatorning motor sifatida ishlatganda yakor chulg'amida induktivlangan teskari EYK va yakorning aylanish chastotasi topilsin. Mashinaning magnit oqimi ikkala rejimda ham o'zgarmas deb hisoblansin.

Javob: $E_r = 108$ V, $n = 818$ ayl/min.

9-BOB. ASINXRON MASHINALAR

Asinxron mashinaning tenglamalari va parametrlarini keltirish

Asinxron mashina stator chulg'amida hosil bo'lgan EYK

$$E_1 = 4{,}44 f \omega_1 k_{r1} \Phi, \qquad (9.1)$$

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

Rotor chulg'amida hosil bo'lgan EYK

$$E_2 = 4{,}44 f_1 \omega_1 k_{r2} \Phi, \qquad (9.2)$$

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

Asinxron mashinaning toransformatsiya koefisienti

$$\kappa_{KP} = \frac{E_1}{E_2} = \frac{\omega_1 k_{r1}}{\omega_2 k_{r2}}. \qquad (9.3)$$

EYK ning keltirilgan qiymati

$$E'_2 = k_{TP} E_2 = \frac{\omega_1 k_{r1}}{\omega_2 k_{r2}} \cdot 4{,}44 f_1 \omega_1 k_{r2} \Phi = 4{,}44 f_1 \omega_1 k_{r1} \Phi = E_1 = E. \qquad (9.4)$$

Tokning keltirilgan qiymati

$$I'_2 = \frac{m_2}{m_1} \cdot \frac{I_2}{k_{r1}}, \qquad (9.5)$$

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

Keltirilgan aktiv qarshilik

$$R'_2 = \frac{m_1}{m_2} k^2_{TP} R_2. \qquad (9.6)$$

Keltirilgan induktiv qarshilik

$$x'_2 = \frac{m_1}{m_2} k^2_{TP} x_2. \qquad (9.7)$$

Keltirilgan to'la qarshilik

$$z'_2 = \frac{m_1}{m_2} k^2_{TP} z_2. \qquad (9.8)$$

Asinxron mashinadagi quvvat va isroflar

Uch fazali asinxron motor tarmoqdan P_1 quvvatni iste`mol qiladi

$$P_1 = 3 U_1 I_1 \cos\varphi_1 \qquad (9.9)$$

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

Po'latdagi isrof

$$P_{s1} = P_{y1} + P_{T1}, \quad (9.10)$$

bu yerda: $P_{\beta 1}$, P_{T1} – stator yarmosidagi va tishlaridagi isrof.

Yarmodagi isrof

$$P_{\beta 1} = 2P_{1.0}B^2_{\beta 1}m_{y1}; \quad (9.11)$$

Tishlardagi isrof

$$P_{T1} = 3P_{1.0}(B_{T1}\kappa_\delta)^2 m_{T1}, \quad (9.12)$$

bu yerda: $P_{1.0}$ – stator po'latidagi solishtirma isrof, W/kg; $B_{\beta 1}$ – yarmodagi o'rtacha induksiya, Tl; $m_{\beta 1}$ – yakorning massasi, kg; m_{T1} – tishlarning massasi, kg; B_{T1} – tishlardagi o'rtacha induksiya, Tl; κ_δ -havo bo'shlig'i (zazor) koeffisienti.

Stator chulg'amidagi isrof

$$P_{r1} = 3I^2_1 R_1, \quad (9.13)$$

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

$$R_1 = \rho_{75}\frac{l_1 2\omega_1}{a_1 c_1 A_1}, \quad (9.14)$$

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.

$$P_{r1} = 2{,}42 j^2_1 m_{r1}. \quad (9.15)$$

Elektromagnit quvvat

$$P_э = P_1 - (P_{s1} + P_{r1}) = P_1 - P_{is1}, \quad (9.16)$$

bu yerda: P_{is1}-stator chulg'ami istemol qilayotgan quvvat.

Asinxron mashina momenti

Asinxron mashinaning elektromagnit quvvati moment bilan quyidagicha bog'langan.

$$P_ў = M \cdot 2\pi n. \quad (9.17)$$

Momentni taxminiy quyidagicha yozish mumkin.

$$M = 9{,}55\frac{3}{n}U^2_1 \frac{R'_2/S}{(R_1 + R'_2/S)^2 + x^2}, \quad (9.18)$$

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 ($S = 1$).

$$M_{ish} = 9{,}55\frac{3}{n} I'^2_{2K.T} R'_2, \qquad (9.19)$$

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

Motorning taxminiy maksimal momenti

$$M_{max} = 9{,}55\frac{3}{n} U^2_1 \frac{1}{2(R_1 + \sqrt{R^2_1 + x^2})}. \qquad (9.20)$$

Kritik sirpanish

$$S_{KP} \approx R'_2 / x. \qquad (9.21)$$

Yuqoridagi formulalardan foydalanib, M / M_{max} nisbatni topamiz

$$\frac{M}{M_{max}} = \frac{2}{\frac{S_{KP}}{S} + \frac{S}{S_{KP}}}. \qquad (9.22)$$

Masalalar yechish namunalari

9.1-masala. Stator chulg'ami Y ulangan uch fazli to'rt qutbli asinxron motorning quyidagi parametlari berilgan:

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

$R_1 = 1{,}8$ 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

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

Statordagi quvvat koeffisienti

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

Stator tokining vektor ko'rinishi

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

Taxminiy salt ishlash toki

$$I_0 = j\frac{U_1}{x_1 + x_\mu} = j\frac{220}{2{,}9 + 102} = j2{,}1 \text{ A}$$

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

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

Mexanik quvvat

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

Nominal sirpanish

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

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

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

9.2-masala. Stator chulg'ami Δ ulangan uch fazali to'rt qutbli asinxron motorning quyidagi nominal qiymatlari berilgan:

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

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

Quyidagilar topilsin:

a) statorning ichki diametri $D = 135$ mm, po'lat o'zak uzunligi $l = 175$ mm

stator pazlari soni $z_1 = 36$, pazlardagi simlar soni $z_1 = 36$, stator chulg'amining chulg'am koeffisienti $\kappa_{r1} = 0{,}831$ bo'lsa, havo bo'shlig'idagi o'rtacha induksiya;

b) havo bo'shlig'i $\delta = 0{,}5$ mm, xavo bo'shlig'i koeffisienti $\kappa_\delta = 1{,}128$, tishlarning o'lchamlari: $\hat{a}_1 = 4{,}9$ mm, $L_{T1} = 18{,}5$ mm, $\hat{a}_2 = 5{,}8$ mm, $L_{T2} = 25$ mm, rotor pazlari soni $z_2 = 30$, paketlarni po'lat bilan to'ldirish

koeffisienti $\kappa_n = 0{,}93$ bo'lsa, havo bo'shlig'idagi va tishlardagi magnit kuchlanishlar;

v) $h_{y1} = 35$ mm, $h_{y2} = 14{,}4$ mm bo'lsa, yarmodagi induksiya;

g) 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

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

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

$$B_{T1} = \frac{\tau_{n1} \cdot l}{\hat{a}_1 l_{n1}} B_\delta = \frac{11{,}8 \cdot 175}{4{,}9 \cdot 0{,}93 \cdot 175} = 0{,}668 = 1{,}725 \text{ Tl;}$$

$$B_{T2} = 0{,}95\frac{\tau_{n2}l}{d_2 l_{n1}} B_{\delta} = 0{,}95 \cdot \frac{14{,}13 \cdot 174}{5{,}8 \cdot 0{,}93 \cdot 175} \cdot 0{,}668 = 1{,}66 \text{ Tl.}$$

Shu induksiyalarga mos keluvchi
Maydon kuchlanganliklari

$$H_{T1} = 110 A/sm; H_{T2} = 75 A/sm.$$

Magnit kuchlanishlar

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

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

To'yinish koeffisienti

$$k_T = \frac{F_{\delta T1} + F_{\delta T2}}{F_{\delta \delta}} = \frac{204 + 188}{299} = 1{,}31$$

v) yarmodagi induksiya

$$B_{a1} = \frac{\phi}{2h_{a1} l_1 k_n} = \frac{0{,}954 \cdot 10^{-2}}{2 \cdot 0{,}035 \cdot 0{,}39 \cdot 0{,}175} = 0{,}837 \text{ Tl}$$

$$B_{a2} = 0{,}95\frac{\phi}{2h_{a2} l_2 k_n} = 0{,}95\frac{0{,}954 \cdot 10^{-2}}{2 \cdot 0{,}0144 \cdot 0{,}93 \cdot 0{,}175} = 2{,}035 \text{ Tl}$$

g) 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 $I_{1H} = I_{1,HH} / \sqrt{3} = 9{,}5 / \sqrt{3} = 5{,}5$ A (Δ ulanishda)
Tok zichligi

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

Parallel shaxobchalar soni va kesim $a_1 = 1$;

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

9.3-masala. Uch fazali qisqa tutashgan rotorli asinxron motorning quyidagi parametlari berilgan: $U_{H\Delta} = 380 V$, $I_H = 20{,}3 A$, $P_H = 110 kW, f = 50 Gs$, $2p = 4$, $\eta_H = 87\%$ $P_r = 382$ W, $R_1 = 1{,}135$ Om, $R'_2 = 1{,}28$ Om, $x_\mu = 79$ Om, $x_1 = 2{,}7$ Om, $x'_2 = 3{,}8$ Om.

Topish kerak:
a) yurgazish toki:

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

v) ishchi va kritik sirpanish;

g) 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 koeffisienti

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

$S = \infty$ 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

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

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

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

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

$$P_n = 382 \text{ W}$$

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

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

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

v) istemol qilinayotgan quvvat

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

Stator chulg'amidagi isrof

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

Elektromagnit quvvat

$$P_{\dot{y}} = P_1 - P_{dav} = P_1 - (P_{m1} - P_{r1}) = 11500 - (382 + 468,5) = 10650 \text{ W}$$

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

$$P_{r1} = P_{\dot{y}} - (P + P_{T.B}) = 10650 - (10000 + 100) = 550 \text{ W}$$

Nominal sirpanish

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

Kritik sirpanish

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

g) nominal momenti

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

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

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

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

Maksimal moment

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

$$x = (x_1 + x_2) = (2,7 + 3,8) = 6,5 \text{ Om}.$$

Maksimal momentning nominal momentga nisbati

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

9.4-masala. 8 qutbli uch fazali asinxron motorning nominal kuchlanishi $U_H = 380$ V; $I_H = 51$ A; $n_H = 725$ ayl/min; $\frac{i_{mix}}{i_H} = 3,3$; 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 $S^2_{KP} - 0,22S_{KP} + 0,0011 = 0$ ko'rinishdagiikkinchi 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 yechimi $S_1 = 1,14$ va

$S_2 = 0{,}038$ bo'ladi. $S_1 = 1{,}14$ motorning tormoz ish holatiga to'g'ri keladi. Shu sababli kuchlanish pasaygandagi ishchi sirpanish $S_2 = 0{,}038$ hisoblanadi.

9.5-masala. Qisqa tutashgan rotorli uch fazali motorning stator chulg'ami Δ ulangan. Motorning nominal parametlari quyidagicha: $P_H = 37$ kW, $U_H = 380$ 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:
$I_{ю p} / I_H = 6$; $M_{ю p} / M_H = 2$.

Quyidagilar aniqlansin:

a) Y dan Δ ga ulangandagi yurgizish toki va momenti;

b)transformator yordamida yurgizilgandagi transformatsiyalash koeffisienti.

Yechish.

a) nominal moment

$$i_j = \frac{Đ_j}{\omega} = \frac{37000}{2\pi \cdot 1450/60} = 243{,}3 \text{ N·m}$$

Yurgizish momenti va toki (berilgan shartga asosan)

$$M_{ю p} = 2M_H = 2 \cdot 243{,}3 = 486{,}6 \text{ N·m}$$

$$I_{ю p} = 6I_H = 6 \cdot 73 = 438 \text{ A}$$

Y dan Δ ulab yurgizilgan tok va moment 3 marta kamayadi

$$I_{ю pY} = \frac{I_{ю p}}{3} = \frac{438}{3} = 146 \text{ A}$$

$$M_{ю pY} = \frac{M_{ю p}}{3} = \frac{486{,}6}{3} = 162{,}2 \text{ N·m}$$

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

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

$M_{ю p} / 3 = M'_{ю p} / \kappa^2_{TP}$ bundan $\kappa^2_{TP} = 3$; $\kappa_{TP} = \sqrt{3} = 1{,}73$.

Zarbiy tok

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

Mustaqil yechish uchun masalalar

9.6-masala. 4A160S2UZ tipdagi uch fazali tok tarmog'ida ulangan. Rotorning sirpanishi 2% va 6% ga teng bo'lganda, rotorning aylanish burchak tezligi ω_2 aniqlansin.

Javob: $\omega_2 = 308$ rad/s; $\omega_2 = 295$ rad/s

9.7-masala. Ko'p tezlikli asinxron matorning stator chulg'amlarini qayta ulangan, uning juft qutblar soni 2 martaga ortadi. Aylanuvchi magnit maydonning va rotorning aylanish chastotasi qanday o'zgaradi?

Javob: 2 marta kamayadi

9.8-masala. Nominal quvvatlari $P_{2H} = 0{,}5$ kW, $P_{2H} = 1$ kW bo'lgan bir fazali asinxron motorlar chastotasi $f = 50$ Gs, faza kuchlanishi $U_\phi = 220$ V bo'lgan o'zgaruvchi tok tarmog'iga ulangan. Motorlarning quvvat koeffisientlari tegishlicha $\cos\varphi_{2H} = 0{,}7$; $\cos\varphi_{2H} = 0{,}9$. Motorlar chulg'amidan oqayotgan toklar, reaktiv va to'la quvvatlar aniqlansin.

Javob: $I_{1H} = 3{,}25A$; $I_{2H} = 5{,}05A$; $Q_1 = Q_2 = 0{,}5$ kVA; $S_1 = 0{,}7$ kVA; $S_2 = 1{,}1$ kVA

9.10-masala. 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 rotorningtezligini aniqlang va olingan qiymatlarning fizik manosini tushuntirib bering.

Javob: 0; 1000 ayl/min; 1500 ayl/min; 2000 ayl/min

9.11-masala. 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 $P_1 = 3{,}55$ kW. Agar motorning foydali quvvati $P_2 = 3$ kW bo'lsa, motorning FIK va quvvat koeffisienti nimaga teng?

Javob: $\eta = 0{,}845$; $\cos\varphi = 0{,}88$.

9.13-masala. 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 $\kappa_{r1} = 0{,}92$; $F_{\acute{e}} = 716$ A. Salt ishlash tokining reaktiv tashkil etuvchisi nominal tokning necha foizini tashkel qiladi?

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

9.14-masala. 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 N·m. Motorlarning quvvati aniqlansin.

Javob: 55 kW.

9.15-masala. 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 p, sinxron tezligi n, va nominal sirpanish S_H topilsin. Shuningdek $S = 5\%$ bo'lganda motor rotorida hosil bo'lgan EYK ning chastotasi f_2 aniqlansin.

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

10-BOB. SINXRON MASHINALAR

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.

Qo`zg'atish chulg'ami ikki xil bo'ladi: tarqalgan chulg'am (noayon qutbli rotorda) va yig'ilgan chulg'am (ayon qutbli rotorda).

Tarqalgan chulg'amning MYK

$$F_{fm} = I_f W_f \qquad (10.1)$$

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 MYK ning amplitudasi

$$F_{f1m} = \frac{4\sin(p\pi/2)}{\pi p\pi/2} F_m, \qquad (10.2)$$

bu yerda: $p = \hat{a}/\tau$ – qutbning chulg'am o'ralgan qismini nisbiy uzunligi;

Yig'ilgan cho'lg'amning MYuK

$$F_{fm} = I_f W_f. \qquad (10.3)$$

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

Qo'zg'atish chulg'ami maydoni shaklining koeffisienti

$$k_f = B_{\delta 1m}/B_\delta. \qquad (10.4)$$

bu yerda: $B_{\delta 1m}$ – havo 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)

$$k_f = 8\sin(\frac{p\pi}{2})/(\pi^2 p). \qquad (10.5)$$

Ayon qutbli mashina uchun (to'yinish hisobga olinmasin)

$$k_f = f(\alpha, \gamma, \varepsilon), \qquad (10.6)$$

bu yerda: $a = \hat{a}_p/\tau$ – nisbiy qutb yoyi; $\gamma = \delta_{in}/\delta'$ – qutb chekkalaridagi nisbiy havo bo'shlig'i. Bu yerda $\delta' = k_\delta \delta$ – ekvivalent

havo bo'shlig'i, δ_m – masimal va δ – minimum havo bo'shlig'i, k_δ – havo bo'shlig'i koeffisienti.

Qo'zg'atish oqimi koeffisienti

$$k_\phi = \Phi_{fm} / \Phi_{f1m}, \qquad (10.7)$$

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

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

Qutb berkilish hisobiy koeffisienti

$$a_\delta = B_{\delta yp} / B_\delta. \qquad (10.8)$$

EYK shaklining koeffisienti (to'yinish hisobga olinmagan)

$$k_u = B_{\delta T1} / B_{\delta 1p} = \pi / 2\sqrt{2k_\phi}, \qquad (10.9)$$

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

O'zaro induksiya to'la qarshiligi

$$\Phi_m = \Phi_{fm} = k_\phi \Phi_{f1m} = E_f / (4k_u f_1 \omega_1 k_{u1}), \qquad (10.10)$$

Qo'zg'atish chulg'amidagi MYK

$$F_{fm} = F_1 + F_2, \qquad (10.11)$$

bu yerda: $F_1 = F_\delta + F_{z1} + F_{a1}$; F_δ – havo bo'shlig'ining magnit kuchlanishi; F_{z1} – stator tishining magnit kuchlanishi; F_{a1} – stator yarmasining kuchlanishi; F_2 – rotorning magtit kuchlanishi.

Stator magnit o'tkazgichining to'yinish koeffisienti

$$\kappa_{Za} = (F_\delta + F_{Z1} + F_{a1}) / F_\delta. \qquad (10.12)$$

Yakor chulg'amining magnit yurituvchi kuchi, magnit maydoni, EYK va parametlari

Yakor (stator) chulg'ami asosiy garmonikasining amplitudasi

$$F_{am} = (\sqrt{2} / \pi) m_1 (I \omega_1 k_{r1} / p). \qquad (10.13)$$

Yakor chulg'ami MYK ni bo'ylama tashkil etuvchisining amplitudasi

$$F_{dm} = (\sqrt{2} / \pi) m_1 (I \omega_1 k_{r1} / p) \qquad (10.14)$$

Yakor chulg'ami MYK ni ko'ndalang tashkil etuvchisining amplitudasi

$$F_{qm} = (\sqrt{2}/\pi)m_1(I_d\omega_1 k_{r1}/p). \qquad (10.15)$$

bu yerda: $I_d = I\sin\beta$ va $I_q = I\cos\beta$, β – EYK E_f va tok I (yoki MYK F_{fm}) orasidagi burchak.

Noayon qutbli sinxron mashina uchun:

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

$$B_{ald} = \mu_0 F_{am}/(\delta k_\delta); \qquad (10.16)$$

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

$$\Phi_m = (2/\pi)\tau \cdot l_\delta B_{ald}, \qquad (10.17)$$

O'zaro induksiya oqimining magnit ilashimligi

$$\Psi_{am} = \omega_1 k_{01}\Phi_m, \qquad (10.18)$$

Yakor chulg'ami fazasida o'zaro induksiya oqimi tasirida hosil bo'lgan EYK

$$E_a = 4{,}44 f_1 \Phi_m \omega_1 k_{r1}. \qquad (10.19)$$

Ayon qutbli sinxron mashina uchun:

Bo'ylama va ko'ndalang MYK hosil qilgan induksiyalarning asosiy garmonikalari amplitudasi

$$B_{adlm} = k_d B_{adm}; B_{aqm} = k_q B_{aqm}. \qquad (10.20)$$

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

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

$$\begin{aligned} \Phi_{adm} &= (2/\pi)\tau \cdot l_\delta k_d B_{adm}; \\ \Psi_{adm} &= \omega_1 k_{01}\Phi_{фав}; \\ E_{ad} &= 4{,}44\omega_1 k_{r1} f \Phi_{фав}. \end{aligned} \qquad (10.21)$$

Yakor tokining ko'ndalang tashkil etuvchisiga mos keluvchi o'zaro induksiya magnit oqimi, oqim ilashuvi va EYK:

$$\Phi_{aqm} = (2/\pi)\tau \cdot l_\delta k_q B_{aqm};$$

$$\Psi_{aqm} = \omega_1 k_{01} \Phi_{aqm}; \qquad (10.22)$$

$$E_{aq} = 4{,}44\omega_1 k_1 f \Phi_{aqm}.$$

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

$$F_{afm} = k_a F_{am} \qquad (10.23)$$

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

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

$$F_{adm} = k_{ad} F_{dm}; \quad F_{aqm} = k_{aq} F_{qm}, \qquad (10.24)$$

bu yerda: $k_{ad} = k_d / k_f$ –bo'ylama o'q bo'yicha yakor reaksiyasi koeffisienti; $k_{aq} = k_q / k_f$ –ko'ndalang o'q bo'yicha yakor reaksiyasi koeffisienti.

Yakor chulg'ami parametlari:

Yakor chulg'ami fazasidagi sochilma (tarqoq) induktiv qarshilik

$$x_\delta = 4\pi\mu_0 f W_1^2 (l_\delta / pq_1)\lambda_{\delta 1}, \qquad (10.25)$$

bu yerda: $\lambda_{\delta 1} = \lambda_{n1} + \lambda_{\tau 1} + \lambda_{r1} + \lambda_{a1}$ -sochilma oqim ilashuvi uchun o'tkazuvchanlik koeffisienti.

Noayon qutbli sinxron mashina yakor chulg'amining asosiy induktiv qarshiligi

$$x_a = 4\mu_0 m_1 f (\omega_1 k_{r1})^2 \lambda_\delta / (\pi p), \qquad (10.26)$$

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

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

$$x_{aq} = \frac{4\mu_0}{\pi p} m_1 f (\omega_1 k_{r1})^2 \lambda_{aq}, \qquad (10.27)$$

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 koeffisientlari.

Naoyon qutbli sinxron mashina yakor chulg'amining induktiv qarshiligi $x_1 = x_\delta + x_a$ (10.28)

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

$$x_d = x_\delta + x_{ad};\ x_q = x_\delta + x_{aq}. \qquad (10.29)$$

Sinxron mashina quvvati va foydali ish koeffisienti

Birlamchi motordan generatorga berilayotgan mexanik quvvat

$$P_1 = M_1\Omega \qquad (10.30)$$

bu yerda: M_1 -motor aylaniyotgan tomonga yo'nalgan aylantiruvchi moment; Ω – burchak tezlik.

Generator rotoriga berilgan mexanik quvvat

$$P_B = P_1 - P_f/\eta_f = M_{idd}\Omega \qquad (10.31)$$

bu yerda: P_f/η_f -quzg'atgichning aylantirishga sarf bulgadigan 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

$$P_{idd} = P_A - P_{O'} - P_{I\ .\hat{E}} = M\Omega = P_{\acute{y}i} \qquad (10.32)$$

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

Yuklamadagi generator tomonidan berilayotgan aktiv quvvat

$$P = m_1 UI\cos\varphi = P_{\acute{y}e} - P_{\acute{y}1} \qquad (10.33)$$

bu yerda: $P_{\acute{y}1} = mRI^2$-yakor chulg'amidagi elektr isrofi; R – yakor chulg'amining aktiv qarshiligi.

Sinxron generatorning FIK

$$\eta = P/P_1 = 1 - \sum P/(P + \sum P) \qquad (10.34)$$

bu yerda: $\sum P = P_f/\eta_f + P_T + P_{I\ .\acute{e}} + P_{I\ .\acute{e}} + P_{\acute{y}1}$ – yig'indi isrof.

Elektromagnit quvvat

$$P_{am} = T_1 E_v I' \cos\beta_v' \qquad (10.35)$$

bu yerda: E_v – o'zaro induksiya EYK; $I = \sqrt{(I_M + I\cos\beta_v)^2 + (I\sin\beta_v)^2}$ – qo`shimcha tok $I_M = P_M/(m_1 E_v)$ ni hisobga olingandagi yakor toki; $\cos\beta_v' = (I\cos\beta_v + I_M)/I'$; $\beta_v - E_v$ va I orasidagi burchak.

Masala yechish namunalari

10.1-masala. Ikki qutbli noayon qutbli sinxron mashinaning ichki sinusoida shaklida bo'lishini ta'minlash uchun, rotor qutb bo'linmasining chulg'am o'ralgan qismini uzunligini aniqlang.

Yechish:

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

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

$$â = \delta\tau = 0{,}67 \cdot 1{,}57 = 1{,}052 \text{ m}$$

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

10.2-masala. Noayon qutbli sinxron mashinaning qutbi o'qidagi induksiya 0,85 Tl. $â = 110$ 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 misbiy uzunligi

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

Qutb berkilish hisobiy koeffisienti

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

O'rtacha induksiya

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

10.3-masala. Sinxron mashina qo`zg'atish chulg'ami maydoni shaklining koeffisienti $k_f = 1{,}05$, qutb o'qidagi induksiyaning radial tashkil etuvchisi $B_\delta = 0{,}75$ Tl bo'lsa, havo bo`shlig'idagi qo`zg'atish maydoni induksiyasi $B_{\delta 1m}$ aniqlansin.

Yechish: Qo'zg'atish maydoni induksiyasi

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

10.4-masala. 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

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

10.5-masala. Ayon qutbli sinxron mashinani qutb bo'linmasi $\tau = 23$ sm, hisobiy uzunligi $l_\delta = 12$ sm, qo'zg'atish maydoni shaklining koeffisienti $k_f = 1{,}07$, 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

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

Quzg'atish maydoni oqimining asosiy garmonikasi

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

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

Yechish: Havo bo'shlig'idagi o'rtacha induksiya

$$B_{\delta p} = \frac{\Phi_{fm}}{\tau_\delta} = \frac{1{,}3\cdot 10^{-2}}{16{,}5\cdot 10^{-2}\cdot 14\cdot 10^{-2}} = 0{,}563\ \text{Tl}.$$

Qutb berkilish hisobiy koeffisienti

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

10.7-masala. 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 koeffisienti $k_{r1} = 0{,}92$ bo'lsa, $I = 1500$ A uchun yakorning MYK ga ekvivalent bo'lgan quzg'atish MYK 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 koeffisienti

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

Yakor reaksiyasi koeffisienti

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

Yakorning MYK ga ekvivalent bo'lgan, qo`zg'atish chulg'ami MYuK

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

10.8-masala. Sinxron generatorning faza kuchlanishi $U_\phi = 230$ V, faza toki $I_1 = 54$ A, quvvat koeffisienti $\cos\varphi = 0{,}8$. To'la magnit isrofi $P_M + P_{MK} = 800$ W, to'la elektr isrofi $P_{e1} = 1500$ W, mexanik P_{mex} va P_t / η_f isroflar elektr isrofining $\frac{2}{3}$ qismini tashkel qilsa , generatorning FIK topilsin.

Yechish: To'la quvvat isrofi

$$\sum P = \left(\frac{P_f}{\eta_f} + P_{mex} \right) = \frac{2}{3} P_{e1} = \frac{2}{3} \cdot 1500 = 1000 \text{ W}$$

Generatorning aktiv quvvati

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

Generatorning FIK

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

10.9-masala. Turbogeneratorning nominal liniya kuchlanishi $U_{nl} = 10{,}5$ 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 $U_0 = 24{,}2$ bo'lsa, EYK va kuchlanish orasidagi burchak γ_H nominal yuklama $P_H = 6$ MW da topilsin. Generatorning statik yuklanish qobilyati nimaga teng?

Yechish: Maksimal quvvat

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

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

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

Generatorning statik yuklanish qobiliyati

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

Mustaqil yechish uchun masalalar

10.10-masala. Nominal yuklamada turbogeneratorning faza kuchlanishi $U_{n.f} = 230$ 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 EYK ni toping.

Javob: $E_f = 550{,}5$ V

10.11-masala. Turbogenerator qo'zg`atilgan bo'lib, yuklamada tok $I = 2150$ A, $\cos\varphi = 0{,}8$, $U_{u.\partial} = 0{,}4$ 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 EYK ni aniqlang.

Javob: $E_f = 622{,}3$ V

10.12-masala. Gidrogeneratorning to'la quvvati $S_H = 26MVA$ $\cos\varphi_H = 0{,}8$. Mexanik isrof $P_{мех} = 88$ kW, yakor chulg'amidagi elektr isrofi $P_{э1} = 185$ kW, magnit isrof $P_м + P_{маг} = 138{,}5$ kW, qo'zg'atgichni harakatga keltirishga sarflanayotgan quvvat $P_f / \eta_f = 167$ kW. Generatorning to'la quvvati va FIK topilsin.

Javob: $\sum P = 578{,}5$ kW; $\eta = 0{,}973$

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

Javob: $F_{am} = 1155$ A

10.14-masala. 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 koeffisienti $\kappa_{r1} = 0{,}966$, tarqatish koeffisienti $\kappa_{TK} = 0{,}956$. Yakor chulg'ami MYK ning asosiy garmonikasi amplitudasi topilsin.

Javob: $F_{am} = 34281$ A

10.15-masala. Ayon qutbli sinxron mashinaning quyidagi parametrlari berilgan: maydon shakli koeffisientlari: 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 MYK ning bo'ylama va ko'ndalang tashkel etuvchilari hosil qilgan enduksiyaning asosiy garmonikalari topilsin.

Javob: $B_{ad1m} = 0{,}459$ Tl, $B_{aq1m} = 0{,}22$ Tl

10.16-masala. Gidrogenerator 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 koeffisienti $\kappa_{w1} = 0{,}94$, generator aylanish chastotasi $n = 125$ ayl/min. Magnit oqim Φ_{adm} va Φ_{aqm} lar hosil qilgan EYK lar topilsin.

Javob: $E_{ad} = 7189$ V; $E_{aq} = 1356$ V

10.17-masala. Uch fazali sinxron generatordan yuklama $P_n = 26$ MW quvvatni olmoqda, generatorning elektromagnit quvvati $P_{em} = 26{,}2$ MW, stator po'lat o'zagidagi magnit isrofi $P_{st} = 150$ kW, faza toki $I = 1790$ A.

Javob: $R = 0{,}0052$ Om

10.18-masala. Turbogeneratorning yuklamasi kamaygan vaqtdagi naminal qo'zg'atish toki 15A. Kuchlanishning o'zgarishi aniqlansin.

Javob: $\Delta U = 0{,}2$

11-BOB. SANOAT KORXONALARINING ELEKTR TA`MINOTI

O'rtacha yuklama. Korxonalarning hisobiy yuklamalarini aniqlashda va elektr ta'minoti tizimidagi energiya sarfini, nobudgarchiligini hisoblashda o'rtacha yuklamasi hisobiy yuklamaning eng kichik qiymati to'g'risida ma'lumot beradi. Umumiy holda ma'lum oraliqdagi o'rtacha quvvat quyidagicha ifodalanadi:

$$p_{o`rt} = \frac{1}{t}\int_0^t pdt;\ q_{o`rt} = \frac{1}{t}\int_0^t qdt \qquad (11.1)$$

Eksluatatsiya sharoitida guruh iste'molchilarining o'rtacha quvvatlari aktiv va reaktiv energiya hisoblagichlarining ko'rsatkichlari asosida ushbu munosabatlar orqali topiladi:

$$P_{o`rt} = \frac{E_a}{t_s};\quad Q_{o`rt} = \frac{E_R}{t_s};\quad S_{o`rt} = \sqrt{P_{o`rt}^2 + Q_{o`rt}^2} \qquad (11.2)$$

Bu yerda: E_a, E_R - aktiv va reaktiv elektr energiyalarining ko'rilayotgan t_s vaqt oralig'idagi sarfi.

Korxonaning elektr ta'minotini loyihalash bosqichida guruh iste'molchilarining eng katta yuklamali smenasidagi o'rtacha quvvatni quyidagicha aniqlash mumkin:

$$P_{o`rt} = K_u P_H \qquad (11.3)$$

Bu yerda: P_H - iste'molchilar nominal quvvatlarining yig'indisi bo'lib, takroriy-qisqa muddatli rejimda ishlovchi iste'molchilarni *UD = 100%* rejimga keltirish kerak; K_u - guruh iste'molchilariga tegishli bo'lgan ishlatilish koeffisienti.

Eng yuklangan smenaga reaktiv quvvatning o'rtacha qiymatini guruh iste'molchilari uchun shunday topiladi:

$$Q_{o'rt}=K_{и}Q_n \quad \text{yoki} \quad Q_{o'rt}=P_{o'rt}\cdot tg\varphi \qquad (11.4)$$

Bu yerda tg φ ning qiymatini topishda ma'lumotnomalarda har xil guruh iste'molchilari uchun berilgan quvvat koeffisientidan foydalaniladi. Sex yoki korxonaning yillik o'rtacha quvvati ushbu munosabatdan aniqlanadi:

$$P_{o`rt} = \frac{E_a}{t_y};\quad Q_{o`rt} = \frac{E_R}{t_y} \qquad (11.5)$$

Ifodadagi E_a - yillik iste'mol keltirilgan aktiv energiya miqdori; E_R- yillik iste'mol qilingan reaktiv energiya miqdori; t_y - korxonaning yillik ish vaqti (soat).

Faza bo'yicha oldinda boruvchi toklar hosil qiluvchi iste'molchilarning(sinxron mashinalar, statik kondensatorlar) reaktiv quvvatlari manfiy ifoda bilan qabul qilinadi.

Agar yuklamalar grafigi bir xil vaqt intervalida olingan zinapoya ko'rinishida bo'lsa, o'rta quvvat quyidagicha aniqlanadi:

$$P_{o'rt} = \frac{\sum_{i}^{n} Pi}{n}; \qquad (11.6)$$

O'rtacha kvadrat yuklama. Aktiv va reaktiv toklarning ma'lum intervaldagi o'rtacha kvadrat yuklamalari quyidagi munosabatlar bilan aniqlanadi:

$$P_{jx} = \sqrt{\frac{1}{T}\int_0^T P^2 dt};$$

$$Q_{jx} = \sqrt{\frac{1}{T}\int_0^T q^2 dt}; \qquad (11.7)$$

$$I_{jx} = \sqrt{\frac{1}{T}\int_0^T i^2 dt};$$

bu yerda: T – ko'rilayotgan vaqt oralig'i.

Agar grafik zinapoya ko'rinishiga ega bo'lsa,

$$P_{jx} = \sqrt{\frac{\sum_{1}^{n} P_i^2}{n}}; \quad Q_{jx} = \sqrt{\frac{\sum_{1}^{n} q_i^2}{n}}; \qquad (11.8)$$

bu yerda: $n = \frac{T}{\Delta t}$ - grafikning bir xil oraliqlari soni.

Hisobiy yuklama. Zamonaviy sanoat korxonasining elektr ta'minoti tizimini loyihalashda yechilishi kerak bo'lgan murakkab texnik-iqtisodiy masalalarning asosini kutilayotgan elektr yuklamalarni to'g'ri aniqlash tashkil etadi. Elektr yuklamalarni hisoblash har qanday elektr ta'minlash tizimini loyihalashda birinchi bosqich hisoblanadi. Elektr yuklamalarning ko'rsatkichlari elektr tizimiga sarf bo'ladigan kapital mablag'lar, rangli metallar sarfi, elektr energiyasining nobudgarchiligi va ekspluatatsiya

xarajatlarini belgilaydi. Agar hisobiy quvvatni oshirib aniqlansa, kapital mablag'larning ortishiga, tanqis bo'lgan elektr qurilmalar va o'tkazgichlarning to'la imkoniyat darajasida ishlamasligiga va elektr energiyasining nobudgarchiligi oshishiga sabab bo'ladi. Yuklamani kamaytirib aniqlash esa, elektr qurilmalarining tez ishdan chiqishiga, ayrim agregatlar ish unumdorligining kamayishiga, elektr ta'minoti tizimida nobudgarchiliklarning oshishiga, elektr energiyasi sifat ko'rsatkichlarining yomonlashishiga va elektr ta'minoti tizimining ishonchliligining kamayishiga olib keladi. Shuning uchun kutilayotgan yuklamalarni to'g'ri aniqlash elektr ta'minoti tizimini optimal loyihalashtirishning asosiy omilidir.

Hisobiy aktiv quvvat sifatida shunday davomli o'zgarmas yuklama qabul qilinadiki, uning ta'siridan o'tkazgich haroratining oshishi yoki izolyatsiyaning issiqlikdan eskirish darajasi kutilayotgan o'zgaruvchan yuklamadagiga ekvivalent bo'ladi.

Smena davomida ma'lum vaqt oralig'i (10 min. yoki 30 min. yoki 60 min. yoki.....) uchun olingan barcha o'rtacha quvvatlarning eng kattasi maksimal quvvat sifatida qabul qilinadi. Elektr ta'minoti tizimining elementlarini ularning qizishi nuqtai nazaridan qabul qilinsa, hisobiy quvvat sifatida 30 minutli maksimal yuklama olinadi. Bu vaqt oralig'i ko'ndalang kesim yuzasi kichik va o'rta bo'lgan o'tkazgichlarining qizish vaqt doimiyligiga yaqin hisoblanadi. Agar sex tarmoqlari o'tkazgichlarining qizish vaqt doimiyligi 0,5 soatdan katta bo'lsa, maksimum koeffisientining miqdori quyidagi munosabat orqali qayta hisoblanadi:

$$K_{mt} = 1 + \frac{K_m - 1}{\sqrt{2t}} \qquad (11.9)$$

Bu yerda: K_m-maksimum koeffisientining vaqt doimiyligi 0,5 soat bo'lgandagi qiymati; $K_{m\ t}$ - maksimum koeffisientining vaqt doimiyligi t bo'lgandagi qiymati.

O'tkazgich	qizish vaqt doimiyligi	Ko'ndalang kesim yuzasi, mm²					
		35	50	70	95	120	150
Ochiq holatdagi rezina izolyatsiyali o'tkazgichlar	min	9	12	15	18	21	21
O'sha o'tkazgichlar trubada	min	19	23	27	32	36	40
Qog'oz izolyatsiyali kabellar	min	15	20	25	30	35	40

Ko'ndalang kesim yuzasi har xil bo'lgan o'tkazgichlar uchun qizish vaqt doimiyligi T ning miqdorlari(min.) yuqoridagi jadvalda keltirilgan.

Ko'p hollarda joiz qizish bo'yicha 30 minutli maksimal yuklama hisobiy yuklama sifatida qabul qilingan. Umumiy holda maksimal, o'rtacha kvadrat, o'rtacha va hisobiy yuklamalar o'rtasida quyidagi munosabat saqlanadi:

$$P_{м} \geq P_{т} \geq P_{ўк} \geq P_{ўрт} \qquad (11.10)$$

O'zgarmas yoki deyarli o'zgarmas yuklamada ishlaydigan iste'molchilar uchun (ventilyatorlar, nasoslar, kompressorlarning elektr yuritgichlari)

$$P_{х} = P_{м} = P_{ўк} = P_{ўрт} \qquad (11.11)$$

Sex elektr tarmoqlari kuchlanishini tanlash

1000 Voltgacha bo'lgan sex elektr tarmoqlarida quyidagi kuchlanishli uch fazali tizimlar ishlatilish mumkin: 127-220 V; 220-380V; 380-660 V.

Kuchlanish 127 va 220 V bo'lgan uch fazali tizimni elektr ta'minoti uchun ishlatilsa, elektr energiyasi nobudgarchiligining miqdori katta bo'ladi va rangli metallning sarfi ko'p bo'ladi. SHuning uchun bunday tizimlar faqat yer osti qurilmalarida ishlatiladi. Sanoat korxonalarining elektr ta'minotida 220-380V tizim eng ko'p tarqalgan. Sex podstansiyasidagi kuch transformatorlarining ikkilamchi chulg'amlari yulduz sxemasida ulaniladi. Bunday holda faza liniyalariaro kuchlanish 380 V bo'lsa, nol va faza liniyalari orasidagi kuchlanish 220V ni tashkil etadi. Kuchlanishi 220-380 V tizim ishlatilganda yoritish uskunalari va elektr yuritgichlarni bir tizimga ulash mumkin.

Sex maydonining yuza birligiga to'g'ri keladigan solishtirma yuklama miqdori katta bo'lgan hollarda kuchlanishi 380-660 V bo'lgan uch fazali tizim ishlatiladi. Bunday tizim boshqalariga nisbatan quyidagi afzalliklarga ega:

1. Kuchlanishi 660 V bo'lgan sex tarmoqlari uchun rangli metall kam ishlatiladi; bunday tarmoqlarda elektr energiyasining nobudgarchiligi 380 V li tarmoqlarga nisbatan oz bo'ladi.

2. Kuchlanishi 660 V bo'lgan elektr yuritgichni 380 V li tarmoqka ulash mumkin. Buning uchun yuritgichning chulg'amlarini uchburchak sxemasida ulash kifoya.

3. Elektr yuritgichlarning quvvati 600-700 kW atrofida bo'lganda, ularni 660 V kuchlanishga tayyorlansa, qurilmaning texnik-iqtisodiy ko'rsatkichlari eng optimal bo'lishi isbotlangan.

4. Agar 660 V kuchlanish qabul qilinsa, sex podstansiyalarida katta quvvatli transformatorlarni(2500 kVA gacha) ishlatish mumkin.

Shu bilan birga kuchlanishi 660 V li tarmoqlarning quyidagi kamchiliklari mavjud:

1. Yoritish qurilmalarini elektr energiyasi bilan ta'minlash uchun maxsus 0,66/0,22 transformator o'rnatish kerak bo'ladi;

2. Kuchlanishni o'lchash zanjirlari uchun qo'shimcha 660/100 Voltli kuchlanish transformatorini ishlatishga to'g'ri keladi.

O'tkazgichlar, kabellar va shinalarning kesimlarini tanlash

O'tkazgichlar, kabellar va shinalarni tanlashda texnik va iqtisodiy omillarni hisobga olish kerak. Texnik omillar quyidagilardan iborat:

1. Ishchi (hisobiy) tok ta'sirida uzoq vaqt davomida qizish;

2. Qisqa tutashuv toki ta'siridan qisqa vaqt davomida qizish;

3. Normal va avariya holatlarda kuchlanish nobudgarchiligining miqdori;

4. Tashqi muhit kuchlariga (shamol, simning muz bilan qoplangan qismining og'irligi) va o'z og'irligi ta'siridan sodir bo'ladigan mexanik yuklamaga chidamliligi;

5. Atrof-muhit, kuchlanish va o'tkazgichning kesimiga bog'liq bo'lgan omil - tojlanishga chidamliligi.

Iqtisodiy omil deganda qabul qilingan o'tkazgichlar, kabellar va shinalarga ketadigan kapital va ekspluatatsiya xarajatlari tushuniladi. Yuqorida ko'rsatilgan omillar asosida kesimlarning quyidagi eng kichiklari aniqlanadi:

S_k - qizish bo'yicha minimal joiz kesim;

$S_{q.t}$ - q. t tokining termik ta'siriga bardoshliligi bo'yicha minimal joiz kesim;

S_m - mexanik mustahkamlik bo'yicha minimal joiz kesim;

S_k - tojlanishning shartlaridan kelib chiqadigan minimal joiz kesim;

$S_{\Delta v}$ - kuchlanish yo'qotuvi bo'yicha minimal joiz kesim.

Ishlab chiqarilgan kabellar uchun mexanik mustahkamlik va tojlanishning bo'lmasligi zavod tomonidan kafolatlanadi. Shuning uchun kabellarga S_m va S_k lar aniqlanmaydi.

Transformatorning quvvatini tanlash

Transformatorlar quvvatlari hisobiy yuklamalarga mos ravishda qabul qilinadi. SHu bilan birga transformatorning iqtisodiy ish rejimi va iste'molchilarning elektr ta'minoti bo'yicha ishonchlilikni ta'minlash ham hisobga olinadi. Me'yoriy sharoitda transformatorning yuklamasi uning tabiiy ishlash muddatini qisqartirishi kerak emas.

Transformatorning nominal quvvati deganda shunday yuklanish tushuniladiki, unda nominal ish sharoitida, belgilangan ishlash muddati davomida (taxminan 20 yil) transformator uzluksiz ishlay oladi. Transformatorning normal ish sharoitida quyidagi shartlar bajarilishi zarur:

1. Sovituvchi muhitning harorati - 20 °C;
2. Transformator yog'ining o'rtacha harorati atrof-muhit haroratidan 44°C ga (M va D sovitish tizimlari uchun) yoki 36°C ga (DS, S sovitish tizimlari uchun) oshmasligi kerak;
3. Chulg'amning eng qizigan nuqtasidagi harorat uning o'rtacha haroratidan 13°C ga oshmasligi zarur;
4. Qisqa tutashuv nobudgarchiligining salt ishlash nobudgarchiligiga nisbati taxminan beshga teng bo'lishi kerak;
5. Izolyatsiya harorati o'rtacha (85°C) haroratga nisbatan 6°C o'zgarsa, uning ishlash muddati ikki marotabaga o'zgaradi;
6. O'tish jarayonlarida transformator yog'ining yuza qismidagi harorat 95°C dan, chulg'am metallining eng qizigan qismining harorati esa 140° C dan oshmasligi kerak.

Atrof-muhit haroratining oshishi transformator izolyatsiyasi eskirishini tezlashtiradi. Atrof-muhitning yillik o'rtacha harorati $\theta_{o'rt} \neq 5^0 C$ bo'lsa, transformatorning nominal quvvati uning pasportida ko'rsatilgan quvvatdan farqli bo'ladi, ya'ni

$$S_{nn} = S_{nmn}\left(1 + \frac{5 - \theta_{yqish}}{100}\right) \qquad (11.12)$$

$K_{yu} = \frac{S_{yu}}{S_{nmn}}$ -yuklanish koeffisienti;

S_{yu} -transformatorining yuklamasi;

S_{nmn} -transformatorning pasportida ko'rsatilgan quvvat.

Sanoat korxonalari iste'molchilarining elektr ta'minotida zarur bo'lgan qudratli transformatorlarning soni, quvvati va tiplarini tanlashda quyidagi tartib tavsiya etiladi:

1. Podstansiyada o'rnatiladigan transformatorlarning soni iste'molchilarning elektr ta'minotining ishonchliligiga bo'lgan talabidan kelib chiqadi. Masalan, birinchi toifali iste'molchilar uchun podstansiyaga ikkita transformator o'rnatilishi maqsadga muvofiqdir.

2. Podstansiyadagi transformatorlar quvvatini hisobiy to'la quvvat asosida tanlanadi.

$$S_{X\Sigma} = \sqrt{P_{X\Sigma}^2 + Q_{X\Sigma}^2} \qquad (11.13)$$

Bu yerda: $P_{R\Sigma}$, $Q_{X\Sigma}$ - korxonaning hisobiy aktiv va reaktiv quvvatlari. $Q_{X\Sigma}$ aniqlanganda korxonada o'rnatilgan reaktiv quvvatni kompensatsiyalovchi qurilmalarning quvvatini hisobga olish kerak.

Reaktiv quvvatni liniya va transformatorlar orqali uzatish elektr energiyasining qo'shimcha nobudgarchiligiga, kuchlanish yo'qotuvining oshishiga va ta'minot tizimiga ketadigan xarajatlarning ortishiga olib keladi.

1. Liniya va transformatorlardan reaktiv quvvat o'tishi natijasida qo'shimcha aktiv quvvat va energiya nobudgarchiligi sodir bo'ladi. Agar R qarshilikka ega bo'lgan liniya orqali P va Q quvvatlari uzatilsa, aktiv quvvat nobudgarchiligi quyidagicha aniqlanadi:

$$\Delta P = I^2 R = \left(\frac{S}{U}\right)^2 R = \frac{P^2+Q^2}{U^2} R = \frac{P^2}{U^2} R + \frac{Q^2}{U^2} R = \Delta P_u + \Delta P_p \qquad (11.14)$$

Demak, reaktiv quvvatni liniyadan uzatish natijasida qo'shimcha aktiv quvvat nobudgarchiligi ($\Delta P_p = \frac{Q^2}{U^2} R$) sodir bo'lib, uning qiymati Q ning kvadratiga to'g'ri proporsionaldir. Shuning uchun elektr stansiyalari generatorlaridan iste'molchilarga reaktiv quvvat uzatish maqsadga muvofiq emas.

2. Aktiv va reaktiv qarshiliklari R va X bo'lgan energetika tizimi elementidan P va Q quvvatli energiya uzatilganda undagi kuchlanishning yo'qotuvi quyidagicha topiladi:

$$\Delta U = IR\cos\varphi + IX\sin\varphi = \frac{UI\cos\varphi}{U} R + \frac{UI\sin\varphi}{U} X = \frac{P}{U} R + \frac{Q}{U} X = \Delta U_u + \Delta U_p \qquad (11.15)$$

Bu yerda: ΔU_a - aktiv quvvatni uzatish bilan bog'liq bo'lgan kuchlanishning yo'qotuvi; ΔU_p - reaktiv quvvatni uzatish bilan bog'liq bo'lgan kuchlanishning yo'qotuvi.

Demak, reaktiv quvvat uzatilishi natijasida elektr ta'minoti tizimi elementida qo'shimcha kuchlanish yo'qotuvi ($\Delta U_p = \frac{Q}{U} x$) sodir bo'lib, uning miqdori Q va X larga to'g'ri proporsionaldir.

3. Korxona elektr ta'minoti tizimining katta miqdorda reaktiv quvvat bilan yuklanishi havo va kabel liniyalarining kesimi oshishiga va transformatorlar quvvatlarining ortishiga olib keladi. Ma'lumki, liniyalarning kesimlari va transformatorlarning quvvatlari hisobiy tok va to'la quvvat bo'yicha qabul qilinadi.

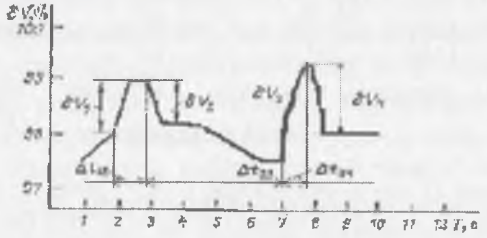
Agar

$$S_X^2 = P_X^2 + Q_X^2, \quad I_X^2 = \frac{P_X^2}{U_X^2} + \frac{Q_X^2}{U_X^2} \qquad (11.16)$$

ekanligini e'tiborga olsak, S_x va I_x qiymatlarni Q ning hisobiga qo'shimcha ortishini ko'ramiz. Shuning uchun, reaktiv quvvat elektr ta'minoti tizimi elementning o'tkazish qobiliyatini kamaytiradi deyiladi.

Masala yechish namunalari

11.1-masala. 900 sek. oralig'ida 4,5% amplitudali 10 ta va 40 ta 3% amplitudadagi kuchlanishning quloch yoyishini qayd qilindi. Bunday tarmoqdan lyuminessent lampalarining energiya bilan ta'minlanishi joizligini aniqlang.



Yechish: Yuqoridagi 3 egri chiziqdan

$$\delta V_1 = 4{,}5\%; \quad \Delta_1' = 45 \text{ sek}$$

$$\delta V_2 = 3\%; \quad \Delta_2' = 10 \text{ sek}$$

Kuchlanishning qulochlarni sodir bo'lishi mumkin bo'lgan minimal oralig'ini aniqlaymiz

$$T = 10 \cdot 4{,}5 + 40 \cdot 10 = 850 < 900$$

Shunday qilib, tarmoqning ushbu nuqtasiga lyuminessent lampalarini ulash mumkin ekan.

11.2-masala. Taqsimlash punktiga ulangan yuritgichlar guruhining cho'qqi tokini aniqlang. Elektr motorlarning nominal ko'rsatkichlari quyidagi jadvalda ko'rsatilgan.

Iste'molchining raqami	Nominal quvvati	FIK	cosφ/tgφ	K_I	λ	I_n	I_{ISH}
1	4	0,80	0,8/0,75	0,15	2,5	9,5	24
2	4	0,80	0,8/0,75				
3	10	0,86	0,83/0,68	0,2	5	21,3	106
4	10	0,86	0,83/0,68				
5	5	0,82	0,93/0,68	0,2	5	10	50
6	5	0,82	0,93/0,68				

Yechish:

Guruh iste'molchilarining effektiv sonini aniqlash

$$n_э = \frac{\sum_1^6 (P_{ni})^2}{\sum_1^6 P_{ni}^2} = \frac{38^2}{(2 \cdot 4^2 + 2 \cdot 10^2 + 2 \cdot 5^2)} = \frac{38^2}{32 + 200 + 50} = \frac{1600}{280} \approx 6$$

Aktiv va reaktiv yuklamalar:

$$P_y = \sum_1^6 P_{yi} = \sum_1^6 K_n \cdot P_{Hi} = 0{,}15 \cdot 8 + 0{,}2 \cdot 20 + 0{,}2 \cdot 10 = 1{,}2 + 4 + 2 = 7. \text{ kW}$$

$$Q_y = \sum_1^{} P_y \cdot tg\varphi = 1{,}2 \cdot 0{,}75 + 4 \cdot 0{,}68 + 2 \cdot 0{,}68 = 0{,}9 + 4{,}08 = 4{,}28 \text{ kVar}$$

Guruhiy ishlatilish koeffisientini topamiz:

$$K_{na} = \frac{P_y}{\sum P_{Hi}} = \frac{7{,}2}{38} \approx 0{,}19$$

Taqsimlash punkti ulangan yuritgichlarning hisobiy toki

$$I_X = \frac{S_X}{\sqrt{3}\ U_H} = \frac{\sqrt{(K_M P_y)^2 + Q_y^2}}{\sqrt{3}\ U_H} = \frac{\sqrt{(2{,}2 \cdot 7{,}2)^2 + 4.28^2}}{\sqrt{3} \cdot 0.380} = 24.8A$$

$n_э = 6$ va $K_{na} = 0{,}19$ bo'lganda, maksimum koeffisienti $K_M = 2{,}2$

Elektr yuritmalarning ishga tushirish toklari

$$I_{ишга12} = \gamma \frac{P_H}{\sqrt{3} \cdot U_H \cdot \cos\varphi \cdot \eta} = 2{,}5 \frac{4}{1{,}73 \cdot 0{,}38 \cdot 0{,}8 \cdot 0{,}8} \approx 24A$$

$$I_{ишга4} = 5 \cdot \frac{10}{0{,}66 \cdot 0{,}83 \cdot 0{,}86} \approx 106A$$

$$I_{ишга45} = 5 \cdot \frac{5}{0{,}66 \cdot 0{,}93 \cdot 0{,}82} = 50A$$

Maksimal tok uchinchi va to'rtinchi yuritmalarda

$$I_{ишга4} = 106A$$

Yuqoridagi munosabatdan yuritmalarning cho'qqi toki

$$I_ч = 109{,}5 + (24{,}8 - 0{,}2 \cdot 21{,}3) = 130A$$

11.3-masala. Mexanika sexining hisobiy yuklamasini tartiblangan diagramma usuli bilan aniqlang. Ma'lumotlar jadvalda keltirilgan.

Korxonaning yillik ishlash vaqti

Smenaning davomiyligi, soat	Smenalar soniga qarab T_y soat		
	Bir	Ikki	Uch
8	2250	4500	6600
7	2000	4000	5870

Yechish:

Mexanika sexining barcha elektr iste'molchilarini ish rejimiga asosan ikki guruhga bo'lamiz. Yuklama grafigi o'zgaruvchan elektr iste'molchilar guruhi va yuklama grafigi kam o'zgaruvchan elektr iste'molchilar guruhi.

Elektr iste'molchilarining hujjatidagi ma'lumotlar asosida 1÷5 bandlarni to'ldiramiz.

I guruh iste'molchilari uchun

$$m = \frac{P_{H\,max}}{P_{H\,min}}$$

O'rtacha aktiv va reaktiv yuklamalarni maksimal yuklangan smena uchun hisoblaymiz.

$P_y = P_H \cdot K_H$; $Q_y = P_y tg\alpha$; $m = \frac{P_{H\,max}}{P_{H\,min}} = 2{,}5 \le 3$ bo'lgan iste'molchilar guruhi uchun $n_{эф} = n$ qabul qilamiz.

I guruh uchun ishlatish koeffisientini hisoblaymiz.

$$K_u = \frac{P_y}{P_H} = \frac{76,4}{304} = 0,25$$

K_i va n_{ef} ga bog'liq holda jadvaldan $K_M$ni aniqlaymiz.

Aktiv hisobiy yuklamani aniqlaymiz

$$P_x = P_{yrm} K_u$$

n_{EF}>10 bo'lgani uchun, qabul qilish mumkin:

$$Q_x = Q_y$$

I – guruh uchun hisobiy to'la yuklama quyidagicha aniqlanadi:

$$S_x = \sqrt{P_x^2 + Q_x^2}$$

2-guruh iste'molchilari uchun 9- va 10- bandlarni 1-guruh iste'molchilarning aniqlash tartibiga o'xshab aniqlanadi.

Yuklama grafigi kam o'zgaradigan iste'molchilar uchun maksimum koeffisienti 1 ga teng deb olinishi mumkin, ya'ni.

$$P_x = P_y \text{ va } Q_x = Q_y$$

1- va 2-guruh elektr iste'molchilarning P_X va Q_X natijalarini qo'shib, mexanika sexining umumiy P_X va Q_X larini aniqlanadi, keyin olingan natijalar asosida mexanika sexining to'la yuklamasi hisoblanadi:

$$S_x = 462,8 \text{ kVA}$$

11.4-masala. Uch fazali tizimda E_A=220 V E_B=210 V E_C=210 V. Fazalararo burchaklar teng. Nosinusoidallik koeffisientining miqdorini aniqlang.

Echish.

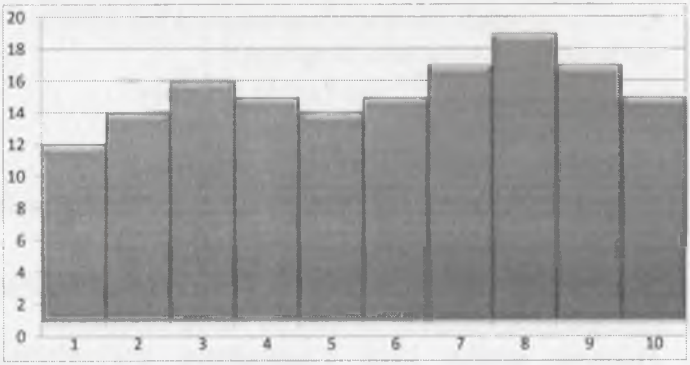
$$E_2 = \frac{1}{3}(E_A + a^2 E_B + aE_C) = \frac{1}{3}[(220 + 210(-\frac{1}{2} - j\frac{\sqrt{3}}{2}) + 210(-\frac{1}{2} + j\frac{\sqrt{3}}{2})] = 3,33 \text{ V}$$

$$K_{HC} = \frac{E_2}{E_H} 100\% = \frac{3,3}{220} \cdot 100 = 1,5\%$$

Demak, $K_{HC} < 2\%$ shuning uchun nosimmetriklik joiz chegarada ekan.

Elektr ta'minoti tizimida kuchlanishning nosimmetrikligi tarmoq elementlarining va iste'molchilarning ishlash rejimiga salbiy ta'sir etadi

11.5-masala. Quyidagi ko'rsatilgan grafik uchun o'rtacha va o'rtacha kvadrat quvvatni aniqlang:



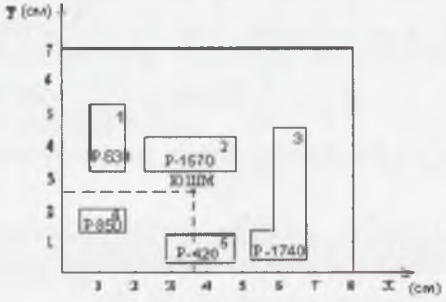
Grafik uchun o'rtacha quvvatni aniqlang

$$P_{o'rt} = \frac{12+14+16+15+14+15+17+19+17+15}{10} = \frac{154}{10} = 15{,}4 \text{ W}$$

Yuqorida keltirilgan grafik uchun o'rtacha kvadrat yuklama miqdorini aniqlang.

$$P_{kv} = \sqrt{\frac{12^2+14^2+16^2+15^2+14^2+15^2+17^2+19^2+17^2+15^2}{10}} = \sqrt{\frac{2406}{10}} = 15{,}5 \text{ kVt}$$

11.6-masala. Quyidagi rasmda ko'rsatilgan korxonaning elektr yuklamalari markazining koordinatalarini aniqlang:



11.1 – rasm. Koxonaning bosh rejasi

Yechish: Yuklama joylashishining markazi sex maydonining og'irlik markazi bilan to'g'ri keladi deb qabul qilib, ushbu korxona

sexlarining koordinatalarini aniqlaymiz. Buning uchun zavod rejasida koordinat o'qlarini chizamiz.

$x_1 = 1{,}3\,\text{sm}$ $x_2 = 3{,}5\,\text{sm}$ $x_3 = 5{,}8\,\text{sm}$ $x_4 = 1\,\text{sm}$ $x_5 = 3{,}8\,\text{sm}$

$y_1 = 4{,}2\,\text{sm}$ $y_2 = 3{,}5\,\text{sm}$ $y_3 = 2{,}5\,\text{sm}$ $y_4 = 1{,}6\,\text{sm}$ $y_5 = 0{,}8\,\text{sm}$

Korxona elektr yuklamasi markazining koordinatalarini aniqlaymiz:

$$X_0 = \frac{630 \cdot 1{,}3 + 1570 \cdot 3{,}5 + 1740 \cdot 5{,}8 + 850 \cdot 1 + 420 \cdot 3{,}8}{630 + 1570 + 1740 + 850 + 420} = \frac{18852}{5210} = 3{,}6sm$$

$$y_0 = \frac{630 \cdot 4{,}2 + 1570 \cdot 3{,}5 + 1740 \cdot 2{,}5 + 850 \cdot 1{,}6 + 420 \cdot 0{,}8}{630 + 1570 + 1740 + 850 + 420} = \frac{14187}{5210} = 2{,}7sm$$

11.7-masala. Podstansiyada o'rnatilgan ikkita S_{nmn}=10MVA quvvatli transformatorlarning iqtisodiy maqsadga muvofiq rejimlari aniqlansin. Transformatorning texnik ko'rsatkichlari quyidagicha: ΔP_{cu}=15kW, ΔP_{qm}=58 kW, U_K=10,5%, I_{su}=0,75%.

Yechish. Bitta transformatordagi nobudgarchiliklar yuqorida keltirilgan formulalar orqali quyidagicha aniqlanadi:

$$\Delta Q_{cu} = 10 \cdot \frac{0{,}75}{100}\ kVar$$

$$\Delta Q_{km} = 10 \cdot \frac{10{,}5}{100} = 1050\ kVar$$

$$\Delta P'_{cu} = 15 + 0{,}05 \cdot 75 = 19\ kW$$

$$\Delta P'_{km} = 58 + 0{,}05 \cdot 1050 = 110\ kW$$

Bu yerda nobudgarchilikning o'zgarish koeffisienti miqdori K_o=*0,05 kW/kVar* deb qabul qilinadi.

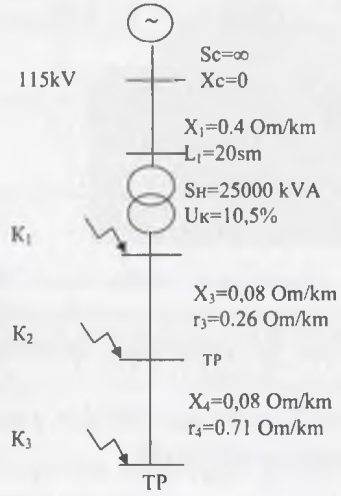
$$\Delta P'_T = \Delta P'_{cu} + K_{ko}^2 \Delta P'_{km} = 19 + K_{ko}^2 = 110\ kW$$

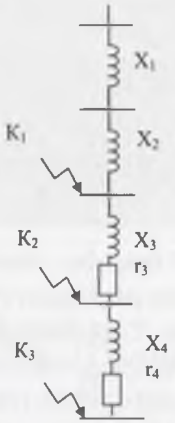
$$S_A = 10 \cdot \sqrt{2\frac{19}{110}} \approx 5{,}8MBA = 110\ kW$$

Demak, podstansiyaning yuklamasi 5,8 MVA dan kam bo'lsa, faqat bitta transformator yuklanishi kerak. Agar yuklama bu miqdordan katta bo'lsa, ikkala transformatorni parallel ulab ishlatish zarur.

11.9-masala. Cheksiz quvvatli sistemadan ta'minlanayotgan iste'molchilar uchun K_1, K_2, K_3 nuqtalardagi qisqa tutashuv toklarini hisoblang.

Hisob ma'lumotlari rasmda keltirilgan.





Yechish:

1) Hisobni nisbiy birlikda olib boramiz. Bazis quvvatni qabul qilamiz: $S_6 = 100\,\text{MVA}$.

2) Bazisli nisbiy qarshilikni hisoblaymiz:

a) EUL qarshiligi

$$x_1 = x_0 \cdot l / U^2_{HOM} = 0{,}4 \quad 20 \quad 100/115^2 = 0{,}06$$

b) transformator qarshiligi:

$$x_2 = \frac{U_K\,\%}{100} \cdot \frac{S_6}{S_T} = \frac{10{,}5}{100} \cdot \frac{100}{25} = 0{,}42$$

v) podstansiyadan taqsimlash uskunasigacha bo'lgan kabel liniyasi qarshiligi:

$$x_3 = X_0 \ell \frac{S_6}{U_H^2} = 0{,}08 \cdot 0{,}5 \cdot \frac{100}{10{,}5^2} = 0{,}04$$

$$r_3 = r_0 \ell \frac{S_6}{U_H^2} = 0{,}26 \cdot 0{,}5 \cdot \frac{100}{10{,}5^2} = 0{,}14$$

g) TP gacha bo'lgan kabel liniyasining qarshiligi

$$x_4 = X_0 \ell \frac{S_б}{U_н^2} = 0{,}08 \quad 1{,}6 \quad 100/10{,}5^2 = 0{,}14$$

$$r_4 = r_0 \ell \frac{S_б}{U_н^2} = 0{,}71 \quad 1{,}6 \quad 100/10{,}5^2 = 1{,}25$$

3) K_1 nuqtasida q.t. toki va quvvati

$$I_{K1} = I_б / X_{\Sigma 1} = 5{,}3/0{,}48 = 11{,}04 kA$$

bu yerda $X_{\Sigma 1} = x_{\quad} + x_{\quad} = 0{,}06 + 0{,}42 = 0{,}48$

$$I_б = \frac{S_{\quad}}{\sqrt{3}U} = \frac{100}{1.7 \quad 10.5^2} = 5.3\ kA$$

$$i_y = K_{y1}\sqrt{2} I_{K1} = 1.8\sqrt{2} \cdot 11{,}04 = 28{,}1\ kA$$

$$S_{\quad} = S_б / X_{\Sigma 1} = \frac{100}{0{,}48} = 208\ MVA$$

4. K_2 nuqtasida q.t. toki va quvvati

$$I_{K2} = I_б X_{\Sigma 2} = 5{,}3/0{,}52 = 10{,}2 \text{ kA}$$

bu yerda $X_{\Sigma 2} = x_1 + x_2 + x_3 = 0{,}06 + 0{,}42 + 0{,}04 = 0{,}52$

$$i_y = 1.8\sqrt{2} \quad 10{,}2 = 25{,}96\ kA$$

$$S_{K2} = S_б / X_{\Sigma 2} = 100/0{,}52 = \frac{100}{0{,}52} = 192 \text{ MVA}$$

5. K_3 nuqtasida q.t. toki va quvvati

$$I_{K3} = I_б / Z_{\Sigma 3} = 5{,}3/\sqrt{0{,}66^2 + 1{,}39^2} = 5{,}3/1{,}54 = 3{,}44 \text{ kA}$$

bu yerda: $X_{\Sigma 3} = X_{\Sigma 2} + x_4 = 0{,}52 + 0{,}14 = 0{,}66$

$$r_{\Sigma 3} = r_3 + r_4 = 0{,}14 + 1{,}25 = 1{,}39$$

$X_{\Sigma 3} / r_{\Sigma 3} = \frac{0{,}66}{1{,}39}$ bo'lgani uchun, 3 fazali qisqa tutashuv tokining davriy tarkibi karraligi K_U=1

$$\text{unda } i_y = 1 \cdot \sqrt{2} \cdot 3{,}44 = 4{,}86 кA$$

$$S_{K3} = S_б / Z_{\Sigma 3} = 100/1{,}54 = 64.9 MVA$$

Mustaqil yechish uchun masalalar

11.10-masala. Bir smena ichida 380 ming m³ siqiq havo ishlab chiqaruvchi kompressorlarning hisobiy yuklamasini aniqlang. Smena davomi - 8 soat. Elektr energiyasining solishtirma sarfi 80 kVt · soat /ming m³.

Javob: P_h=3800 kW.

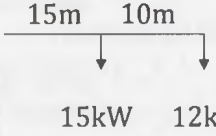
11.11-masala. Mashinasozlik zavodining mexanik sexi hisobiy quvvatini aniqlang. Ishlab chiqarish maydonining 1 m² ga to'g'ri keladigan solishtirma hisobiy quvvat $P_o = 300 \text{W/m}^2$sex yuzasi $F = 18000$ m².

Javob: P_h=5400 kW.

11.12-masala. Uch fazali tizimda E_A=220 V, E_B=210 V, E_C=210 V. Fazalararo burchaklar teng. Nosinusoidallik koeffisientining miqdorini aniqlang.

Javob: $K_{nc} = 1{,}5\%$

11.13-masala. Sxemasi rasmda keltirilgan ko'ndalang kesimi 3x25 mm² APV – 660 simdan bo'lgan, kuchlanishi 380 V uch fazali tarmog'idagi kuchlanish yo'qotilishini aniqlang. Yuklama uchun *cosα=0,85*



Javob: $_{\Delta}U\% = 0{,}47\%$

11.14-masala. Ikkita ko'prikli kranlar uchun burchaksimon po'lat trolley tanlansin. Trolleyning uzunligi 55 m. Kranlar o'rtacha rejimda ishlaydilar. Har bir kran 3 tadan asinxron motorlar bilan jihozlangan. Birinchi krandagi o'rnatilgan quvvat P_1=52kW, ikkinchisidagi - P_2=33kW, η=0,915. Eng katta quvvatli motorning nominal va ishga tushirish toklari I_n=75A, $I_{it\,maks}$=300A.

Javob: Qabul qilingan trolleyning joiz toki 345A, ya'ni $I_j > I_x$ shart bajariladi.

Kuchlanishning nisbiy yo'qotuvi %	Burchaksimon po'latning o'lchamlari, mm, cho'qqi toklari, A.		
	50x50x5	60x60x6	75x75x8
0,17	277	334	427
0,18	304	368	472
0,19	331	402	520
0,2	358	436	562

11.15-masala. Po'lat shina o'tkazgichining hisobiy toki *I_x=115A*, iste'molchining quvvat koeffisienti cosφ=0,65. Kuchlanishning yo'qotuvi 3% dan oshmasligi zarur. Shinaning uzunligi 60m. Sexning po'lat shina o'tkazgichi tanlansin.

Javob: 1) *l=60/2=30m,* 2) $_{\Delta}U\%=2,72\%$, 3) kuchlanish yo'qotuvi 3% dan kichik bo'lganligi uchun o'lchamlari (100x4)bo'lgan tasmasimon po'lat shina qabul qilamiz.

11.16-masala. Podstansiyada o'rnatilgan ikkita S_{ntr}=10MVA quvvatli transformatorlarning iqtisodiy maqsadga muvofiq rejimlari aniqlansin. Transformatorning texnik ko'rsatkichlari quyidagicha: ΔP_o=15kW, ΔP_k=58 kW, U_K=10,5%, I_{su}=0,75%;

Javob: Podstansiyaning yuklamasi 5,8 MVA dan kam bo'lsa faqat bitta transformator yuklanishi kerak. Agar yuklama bu miqdordan katta bo'lsa, ikkala transformatorni parallel ulab ishlatish zarur.

11.17-masala. Korxona bosh pasaytiruvchi podstansiyasidagi transformatorning soni va quvvatini, maksimal yuklama $S_{MAX} = 220$ kVA va maksimum vaqti 2,5 soat bo'lganda aniqlang. O'rtacha kunlik yuklama $S_v = 19000$ kVA. I va II kategoriya iste'molchilari 73% S_{MAX} ni tashkil qiladi.

Javob: Transformatorning tanlangan quvvati (2x16000kVA) korxonani normal va avariya holatlarida elektr bilan ta'minlaydi.

12-BOB. ELEKTR YURITMALAR

Elektr yuritmadagi elektr motor valiga ta`sir etuvchi momentlarning muvozanat tenglamasi:

$$\pm M_{em} = M_s \pm M_{din} = M_s \pm J\frac{d\omega}{dt} \qquad (12.1)$$

bunda, M_{em}- elektr motor validagi aylantiruvchi moment, $N \cdot m$, M_s - statik moment, $N \cdot m$, M_{din}- ishga tushirish va tormozlashda paydo bo`ladigan dinamik moment, $N \cdot m$, $J$ - massa va aylanuvchi detallarning inersiya radiusiga bog`liq inersiya moment, $kg \cdot m^2$, $d\omega/dt$ - elektr motor valining burchak tezlanishi, rad/s^2.

Mexanik tizimdagi barcha harakatlanuvchi qismlarning motor o`qiga keltirilgan inersiya momenti:

$$J = m \cdot \rho^2 = GD^2/4g \qquad (12.2)$$

bunda, G - jismning og`irligi, $D = 2\rho$ (ρ-inersiya radiusi), $g = 9{,}81\ m/s^2$ – erkin tushish tezlanishi.

12.2-formuladagi GD^2 - kattalik siltash moment deb ataladi. Uning qiymati har bir motor qo`zg`aluvchi qismi uchun ma`lumotnomalarda beriladi va bu kattalik o`zgarmas bo`ladi.

Qarshilik momentining tezlikka bog`liqligi:

$$M_s = M_{so} + (M_{sn} - M_{so})(\frac{\omega}{\omega_n})^x \qquad (12.3)$$

bunda, x – tezlik o`zgarishi bilan qarshilik momentini o`zgarishini xarakterlovchi daraja ko`rsatkichi, M_{so} - salt ishlash moment, M_{sn} - nominal qarshilik momenti, ω_n - nominal tezlik, ω - M_s qarshilik momentidagi mexanizmning tezligi.

Qarshilik momentlarini bitta o`qga keltirish:

$$M_{kel} = M_{sm}\frac{1}{i_1 \cdot i_2 \cdot \ldots \cdot i_n \cdot \eta_1 \cdot \eta_2 \cdot \ldots \cdot \eta_n} \qquad (12.4)$$

bunda, n - mexanik uzatmadagi elementlar soni, M_{sm} - n-element-dagi qarshilik momenti, i - mexanik uzatmaning uzatish soni, η - mexanik uzatmaning F.I.K.i.

Inersiya momentlarini bitta o`qga keltirish:

$$J_{kel} = J_m + J_1\frac{1}{i_1^2} + J_2\frac{1}{i_1^2 \cdot i_2^2} + \ldots + J_n\frac{1}{i_1^2 \cdot i_2^2 \cdot \ldots \cdot i_n^2} \quad yoki \quad J_{kel} = \sum_{i=1}^{n} m_i \cdot r_i^2$$

$$yoki \quad J_{kel} = \rho^2 \sum_{i=1}^{n} m_i = m \cdot \rho^2 \qquad (12.5)$$

bunda, J_m - elektr motorning inersiya momenti, $J_1, J_{2,...}$ - mexanik uzatmalarning inersiya momentlari, m – jism massasi, kg, r – m massaning o`g`irlik markazidan aylanish o`qigacha bo`lgan eng qisqa masofa, m, ρ - inersiya radiusi.

Ilgarilanma harakatda elektr motor valiga keltirilgan mexanizmning qarshilik momenti:

$$M_{kel} = Fv/\omega_m\eta \qquad (12.6)$$

bunda, F - mexanizmning qarshilik kuchi, N, v - ilgarilanma harakatning chiziqli tezligi, m/s, ω_m – motor valining burchak tezligi, rad/s.

Elektr yuritmaning harakat tenglamasi:

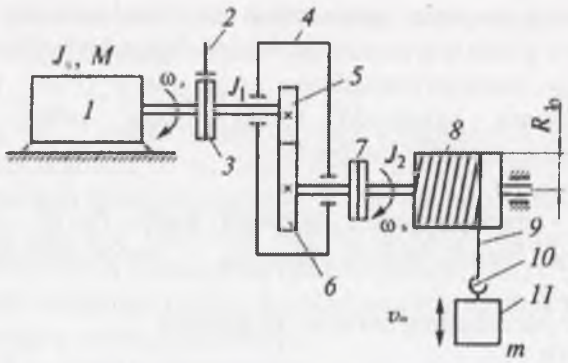
$$\sum F = m\frac{dv}{dt} = ma \text{ (ilgarilanma harakatda)} \qquad (12.7)$$

$$\sum M = J\frac{d\omega}{dt} = J\varepsilon \text{ (aylanma harakatda)} \qquad (12.8)$$

Masala yechish namunalari

12.1-masala. 12.1-rasmda yuk chig'irining elektr yuritmasining kinematik sxemasi berilgan. Elektr motor(1) ω - burchak chastotasi bilan aylanma mexanik harakat hosil qilyapti. Bir pog'onali uzatish qurilmasi (reduktor) (4) esa shu ω chastotani 5 va 6 tishli uzatmalar orqali ω_b chastota bilan yuk chig'irining barabaniga (8) uzatmoqda. O'z navbatida arqon (9) va ilgich (10) orqali chig'ir m massali yuk (11) ni ϑ chiziqli tezlik bilan ko'taradi. Bu sxemada shkiv (2) mexanik to'xtatish vazifasini bajaradi. Kinematik sxema bir massali mutloq qattiq va mexanik elementlarning tirqishlaridagi jarayonlar hisobga olinmaydi.

Masalaning berilishi: Motorning inersiya moment $J_D = 0{,}1\ kg \cdot m^2$; tishli uzatma (5) va muftalar(3)ning inersiya momentlari $J_1 = 0.02\ kg \cdot m^2$; tishli uzatma(6), mufta(7) va baraban(8)larning inersiya moment $J_2 = 2\ kg \cdot m^2; m = 1000\ kg$; chig'ir baraban radiusi R_b=1,15 m; 5 va 6 tishli uzatmalarning tishlar soni Z_1=14, Z_2=86; Tishli uzatmaning foydali ish koeffitsenti $\eta_r = 0.97$; barabanning foydali ish koeffitsenti $\eta_b = 0.96$; erkin tushish tezlanishi g=9.81 m/s². Yuk chig'irining yuklama momentini elektr motor valiga keltiring.



12.1-rasm. Yuk chig`iri elektr yuritmasining kinematik sxemasi: 1-elektr motor, 2-mexanik tormoz, 3,7-mexanik muftalar, 4- pog'onali uzatish qurilmasi (reduktor), 5,6-tishli uzatmalar, 8-yuk chig`irining barabani, 9-arqon, 10-ilgich, 11-yuk

Yechish:

Reduktorning uzatishlar sonini va kinematik sxemaning keltirilgan radusini aniqlaymiz.

$$i = \frac{Z_2}{Z_1} = \frac{86}{14} = 6.14$$

$$\rho = \frac{\vartheta_{io}}{\omega} = \frac{R_b}{i} = \frac{0.15}{6.14} = 0.025\ m$$

Bir massali sxemaning yig'indi inersiya mamentini aniqlaymiz.

$$J = J_D + J_1 + \frac{J_2}{i} + m\rho^2 = 0.1 + 0.02 + \frac{2}{6.14^2} + 1000 \cdot 0.025^2 = 0.8\ kg \cdot m^2.$$

Yukning keltirilgan momentini topamiz.

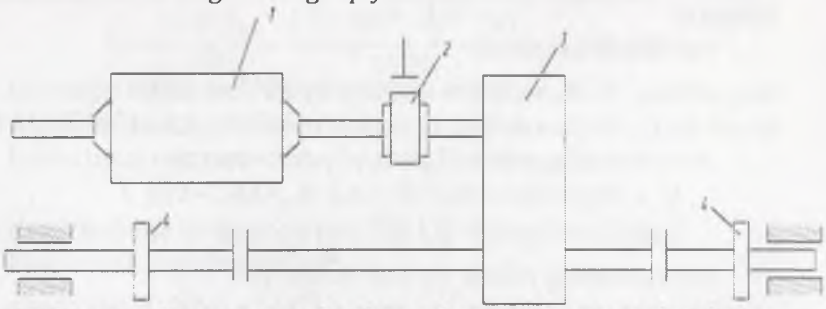
$$M_s = (mg\rho)/\eta_r\ \eta_b = 1000 \cdot 9.81 \cdot 0.025/097 \cdot 0.96 = 263\ N \cdot m$$

12.2-masala. Ko`priksimon kranning xarakatlanuvchi aravachasining qarshilik momentini va inersiya momentini motor valiga keltirilgan qiymatini hisoblang.

Ko'priksimon kanning xarakatlanuchi aravachasining elektr yuritmasi

Aravachaning ishlash ketma – ketligi.Aravacha kranning bir boshdan ikkinchi boshiga xarakat qiladi. Dastlabki xolat. Aravacha eng oxirgi xolatida turibti. Kranning ko'taruvchi mexanizmining

ilgaki pastka tushirilgan, yuk ilgakka ilingan. Mexanizm tarmoqqa ulanib yuk yuqoriga ko'tariladi, yuk eng baland nuqtaga chiqariladi va to'xtatiladi, aravacha xarakatga keltiriladi, aravacha kranning bir tomonidan ikkinchi tomoniga o'tkazilib to'xtatiladi va kran ko'prigi ishga tushirilib kerakli joyga xarakatlantiriladi va to'xtatiladi. YUk pastga tushiriladi, yukni ilgakdan olinadi, ilgan yuqoriga ko'tarilib, kran xarkatga kelib oldingi xolatiga qaytadi. Aravacha xarakatlantirilib oldingi xolatiga qaytariladi va to'xtatiladi.



12.2-rasm. Kran aravachasi xarakatlanish mexanizmining kinematik sxemasi:1 – elektr motor, 2 – tormozlovchi shkiv, 3 – reduktor; 4 – harakatlanuvchi aravacha

Masalaning berilishi:
Aravachaning og`irligi $G_T = 5\ t$
Yukning og`irligi $G_\Gamma = 25\ t.$
G`ildirakning diametri $Д_K = 0.5$ m.
Aravachaning harakatlanish tezligi $V_T = 75$ m/min.
Safning diametri $d_{ts} = 0.07$ m.
Ko`tarish va tushirish vaqti $t_2 = 1{,}2\ min.$
Harakatlanish vaqti $t_2 = 1{,}2\ min.$

Yechish.
Elektr yuritmaning quvvat va qarshilik momentini hisoblash.

$$M_{TR} = \frac{G_\Sigma \cdot d_{ts} \cdot \mu_{ts}}{2} = \frac{60 \cdot 0.5 \cdot 0.1}{2} = 1.5kN \cdot m$$

bu erda, μs – podshipnikning sirpanish koeffitsenti: μ_s = 0,015 ÷ 0.15.

G Σ – yuk va aravachaning og'irliklarini yig'indisi

$$G_{\Sigma} = 2 \cdot (C_T + G_G) = 2(5+25) = 60 \cdot 10^3 kg$$

Podshipnikning quvvati

$$P_{TR} = \frac{G_{\Sigma} \cdot d_{ts} \cdot \mu_{ts} \cdot V_T}{\eta \cdot Д_K} = \frac{60000 \cdot 0.5 \cdot 0.1 \cdot 75}{0.8 \cdot 0.07 \cdot 60} = 67kw$$

bu erda η – foydali ish koeffitsienti η ≈ 0,8, D_K – aravachaning diametri, V_T – aravachaning xarakatlanish tezligi, D_{ts}– sapfning diametri.

Tebranish momenti

$$M_K = G_{\Sigma} f = 60000 \cdot 8 \cdot 10^{-4} = 48 \text{ N} \cdot \text{m}$$

bu yerda, f – tebranishning sirpanish koeffitsient f = (5÷12) $\cdot 10^{-4}$

Aravachaning yuki bo'lgan yig'indi momenti

$$M = M_{ST} + M_{SK} = (G_T + G_G) \cdot d_{TS} \cdot \mu_{TS} \cdot 2(G_T + G_K) \cdot f$$

$$+ M_{SK} = (5+25) \cdot 10^3 \cdot 0.5 \cdot 0.1 \cdot 2 \cdot (5+25) \cdot 10^3 \cdot 8 \cdot 10^{-4} + 48 = 67.2Nm$$

Aravachaning yuksiz yig'indi momenti

$$M_{SP} = G_T \cdot d_{ST} \cdot \mu_{ST} + 2G_T \cdot f = 5000 \cdot 0.5 \cdot 0.1 + 2 \cdot 50000 \cdot 8 \cdot 10^{-4} = 258Nm$$

12.3-masala. Ishqalanish shkivi va muvozanatlangan arqonli shaxta ko'targichi keltirilgan inersiya moment hisoblansin. Ko'targichning ish unumdorligi 2520 kN/soat. Yuritma ishqalanish shkivi bilan umumiy o'qda bo'lgan ikkita elektr motor orqali amalga oshiriladi.

Masalaning berilishi:

Shaxtaning chuqurligi N=915 m

Foydali yukning og'irlik kuchi G=58.8 kN.

Har bir quttining og'irligi G_k=58.8 kN.

Har bir quttidagi vagonchalarning og;irligi G_b=58.8 kN.

Bosh va muvozanatlovchi arqonlarning 1 m ga to'g'ri keladigan umumiy og'irlik kuchi G_{arq}=106 N/m.

Ishqalanish shikivining diametri $d_{sh.i}$=6.44 m.

Ishqalanish shkivining og'irlik kuchi $G_{sh.i}$=143 kN.

Ishqalaninsh shkivining inersiya diametri $D_{sh.i}$=0.67 $d_{sh.i.}$

Yo'naltiruvchi shkivlar diametri $d_{y.sh}$=5 m.

Har bir yo'naltiruvchi shkivning og'irlik kuchi $G_{sh.i}$=47.5 kN.

Yo'naltiruvchi shkivning inersiya diametri $D_{y.sh}$=0.7 $d_{y.sh.}$

Ko'targichningnominal tezligi v_n=16 m/s.

Ko'tarishdagi tezlanish a_1=0.89 m/s².

Ko'tarishdagi sekinlanish tezlanishi a_s=1 m/s².

Siklning davri t_s=89.2 s.

Ishqalanish foydali yukning 20% ga ko'payishida hisobga olinadi.

Yechish:

Quyidagi formula bo'yicha dvigatelning taxminiy quvvatini aniqlaymiz.

$$P_n = \frac{1.2GJ_n}{1000} = \frac{1.2 \cdot 58.8 \cdot 10^3 \cdot 16}{1000} = 1130\ kW$$

Dinamik momentlarning ta'sirini oldindan 1.25 koeffitsiyent bilan hisobga olamiz.

Ikkita motorning zaruriy quvvatini hisoblaymiz:

$$P = 1.25P_n = 1.25 \cdot 1130 = 1400\ kW$$

Har bir motorning quvvatini 700 kW deb qabul qilamiz.

Motorning nominal tezligi:

$$\omega = \frac{2J_n}{d_{sh.i}} = \frac{2 \cdot 16}{6.44} = 4.96 \frac{rad}{s}\ (47.5\ ayl/min)$$

700 kW quvvatga va ω =4.96 rad/s ga ega bo'lgan dvigatel uchun J=27.3103 kg·m² ikkita dvigatelning inersiya moment: 2·J=54.6 ·10³ kg ·m²

Qarshilik momentini ishqalanish shkivi aylanmasi bo'yicha ta'sir etayotgan hisobiy zo'riqish bo'yicha hisoblaymiz:

$$M_s = 1.2G\frac{d_{sh.i}}{2} = 1.2 \cdot 58.8 \cdot 3.22 = 227\ kN \cdot m$$

Tezlanish vaqti:

$$t_1 = \frac{J}{a_1} = \frac{16}{0.89} = 18\ s$$

Qutining tezlanish davomida bosib o'tgan yo'li:

$$h_1 = \frac{a_1 t_1}{2} = \frac{0.89 \cdot 18^2}{2} = 144.3\ m$$

Sekinlashish vaqti:

$$t_s = \frac{J_n}{a_s} = \frac{16}{1} = 16\ s$$

Qutining sekinlanish davomida bosib o'tgan yo'li:

$$h_s = \frac{a_s t_s^2}{2} = 1 \cdot \frac{256}{2} = 128\ m$$

Turg'un (o'rnatilgan) tezlikda harakatlanishga to'g'ri keladigan yo'l:

$$h_2 = H - h_1 - h_s = 915 - 144.3 - 128 = 642.7\ m$$

Turg'un (o'rnatilgan) harakat vaqti:

$$t_2 = \frac{h_2}{J_n} = \frac{642.7}{16} = 40.2\ s$$

Pauza vaqti:

$$h_2 = H - h_1 - h_s - t_2 - t_s = 89.2 - 18 - 40.2 - 16 = 15\ s$$

Dinamik momentni aniqlash uchun tizimning dvigatel o'qiga keltirilgan umumiy inersiya momentini aniqlaymiz.

Ishqalanish kuchining inersiya moment:

$$J_{sh.i} = m_{sh.i} \cdot R_{sh.i}^2 = 143 \cdot \frac{10^3}{9.81 \cdot 4} \cdot (0.67 \cdot 6.44)^2 = 69.5 \cdot 10^3\ kg \cdot m^2$$

Yo'naltiruvchi shkivining inersiya moment:

$$J_{y.sh} = m_{y.sh} \cdot R_{y.sh}^2 = 47.5 \cdot \frac{10^3}{9.81 \cdot 4} \cdot (0.7 \cdot 5)^2 = 14.8 \cdot 10^3\ kg \cdot m^2$$

Yo'naltiruvchi shkivining aylanish tezligi:

$$\omega_{y.sh} = \frac{2J_n}{d_{y.sh}} = \frac{2 \cdot 16}{5} = 6.4 \cdot 10^3 \frac{rad}{s}$$

Ikkala yo'naltiruvchi shkivlarning dvigatel o'qiga keltirilgan inersiya moment:

$$J = 2J_{y.sh}\left(\frac{\omega_{y.sh}}{\omega_d}\right) = 2 \cdot 14.8 \cdot 10^3 \frac{6.4}{4.96} = 49.5 \cdot 10^3\ kg \cdot m^2$$

Tizimning barcha aylantiruvchiqismlarining keltirilgan inersiya moment:

Tizimning ilgarilama harakatdagi qismlarining og'irlik kuchi:

$$G_{umum} = G + 2G_{kl} + 2G_b + G_{arq}L_{ark} =$$

$$58.8 + 2 \cdot 47.75 + 2 \cdot 29.4 + 0.106 \cdot 1920 = 416.7\ kN$$

bu yerda:

$$L_{ark} \gg 2H + 90 = 2 \cdot 915 + 90 = 1920\ m$$

90 m ishqalanish shkivi va yo'naltruvchi shkiv g'ildiraklarini orab olish hisobiga qo'shiladi:

Tizimning ilgarilama harakatlanayotagan massalaridan keltirilgan umumiy inersiya moment:

$$J_2 = \frac{G_{umum} J_n^2}{9.81 \cdot \omega_d^2} = \frac{416.7 \cdot 16^2 \cdot 10^3}{9.81 \cdot 4.96^2} = 442 \cdot 10^3\ kg \cdot m^2$$

Barcha tizimning keltirilgan inersiya moment:

$$J = J_1 + J_2 = (173.6 + 442) \cdot 10^3 = 615.6 \cdot 10^3\ kg \cdot m^2$$

Yuritmaning tezlanayotgandagi inersiya moment:

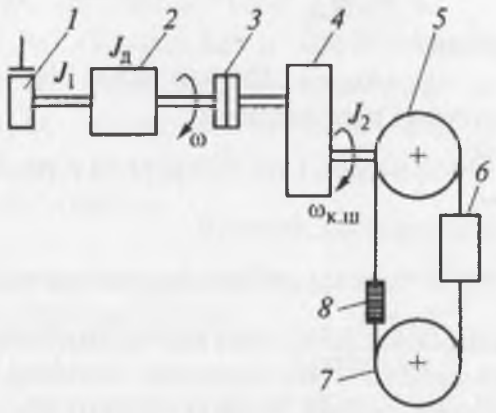
$$M_{din.s} = \frac{-d\omega}{dt} = -615.6 \cdot 10^3 \cdot \frac{4.96}{16} = -190.5 \cdot 10^3 Nm = -190.5 kNm$$

Dvigatel moment: $M = M_s + M_{din}$

Tezlanish: t_1=18 s; M_1=227+171=398 kN·m

Turg'un (o'rnatilgan) rejim: t_2=40.2 s; M_2=227 kN·m

12.4-masala. 12.3 – rasmda kinematik sxemasi ko'rsatilgan yuk lifti 1500 kg yuk ko'tarilishi va tushirish jarayonidagi qarshilik moment aniqlansin.



12.3-rasm. Yuk liftining kinematik sxemasi. 1-tormoz, 2-elektr motor, 3-mufta, 4-reduktor, 5-shkiv, 6-kabina, 7-arqon, 8-muvozanatlovchi yuk

Masalaning berilishi:

Liftning nominal tezligi: $v = 0.75$ m/s

Yetaklovchi kanat shkivining diametri: $D_{sh} = 0.8$ m

Reduktopning uzatish soni: $i = 53$

Kabinaning xususiy massasi: $M_o = 3200$ kg

Yukning nominal massasi: $M = 1500$ kg

Muvozanatlash koeffitsienti: $\alpha = 0.45$

Liftning foydali ish koeffitsienti: $\eta = 0.7$
Yurgizishda talab qilingan tezlanish: $a = 0.5$ m/s^2
Bip soatdagi ish davrlari soni: $N = 65$ marta
Ko'tarish balandligi: $H = 9$ m
Zaxira koeffitsienti: $K_z = 1.4$

Yechish:

Liftning tormozlash va yurgizish vaqti

$$t_{yur} = t_{to'x} = v_{nom} / a = 0.75/0.50 = 1.50 \text{ s}$$

Barqaror tezlikda harakatlanish masofasi

$$H_{bar} = H - 2\frac{v_{nom} \cdot t_n}{2} = 9 - 0.75 \cdot 1.50 = 7.88 \text{ m}$$

Barqaror tezlikda harakatlanish vaqti

$$t_{bar} = \frac{H_{bar}}{v_{nom}} = 7.88/0.75 = 10.5 \text{ s}$$

Yukning og'irligi

$$G_{nom} = m_{nom} \cdot g = 1500 \cdot 9.81 = 14715 \text{ kg}$$

Yukni ko'tarishdagi statik moment:

$$M_{ST1} = \frac{(1-\alpha) \cdot G \cdot D_{k.sh.}}{2 \cdot i \cdot \eta_{l.nom}} = (1-0.45) \cdot 14715 \cdot 0.80/(2 \cdot 53 \cdot 0.70) = 87.3 \text{ N·m}$$

Yukni tushirishdagi statik moment:

$$M_{ST2} = \frac{\alpha \cdot G_{nom} \cdot D_{k.sh.}}{2 \cdot i \cdot \eta_{l.nom}} = (0.45 \cdot 14715 \cdot 0.80)/(2 \cdot 53 \cdot 0.70) = 71.4 \text{ N·m}$$

12.5-masala. Markazdan qochma kuchga asoslanib ishlaydigan nasos qurilmasi statik momentini hisoblang va statik moment va chastotaga bog'liqlik tavsifi grafigini chizing.

Korxona suv ta'minoti tizimida o'rnatilgan markazdan qochma nasos quyidagi nominal texnik ko'rsatkichlarga ega: suv uzatishi Q=100 m^3 / soat, bosim kuchi hosil qiluvchi balandlik H = 32 m.

Yechish:

Nasos qurilmasi uchun elektr motor tanlash uning statik momenti qiymati asosida tanlanadi. Shuning uchun nasos qurilmasining mexanik tavsifini hisoblash kerak bo'ladi. Buning uchun nasos qurilmasining mexanik quvvatini hisoblab aniqlaymiz:

$$Nu = \rho \cdot g \cdot Q \cdot H / \eta = 0{,}1 \cdot 9{,}81 \cdot 360 \cdot 32 / 0{,}8 = 14 \text{ kW}$$

Markazdan qochma motorning nominal tezligi $\omega_{н} = 154c^{-1}$ ga va mos ravishda statik momenti $M_{сн} = \frac{N}{\omega_{н}} = \frac{14000}{154} = 90{,}9Нм$ ga teng. Nasos qurilmasini boshqarish uchun chastotani o'zgartirib tezligi rostlanadigan asinxron elektr yuritma tanlangan ekan unda nasos qurilmasining statik momentini chastotaga bog'liq tavsifini hisoblaymiz.

Nasos qurilmasi uchun statik momentning boshlang'ich qiymatini nominal qiymatining 10% ni tashkil etadi, ya'ni $M_{бош} = 0{,}1 \cdot M_{ном} = 0{,}1 \cdot 90{,}9 = 9{,}09Нм$ ga teng. Nasos qurilmasining statik momentining chastotaga bog'liq o'zgarishi quyidagi formula bilan hisoblanadi

$$M_C = 9{,}09 + 80{,}9 \cdot \alpha^2 \cdot (1-s)^2.$$

$\alpha = 1$, $M_C = 10 + 80{,}9 \cdot (1-0{,}019)^2 = 87{,}9Н \cdot м$;

$\alpha = 0{,}8$, $M_C = 10 + 80{,}9 \cdot 0{,}8^2 \cdot (1-0{,}019)^2 = 59{,}8Н \cdot м$;

$\alpha = 0{,}6$, $M_C = 10 + 80{,}9 \cdot 0{,}6^2 \cdot (1-0{,}019)^2 = 28Н \cdot м$;

$\alpha = 0{,}4$, $M_C = 10 + 80{,}9 \cdot 0{,}4^2 \cdot (1-0{,}013)^2 = 22Н \cdot м$;

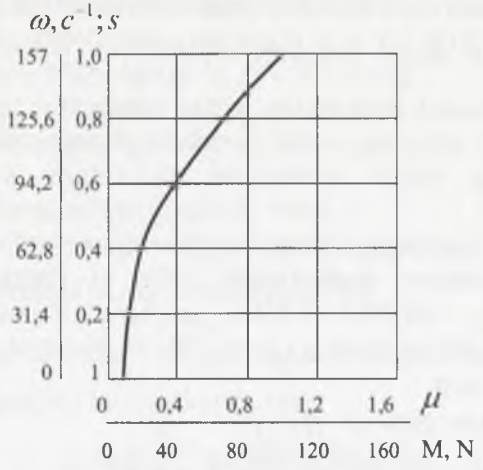
$\alpha = 0{,}2$, $M_C = 10 + 80{,}9 \cdot 0{,}2^2 \cdot (1-0{,}013)^2 = 13Н \cdot м$;

$\alpha = 0$, $M_C = 10Н \cdot м$.

Nasos qurilmasining hisoblangan statik momenti qiymatlarini quyidagi jadvalga qayd qilamiz.

Statik moment ko'rsatkichlari	Chastota, $\alpha = \frac{f_1}{f_{1н}}$					
	0	0,2	0,4	0,6	0,8	1
$\mu_c = \frac{M_C}{M_{сн}}$	0,11	0,15	0,25	0,32	0,68	1
M_S, Nm	10	13	22	28	59,8	87,9

Yuqorida qayd qilingan nasos qurilmasining mexanik tavsifi ko'rsatkichlari asosida statik moment va chastotaga bog'liqlik tavsifi grafigini chizamiz (12.4 – rasm).



12.4 – rasm. Nasos qurilmasining mexanik tavsifi

Mustaqil yechish masalalar

12.6-masala. Elektr yuritma motori validagi o`zgarmas qarshilik momenti 13 N·m ga teng, aylanuvchi massalarning inersiya momenti 0,22 kg·m^2. Agar Δt=1 s vaqtda aylanish chastotasi 100 ayl/min dan oshmasa, motor rotori qanday moment hosil qilishi kerak?

12.7-masala. Massasi 45 kg li mexanizmning inersiya radiusi 0,25 m. Agar Δt=1 s vaqtda aylanish chastotasi 100 ayl/min dan oshmasa, motorning ishga tushirishdagi qarshilik momentining eng katta o`zgarishi aniqlansin? O`zgarmas qarshilik momenti 15 N·m.

12.8-masala. Elektr motor valida nominal quvvat 1,1 kW, nominal aylanish chastotasi 950 rad/min. Agar yuklamaning o`zgarmas qarshilik momenti 23; 34,5; 46 N·m bo`lsa, reduktor qanday uzatish koeffisientiga ega bo`lishi kerak? Reduktorning F.I.K.i 96 %. Har bir holda aylanish chastotasi aniqlansin?

13-BOB. ELEKTRONIKA ASOSLARI

Yarim o'tkazgichli asboblar

Diodning o'zgarmas tokka qarshiligi:

$$R_0 = \frac{U_a}{I_a}, \qquad (13.1)$$

bunda, U_a – to'g`ri yo'nalishdagi diod kuchlanishi, $V$; $I_a$ – to'g`ri yo'nalishda diod orqali o'tuvchi tok, A.

Diodning o'zgaruvchan tokka qarshiligi (differensial qarshilik):

$$R_i = \frac{\Delta U_a}{\Delta I_a}, \qquad (13.2)$$

bunda ΔU_a - to'g`ri kuchlanish o'zgarishi, $V$; $\Delta I_a$ - to'g`ri kuchlanish ta'sirida to'g`ri tokning o'zgarishi, A.

Diod volt-amper xarakteristikasi qiya (tik)ligi:

$$S = \frac{\Delta I_a}{\Delta U_a}, \qquad (13.3)$$

Diod anodidagi quvvat isrofi:

$$P_a = I_a U_a, \qquad (13.4)$$

Tranzistorning o'zgaruvchan tokka kirish qarshiligi:

$$R_{кир} = \frac{\Delta U_{кир}}{\Delta I_{кир}}, \qquad (13.5)$$

bunda $\Delta U_{кир}$ - kirish kuchlanishi o'zgarishi, V; $\Delta I_{кир}$ - kirish kuchlanish o'zgarishi ta'sirida kirish tokining o'zgarishi, A.

Koeffisientlar:

umumiy emitterli sxemada baza (asos) tokini kuchaytirish

$$h_{21э} = \frac{\Delta I_k}{\Delta I_б}, \qquad (13.6)$$

umumiy bazali sxemada emitter tokini uzatish

$$h_{21б} = \frac{\Delta I_k}{\Delta I_э}, \qquad (13.7)$$

bunda $\Delta I_k, \Delta I_б, \Delta I_э$ - mos holda kollektor, baza, emitter toklari o'zgarishi.

Baza tokini kuchaytirish koeffisienti $h_{21э}$ va emitter tokini uzatish koeffisienti $h_{21б}$ orasidagi bog`lanish

$$h_{21э} = \frac{h_{21б}}{(1 - h_{21б})}, \quad (13.8)$$

Kollektordagi quvvat isrofi

$$P_к = I_к U_к, \quad (13.9)$$

bunda $I_к$ - kollektor toki, *A*, $U_к$ - kollektordagi kuchlanish, *V*.

To'g`rilagichlar

Bitta yarim davrli to'g`ri lagichda to'g`ri langan kuchlanishning o'rtacha qiymati

$$U_{урт} = \frac{U_m}{\pi} = 0{,}318 U_m. \quad (13.10)$$

Ikki yarim davrli to'g`ri lagichda to'g`ri langan kuchlanishning o'rtacha qiymati

$$U_{урт} = \frac{2U_m}{\pi} = 0{,}636 U_m. \quad (13.11)$$

Bir yarim davrli to'g`ri lagich uchun to'g`rilangan kuchlanish

$$U_0 = \frac{U_{2m}}{\pi}, \quad (13.12)$$

bunda U_{2m} - transformator ikkilamchi cho'lg`ami kuchlanishi amplitudasi.

Ikki yarim davrli to'g`ri lagich va ko'prik sxema uchun

$$U_0 = \frac{U'_{2m}}{\pi}, \quad (13.13)$$

bunda U'_{2m} - transformator ikkilamchi chulg`ami kuchlanishi amplitudasi yarimi.

Diodga qo'yilgan eng katta teskari kuchlanish:

bir yarim davrli to'g`ri lagich va ko'prik sxema uchun

$$U_{теск} = U_{2m}, \quad (13.14)$$

ikki yarim davrli o'rta nuqtali to'g`ri lagich uchun

$$U_{теск} = U'_{2m}, \quad (13.15)$$

To'g`ri langan kuchlanishning pulsatsiya koeffisienti

$$K_п = \frac{U_{1m}}{U_0}, \quad (13.16)$$

bunda U_{1m} - yuklamadagi kuchlanish birinchi garmonika amplitudasi.

Silliqlash koeffisienti

$$q = \frac{K_{п\,кир}}{K_{п\,чик}}, \quad (13.17)$$

bunda $K_{п\,кир}$, $K_{п\,чик}$ - silliqlovchi filtr kirish va chiqish pulsatsiya koeffisienti.

Elektron kuchaytirgichlar

Kuchlanish bo'yicha kuchaytirish koeffisienti

$$K_U = \frac{U_{чик}}{U_{кир}} \qquad (13.18)$$

bunda $U_{кир}, U_{чик}$ - kuchaytirish kirishi va chiqishidagi kuchlanishlar.

Kuchlanish bo'yicha kuchaytirish koeffisientining desibellarda ifodalanishi

$$K_U = 20 \lg K \qquad (13.19)$$

Ko'p kaskadli kuchaytirgichning kuchaytirish koeffisienti

$$K = K_1 \cdot K_2 \cdot \ldots \cdot K_n \text{ yoki } K_{дб} = K_{1дб} + K_{2дб} + \ldots + K_{ндб} \qquad (13.20)$$

bunda K_1, K_2, ..., K_n - alohida kaskadlar kuchaytirish koeffisienti.

Kuchaytiruvchi kaskadning chastota buzilish koeffisienti

$$M = \frac{K_0}{K} \qquad (13.21)$$

bunda K_0 – o'rta chastotalardagi kuchaytirish koeffisienti, K – ishchi diapazonning biror-bir chastotadagi kuchaytirish koeffisienti.

Chastota buzilishi koeffisientining desibelldagi ifodasi

$$M_{дб} = 20 \lg M \qquad (13.22)$$

Ko'p kaskadli kuchaytirgichning chastota buzilish koeffisienti

$$M_{ум} = M_1 \cdot M_2 \cdot \ldots \cdot M_n \text{ yoki } M_{умдб} = M_{1дб} + M_{2дб} + \ldots + M_{ндб} \qquad (13.23)$$

Lampali kaskadning o'rta chastotalardagi kuchaytirish koeffisienti

$$K_0 = \frac{\mu R_{ю}}{(R_{ю} + R_i)} \qquad (13.24)$$

bunda μ - elektron lampaning statik kuchaytirish koeffisienti, R_i – o'zgaruvchan tokka elektron lampaning ichki qarshiligi, Om, R_{yu} – anod yuklamasi qarshiligi, Om.

O'rta chastotalardagi tranzistor kaskadi kuchaytirish koeffisienti

$$K_0 = h_{21э} \frac{R_{ю}}{R_{кир}} \qquad (13.25)$$

bunda h_{21e} – umumiy emitterli sxemada baza toki statik kuchaytirish koeffisienti, R_{yu} –kollektor yuklamasi qarshiligi, Om, R_{kir} –tranzistor kirish qarshiligi, Om.

Lampali kuchaytirish kaskadi katod zanjiridagi avtomatik siljish qarshiligi

$$R_к = \frac{E_c}{I_{к0}} \qquad (13.26)$$

bunda E_c – siljish kuchlanishi, V, $I_{k\,0}$ – katod tokining o'zgarmas tashkil etuvchisi, A.

Emitterli temperatura stabilizatsiyali sxemadan foydalanilgan tranzistorli kaskaddagi kuchlanish siljishi

$$I_{БЭ} = I_{бул} - I_{э0}R_э \qquad (13.27)$$

bunda $I_{бул} = \frac{E_К}{R_1 + R_2}$ - tranzistorning baza zanjiridagi bo'luvchining o'zgarmas toki, I_{e0} – emitter tokining o'zgarmas tashkil etuvchisi.

Katod (emitter) zanjiridagi ajratuvchi kondensator si\imi

$$C \geq \frac{10}{2\pi f_к R} \qquad (13.28)$$

bunda f_k – kuchaytiriluvchi tebranishlar spektrining quyi chastotasi, R – katod (emitter) zanjiridagi rezistor qarshiligi, Om.

Kuchaytirgichning elektr F.I.K.

$$\eta = \frac{P_{чик}}{P_0} \qquad (13.29)$$

bunda $P_{чик}$ - kuchaytirgich chiqishidagi quvvat, P_0 - kollektorli (anodli) ozuqa manbai sarflanuvchi quvvat.

Yuklamada ajralib chiquvchi quvvat

$$P_ю = \eta_Т P_{чик} \qquad (13.30)$$

bunda $\eta_Т$ - chiqish transformatorining F.I.K., $P_{чик}$ - tranzistor beruvchi quvvat.

Transformatorning birlamchi chulg`ami bo'yicha qayta щisoblangan yuklama qarshiligi (keltirilgan qarshilik).

$$R'_ю = \frac{R_ю}{n^2} \qquad (13.31)$$

bunda R_{yu} – yuklama qarshiligi, n – chiqish transformatorining transformatsiya koeffisienti.

Teskari manfiy bog`lanishli kaskadning kuchaytirish koeffisienti

$$K_0^* = \frac{K_0}{(1 + K_{тб} K_0)} \qquad (13.32)$$

bunda K_0 – kaskadning manfiy teskari bog`lanish(MTB) kiritilgunga qadar kuchaytirish koeffisienti, $K_0$ –teskari bog`lanish koeffisienti.

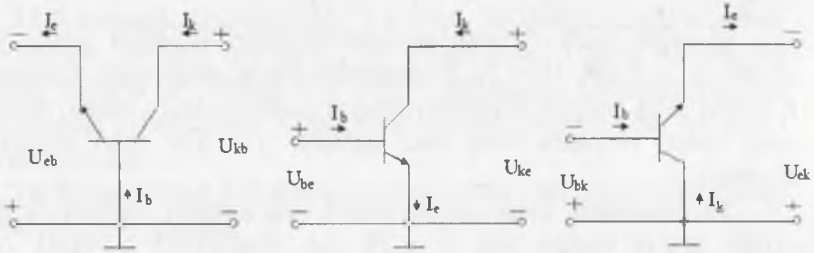
Tebranish konturining moniyligi

$$Q = \frac{Z_T}{\Gamma_к} \qquad (13.33)$$

bunda Z_T - konturning to'lqin qarshiligi, Om, $\Gamma_к$ - isroflar qarshiligi, Om.

Masala yechish namunalari

13.1-masala. Umumiy emitterli sxema bo'yicha ulangan tranzistor KT315A da baza toki *0,1 mA* ga o'zgardi. Agar baza tokini uzatish koeffisienti $h_{21б} = 0{,}975$ bo'lsa, emitter toki o'zgarishini toping.



13.1-rasm. Tranzistorning sxemaga ulash usullari

Yechish: (13.6) va (13.8) formulalardan foydalanib, kollektor toki o'zgarishini aniqlaymiz:

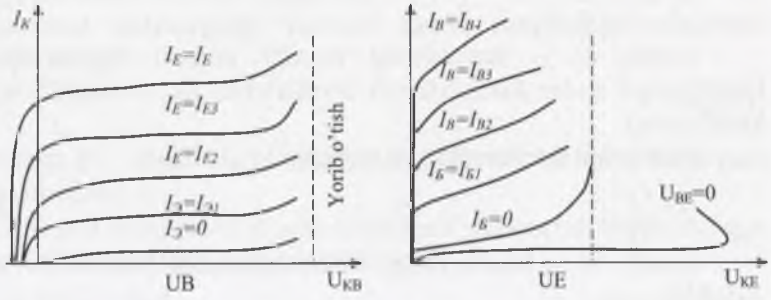
$$\Delta I_к = h_{21э} \Delta I_б = \frac{h_{21б} \Delta I_б}{(1 - h_{21б})} = \frac{0{,}975 \cdot 0{,}1}{(1 - 0{,}975)} = 3{,}9\ мА$$

Emitter toki o'zgarishini topamiz:

$$\Delta I_э = \Delta I_к + \Delta I_б = 3{,}9 + 0{,}1 = 4\ мА.$$

13.2-masala. Umumiy emitterli sxemadagi KT339A tranzistorning chiqish xarakteristikalari oilasi (3.1 - rasm)ga ko'ra kollektor toki $I_к = 6\ мА$, kollektordagi quvvat isrofi $P_к = 72\ мВт$

bo'lgan ishchi nuqtadagi baza toki $I_б$ va kollektor kuchlanishi $U_к$ ni aniqlang.



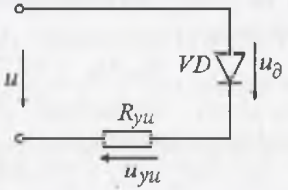
13.2– rasm. Umumiy baza (UB) va umumiy emmiter sxemada ulangan tranzistorning chiqish tavsiflari

Yechish: Yuqorida keltirilgan(13.9) formulaga ko'ra kollektordagi kuchlanish $U_к$ ni aniqlaymiz:

$$U_к = \frac{P_к}{I_к} = \frac{72 \cdot 10^{-3}}{6 \cdot 10^{-3}} = 12 \text{ V}$$

Shunday qilib, chiqish xarakteristikalarida ishchi nuqta ning щolati $I_k = 6\ mA$, $U_k = 12\ V$ qiymatlar bilan aniqlanadi. Tranzistor KT339A ning chiqish xarakteristikalari oilasiga ko'ra ishchi nuqta *A* ning holati bo'yicha baza toki qiymati $I_b = 150\ mkA$ ekanligini topamiz.

13.3-masala. Bitta yarim davrli to'g`rilagich sxemasida diod orqali to'g`ri langan tok $I_0 = 75\ mA$ o'tadi(13.3 - rasm). Agar transformator ikkilamchi chulg`ami kuchlanishi amplitudasi $U_{2m} = 200V$ bo'lsa, yuklama qarshiligi R_{yu} ni aniqlang.



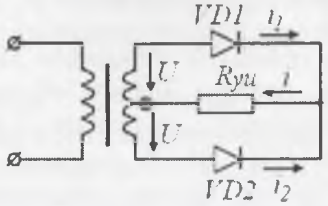
13.3 – rasm. Bitta yarim davrli to'g`rilagich sxemasi

Yechish: Yuklamadagi to'g`ri langan kuchlanish $U_0 = \frac{U_{2m}}{\pi}$.

Yuklama qarshiligi

$$R_{io} = \frac{U_0}{I_0} = \frac{U_{2m}}{\pi I_0} = \frac{220}{3.14 \cdot 75 \cdot 10^{-3}} = 850\,\text{Om}.$$

13.4-masala. To'g`rilagichning ikki yarim davrli sxemasi transformatori ikkilamchi chulg`ami kuchlanishi amplitudasi $U_{2m}^{'} = 210$ V(4.2 - rasm). Agar yuklama qarshiligi $R_{yu} = 500\ Om$ bo'lsa, щar bir dioddan o'tuvchi to'g`ri langan tok I_0 ni toping.



13.4 – rasm. Bitta yarim davrli to'g`rilagich sxemasi

Yechish: To'g`rilangan kuchlanish ga asosan $U_0 = \frac{2U_{2m}^{'}}{\pi}$.

Diod orqali o'tuvchi tok $I_0 = \frac{U_0}{2R_{io}} = \frac{U_{2m}}{\pi R_{io}} = \frac{210}{3{,}14 \cdot 510} = 131\,\text{mA}.$

13.5-masala. Qarshiliklari $R = 25\,Om$ bo'lgan chiziqli rezistor, $R_H = 500\,Om$ bo'lgan yuklama va ideal diod o'zaro ketma-ket ulangan hamda $e = 950\sin 314t$ EYK manbaidan ta'minlanmoqda. Yuklamadagi kuchlanish o'zgarmas tashkil etuvchisini va aktiv quvvatni toping.

Yechish: Manba EYuKning musbat yarim davrida yuklamadagi kuchlanish oniy qiymati:

$$u_{yu} = \frac{R_{yu}}{R + R_{yu}} e = \frac{500}{250 + 500} 950\sin 314t = 632\sin\alpha \quad (0 < \alpha < \pi)$$

Kuchlanishning doimiy tashkil etuvchisi

$$U_{yu(0)} = U_{yu(o'r)} = \frac{1}{2\pi}\int_0^{2\pi} u_{yu}\,d\alpha = \frac{1}{2\pi}\int_0^{\pi} 632\sin\alpha d\alpha = \frac{632}{\pi} \approx 200\,V.$$

Yuklamadagi aktiv quvvat

$$P = \frac{1}{2\pi}\int_0^{2\pi} pd\alpha = \frac{1}{2\pi}\int_0^{2\pi} \frac{U_{yu}^2}{R_{yu}} = \frac{1}{2\pi}\int_0^{2\pi} \frac{632^2}{500}\sin^2 \alpha d\alpha =$$

$$= \frac{800}{2\pi}\int_0^{\pi} \sin^2 \alpha d\alpha = \frac{800}{4\pi}\int_0^{\pi} (1-\cos 2\alpha) d\alpha =$$

$$\frac{200}{\pi}\int_0^{\pi} d\alpha - \frac{200}{\pi}\int_0^{\pi} \cos 2\alpha d\alpha = 200 - \frac{200}{2\pi}(0-0) = 200 \text{ Vt.}$$

13.6-masala. Induktivli silliqlovchi filtri bo'lgan ikki yarim davrli to'g`rilagich sxemasi uchun silliqlash koeffisienti *q* ni aniqlang. Transformator ikkilamchi ikkilamchi chulg`ami kuchlanishi amplitudasi 300 V, yuklama orqali o'tuvchi to'g`ri langan tok I_0 = *200 mA*, tarmoq chastotasi f_T = *50 Gs*, drossel induktivligi L_f = *10 Gn*.

Yechish:

Yuklamadagi to'g`rilangan kuchlanish

$$U_0 = \frac{2U_{2m}^{'}}{\pi} = \frac{2 \cdot 300}{3.14} = 191 \text{ V}$$

Yuklama qarshiligi

$$R_{yu} = \frac{U_0}{I_0} = \frac{191}{200 \cdot 10^{-3}} = 955 \text{Om}$$

Silliqlash koeffisienti

$$q = \frac{K_{n\,kup}}{K_{n\,chik}} = \frac{X_{1\phi}}{R_{yu}} = \frac{2\pi f_n L_\phi}{R_{yu}} = \frac{2 \cdot 3{,}14 \cdot 50 \cdot 2}{955} = 6{,}6.$$

Mustaqil yechish uchun masalalar

13.7-masala. Kremniyli to'g`ri lagich diodi KD103A ning volt-amper xarakteristikasiga ko'ra *t* = *20⁰C* bo'lgan hol uchun kuchlanishi $U_{to'g`ri}$ = *0,4; 0,6; 0,8 V* qiymatlariga mos kelgan o'zgarmas tokka qarshilikni diod to'g`ri ulanganda aniqlang. $R_0 = f(U_{to'g`ri})$ bog`lanish grafigini quring.

13.8-masala. Diod KD103A ning *t* = *20⁰C* dagi VAX ga ko'ra diod teskari ulangan hol uchun U_{tesk} = *-50; -100; -200 V* bo'lganda o'zgarmas tokka qarshilikni aniqlang. $R_0 = f(U_{tesk})$ bog`lanish grafigini quring.

13.9-masala. Bir yarim davrli to'g`ri lagich sxemasidagi yuklama R_{yu} = *510 Om* o'zgarmas kuchlanishi U_0 = *100 V*. Teskari

kuchlanishning eng katta qiymati $U_{tesk} = 400\ V$, eng katta to'g`ri langan tok $I_0 = 400\ mA$. Bo'lgan D205 diod sxemada to'g`ri tanlanganmi?

Javob: Ha

13.10-masala. To'g`rilagichning 13.4-rasmda ko'rsatilgan sxemasi uchun transformator birlamchi chulg`ami kuchlanishi amplitudasi U_{1m} =220 V, transformatsiya koeffisienti $n = 1,43$ bo'lganda to'g`ri langan kuchlanish U_0 qiymatini aniqlang?

Javob: $U_0 = 100\ V$.

13.11-masala. Agar 4.1–rasmdagi sxema transformatori ikkilamchi chulg`amidagi kuchlanish amplitudasi $U_{1m} = 250\ V$ bo'lsa, yuklamadagi o'zgarmas kuchlanish U_0 ni aniqlang?

Javob: $U_0 = 80\ V$.

13.12-masala. Ikki yarim davrli to'g`ri lagich sxemasi (4.2 - rasm)da yuklama orqali $I_0 = 600\ mA$ tok o'tadi. Sxemada eng katta o'rtacha to'g`ri toki 400 mA gacha bo'lgan D229V tipdagi diodni ishlatsa bo'ladimi?

Javob: Ha.

13.13-masala. To'g`rilagich yuklamasidagi kuchlanish birinchi garmonikasining chastotasi pulsatsiyasini transformator birlamchi chulg`ami kuchlanishi chastotasi $f_T = 400\ Gs$ bo'lgan hol uchun aniqlang?

Javob: $f_T = 800\ Gs$.

13.14-masala. To'g`rilagich sxemasi uchun transformator ikkilamchi chulg`amidagi kuchlanish ta'sir etuvchi qiymati $U_2 = 120\ V$ bo'lganda yuklamadagi to'g`ri langan kuchlanish U_0 qiymatini aniqlang?

Javob: $U_0 = 108\ V$.

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