

**O'ZBEKISTON RESPUBLIKASI  
OLIY VA O'RTA MAXSUS TA'LIM VAZIRLIGI**

**NAMANGAN MUHANDISLIK-PEDAGOGIKA INSTITUTI**

**MUHANDISLIK-TEXNIKA FAKULTETI**

**ELEKTR ENERGETIKA KAFEDRASI**

**«ELEKTROMEXANIKA» fanidan**

# **kurs loyihasi**

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## **Mavzu : Sanoat korxonalarining transformatorlarini loyihasini ishlab chiqish**

1. Kirish. Transformator texnologiyasi, elektr mashinalari talablar va hisoblash uchun berilganlar.
2. Transformatorning asosiy kattaliklarini hisoblash.
3. Transformatorning chulg'amlarini hisoblash
4. Kiska tutashuv parametrlarini hisoblash.
5. Transformatorni magnit sistemalari hisobi
6. Transformatorning issiqlik hisobi
7. Xulosa
8. Foydalanilgan adabiyotlar ruyxati

### **Transformator hisobi**

Hisoblash uchun berilganlar:

1. Transformator turi TM 1600/35.
2. Transformator kuvvati  $S = 1600$  kV.A.
3. Fazalar soni  $m = 3$ , chastotasi  $f = 50$  Gts
4. CHulgamdagi nominal kuchlanishlar  
VN. 35000 V  
NN. 690 V.
5. Sxemasi va ulanish gruppalar U/U-0
6. Tarmoklarni kayta ulash PBV

#### **Variant I (mis uchun).**

Kiska tutashuv kuchlanishi  $U_k = 6,5$  %

Kiska tutashuvdagi isroflar  $P_k = 18000$  Vt.

Salt ishlashdagi isrof  $P_x = 3100$  Vt.

Salt ishlashdagi tok  $i_0 = 1,3$  %.

## 1. Asosiy elektr kattaliklarni hisoblash.

Bitta fazalardagi va bitta sterjendagi kuvvat (1)

$$S_{\phi} = S' = \frac{S}{m} = \frac{1600}{3} = 533,3 \text{ , kVA}$$

CHulg'amlardagi nominal toklari (2)

$$\text{VN} \quad I_2 = \frac{S \cdot 10^3}{\sqrt{3} \cdot U} = \frac{1600 \cdot 10^3}{\sqrt{3} \cdot 35000} = 26,4 \text{ A} , \quad \text{NN} \quad I_1 = \frac{S \cdot 10^3}{\sqrt{3} \cdot U} = \frac{1600 \cdot 10^3}{\sqrt{3} \cdot 690} = 1339 \text{ A}$$

Sterjendagi chulg'amlarning faza toklari (uchfazali transformatorlarda)

Yulduz va zigzag usulida ulanganda chulgamdagi faza toklari (4)

$$I_{\phi 2} = I_2 = 26,4 \text{ A} \quad I_{\phi 1} = I_1 = 1339 \text{ A}$$

Yulduz va zigzag usulida ulanganda chulgamdagi faza kuchlanishlari(6):

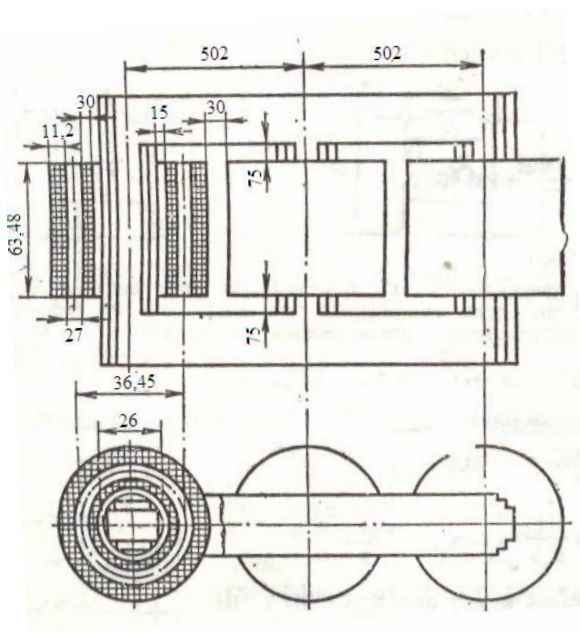
$$U_{\phi 2} = \frac{U_{BH}}{\sqrt{3}} = \frac{35000}{\sqrt{3}} = 20207 \text{ V} \quad U_{\phi 1} = U_{HH} = \frac{690}{\sqrt{3}} = 399 \text{ V}$$

Sinash kuchlanishi kuchlanish sinfi bo'yicha transformatorning har bir chulgami uchun [5] 4.1-jadvalda berilgan.

VN uchun  $U_{isp}=85 \text{ kV}$  NN uchun  $U_{isp}=5 \text{ kV}$

Transformatorning asosiy kattaliklarini hisoblash uchun uning asosiy o'lchamlari bilan tanishib chiqamiz.

### Transformatorning asosiy ulchamlari



1 -rasm da transformatorni asosiy o'lchamlari keltirilgan

VNni sinash kuchlanishlar  $U_{BHcun} = 85 \text{ kV}$  uchun [5] 4.5-jadvaldan izolyatsiya masofalari tanlanadi.  $a_{12} = 27 \text{ mm} , a_{22} = 30 \text{ mm} , l_0 = 75 \text{ mm}$

NNni sinash kuchlanishlar  $U_{HHcun} = 5 \text{ kV}$  uchun [5] 4.4-jadvaldan izolyatsiya masofalari tanlanadi.  $a_{01} = 15 \text{ mm} .$

Ikala chulgamni keltirilgan qarshiliklarini aniqlash (8):  $k = 0,51$  [5] 3.3- jadvaldan tanlanadi.  $\frac{a_1 + a_2}{3} = k \cdot \sqrt[4]{S'} = 0,51 \cdot \sqrt[4]{533,3} = 0,0245 \text{ m}$

Kanalni keltirilgan eni (9):  $a_p = a_{12} + \frac{a_1 + a_2}{3} = 0,027 + 0,0245 = 0,0515 \text{ m}$

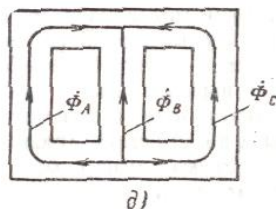
Qisqa tutashuv kuchlanishlarini aktiv tuzuvchilari quyidagi formula bilan aniqlanadi, %

$$(10) \quad U_a = \frac{P_K}{10 \cdot S} = \frac{18000}{10 \cdot 1600} = 1,125\%$$

Qisqa tutashuv kuchlanishi  $U_K$  ni berilgan qiymatlarida reaktiv tuzuvchilarini aniqlash

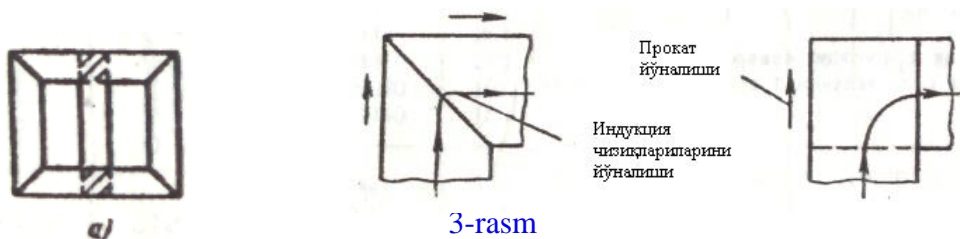
$$(11): \quad U_p = \sqrt{U_K^2 - U_a^2} = \sqrt{6,5^2 - 1,125^2} = 6,4\%$$

2-rasmdan transformatorning magnit sistemasini, ya'ni o'zagini sxemasini tanlaymiz.



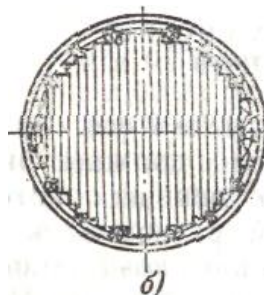
2-rasm

3-rasmdan yarmo va sterjenlar o'rtasidagi choklarni formalari tanlanadi.



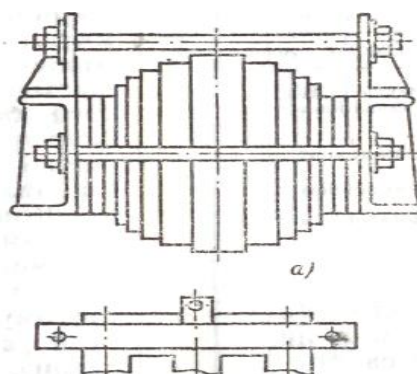
3-rasm

4-rasmdan sterjenni kesish va yig'ish usullarini tanlaymiz.



4-rasm

5-rasmdan esa yarmoning yarmo balkalari yordamida yarmoni qisish usullari tanlanadi.



5-rasm

Po'lat markasi 3404 qalinligi 0,35 mm, narxi 0,833 so'm

$B_c = 1,62 \text{ Tl}$  - sterjendagi induksiya, [5] (2.9-jadval);

$k_c$  - po'latning to'ldirish koeffitsienti  $k_c = k_{kp} \cdot k_s$ ;

$k_{kp} = 0,928$  - aylanishning to'ldirish koeffitsienti [5] (2.1-jadval);

$k_3 = 0,97$  -issiqqa chidamli izolyatsion qoplamani [5] 2.6- jadvaldan tanlaymiz.

$$k_c = k_{kp} \cdot k_3 = 0,928 \cdot 0,97 = 0,900$$

Pog'onalar soni 6, yarmoni kuchaytirish koeffitsienti  $k_{\gamma} = 1,03$ . Yarmo induktsiyasi  $B_{\gamma} = \frac{B_c}{k_{\gamma}} = \frac{1,62}{1,03} = 1,573$  Tl. Magnit sistemasidagi boshliqlarini soni burchak chokli sistemalarda 4 ta, to'g'ri chokli sistemalarda 3 ta bo'ladi. To'g'ri chokli bo'shliklardagi induktsiya  $B_3'' = B_c = 1,62$  Tl ; burchak choklilarda esa  $B_3' = \frac{B_c}{\sqrt{2}} = \frac{1,62}{\sqrt{2}} = 1,146$  Tl.

$p_c = 1,353 \frac{Bm}{K^2}$  -sterjenning 1 kg po'latidagi solishtirma isrofi , [5] (8.4-jadval)

$p_{\gamma} = 1,242 \frac{Bm}{K^2}$  -yarmoning 1 kg po'latidagi solishtirma isrofi , [5] (8.4-jadval)

$q_c = 1,956 \frac{B \cdot A}{K^2}$  -sterjen po'latlari uchun solishtirma magnitlanuvchi quvvati  $B_c$  sterjendagi induktsiyasiga qarab [5] 8.11-jadvaldan tanlanadi;

$q_{\gamma} = 1,66 \frac{B \cdot A}{K^2}$  -yarmo po'latlari uchun solishtirma magnitlanuvchi quvvati  $B_{\gamma}$  yarmo induktsiyasiga qarab [5] 8.11-jadvaldan tanlanadi;

$q_3'' = 25100 \frac{B \cdot A}{M^2}$  -to'g'ri chokli bo'shliklardagi solishtirma magnitlanuvchi quvvati  $B_3''$  to'g'ri chokli bo'shliklardagi induktsiyasiga qarab [5] 8.11-jadvaldan tanlanadi;

$q_3' = 3200 \frac{B \cdot A}{M^2}$  -to'g'ri chokli bo'shliklardagi solishtirma magnitlanuvchi quvvati  $B_3'$  burchak chokli bo'shliklardagi induktsiyasiga qarab [5] 8.11-jadvaldan tanlanadi;

Chulg'amlardagi asosiy isroflarni qisqa tutashish isroflariga nisbatini hisoblovchi koeffitsienti  $k_{\delta} = 0,91$  [5] 3.6-jadval va mis yoki alyumin chulg'amlari uchun doimiy koeffitsientlar  $a = 1,4$  [5] (3.4)-jadval va  $\epsilon = 0,31$  [5] 3.5-jadvaldan topiladi.  $k_p = 0,95$  -ideal maydon tarqalishini real xolatga bog'liq keltirilgan koeffitsient

$\beta = 1,804$  chulg'amlar balandligi bilan sterjen diametri orasidagi bog'likligi [5] (12.1- jadval)

### Asosiy koeffitsientlarni hisoblash

Doimiy koeffitsient:

$$A = 0,507 \cdot \sqrt[4]{\frac{S' \cdot a_p \cdot k_p}{f \cdot U_p \cdot B_c^2 \cdot k_c^2}} = 16 \cdot \sqrt[4]{\frac{533,3 \cdot 0,515 \cdot 0,95}{50 \cdot 6,4 \cdot 1,62^2 \cdot 0,9^2}} = 0,2243$$

Sovuq ishlovda olingan po'lat uchun asosiy koeffitsientlar: (14), (15), (16), (17), (18)

$$A_1 = 5,633 \cdot 10^4 \cdot A^3 \cdot a \cdot k_c = 5,633 \cdot 10^4 \cdot 1,4 \cdot 0,2243^3 \cdot 0,9 = 800,9 \text{ kg}$$

$$A_2 = 3,605 \cdot 10^4 \cdot A^2 \cdot l_0 \cdot k_c = 3,605 \cdot 10^4 \cdot 0,2243^2 \cdot 0,9 \cdot 0,075 = 122,4 \text{ kg}$$

$$B_1 = 2,40 \cdot 10^{-2} \cdot A^3 \cdot k_{\gamma} \cdot k_c (a + b + e) = 2,4 \cdot 10^4 \cdot 0,9 \cdot 1,03 \cdot 0,2243^3 (1,4 + 0,31 + 0,411) = 529,7 \text{ kg}$$

$$B_2 = 2,40 \cdot 10^{-2} \cdot A^2 \cdot k_{\gamma} \cdot k_c (a_{12} + a_{22}) = 2,4 \cdot 10^4 \cdot 0,9 \cdot 1,03 \cdot 0,2243^2 \cdot (0,027 + 0,03) = 61,1 \text{ kg}$$

$$C_1 = K_0 \frac{S \cdot a^2}{k_{\delta} \cdot k_c^2 \cdot B_c \cdot U_a \cdot A^2} = 2,46 \cdot 10^{-2} \frac{1600 \cdot 1,4^2}{0,91 \cdot 0,9^2 \cdot 1,62^2 \cdot 1,125 \cdot 0,2243^2} = 722,4$$

Uch fazali transformatorning mis chulg'ami uchun (20)

$$M_M = 0,244 \cdot 10^{-6} \cdot k_{\kappa,3}^2 \cdot k_{\delta} \cdot k_p \cdot \frac{P_{\kappa}}{a \cdot A} = 0,244 \cdot 10^{-6} \cdot 34,2^2 \cdot 0,91 \cdot 0,95 \cdot \frac{18000}{1,4 \cdot 0,2243} = 14,14 \text{ MPa}$$

$$k_{\gamma,3} = 1,41 \cdot \frac{100}{U_K} \left(1 + e^{-\frac{\pi \cdot U_a}{U_p}}\right) = 1,41 \cdot \frac{100}{6,5} \cdot \left(1 + e^{-\frac{\pi \cdot 1,125}{6,4}}\right) = 34,2$$

Transformatorning aktiv qismlarini minimal qiymati quyidagicha aniqlanadi(22), (23),  
 (24), (25):  $B = \frac{2 A_2 + B_2}{3 B_1} = \frac{2 \cdot 122,4 + 61,1}{3 \cdot 529,7} = 0,232$ ,  $C = \frac{A_1}{3 B_1} = \frac{800,9}{3 \cdot 529,7} = 0,504$ ,

$k_{o.c} = 2,36 \frac{\text{py}\delta}{\text{K}^2}$  [5] 3.7- jadvaldan quvvatiga qarab tanlanadi,;  $k_{u.p} = 1,06$

$$D = \frac{2 C_1}{3 B_1} k_{o.c} \cdot k_{u.p} = \frac{2}{3} \cdot \frac{722,4}{529,7} \cdot 2,36 \cdot 1,06 = 2,27$$

$$x^5 + 0,232x^4 - 0,504x - 2,27 = 0 \quad \text{tenglama tuziladi.}$$

$$\text{Mis uchun(27)} \quad x_{\Delta} \leq 4,5 \sqrt{\frac{2,4 \cdot C_1}{k_{\delta} P_K}} = 4,5 \cdot \sqrt{\frac{2,4 \cdot 736,4}{0,91 \cdot 18000}} = 1,46 ; \beta_{\Delta} = x_{\Delta}^4 = 1,46^4 = 4,56$$

$$x_{\sigma} \leq \sqrt[3]{\frac{60}{M_M}} = \sqrt[3]{\frac{60}{13,89}} = 1,63 ; \beta_{\sigma} = x_{\sigma}^4 = 1,63^4 = 7,04$$

$\beta = 1,804$  qiymati bo'yicha magnit sistemani massasidan boshlab hamma hisoblashlarni ko'rib chiqamiz (29).

$$x = \sqrt[4]{\beta} = \sqrt[4]{1,804} = 1,161, \quad x^2 = \sqrt[4]{\beta^2} = \sqrt[4]{1,804^2} = 1,346, \quad x^3 = \sqrt[4]{\beta^3} = \sqrt[4]{1,804^3} = 1,562$$

- sterjen diametri (13)  $d = A \cdot x = 0,2243 \cdot 1,161 = 28 \text{ m}$

- to'g'ri chok uchun  $\Pi_3$  kanal yuzasi sterjenning aktiv kesimiga teng(30):

$$\Pi_3'' = \Pi_c = 0,785 \cdot k_c \cdot A^2 \cdot x^2 = 0,785 \cdot 0,9 \cdot 0,2243^2 \cdot 1,346 = 0,4778 \text{ m}^2$$

- egri chok uchun (31)  $\Pi_3' = \sqrt{2} \cdot \Pi_c = \sqrt{2} \cdot 0,4778 = 0,674$

- chulg'amning o'rtacha diametri (32)  $d_{12} = a \cdot A \cdot x = 1,4 \cdot 0,2243 \cdot 1,161 = 0,3645 \text{ m}$

- chulg'amning balandligi (33)  $l = \frac{\pi \cdot d_{12}}{\beta} = \frac{3,14 \cdot 0,3645}{1,804} = 0,6348 \text{ m}$

- sterjen balandligi (34)  $l_c = l + 2l_0 = 0,6348 + 2 \cdot 0,075 = 0,7848 \text{ m}$

- sterjenning o'qlari orasidagi masofa (35)

$$C = d_{12} + a_{12} + bd + a_{22} = 0,3645 + 0,027 + 0,31 \cdot 0,26 + 0,03 = 0,5021 \text{ m}$$

- bitta o'ramning EYuK si (36)

$$U_B = 4,44 \cdot f \cdot B_c \cdot \Pi_c \cdot 10^{-4} = 4,44 \cdot 50 \cdot 1,62 \cdot 0,04778 = 17,18 \text{ V}$$

- sterjenlardagi po'lat massasi (37)  $G_c = \frac{A_1}{x} + A_2 x^2 = \frac{800,9}{1,161} + 122,4 \cdot 1,346 = 854,9 \text{ kg}$

- yarmolardagi po'latning massasi (38)  $G_y = B_1 x^3 + B_2 x^2 = 529,7 \cdot 1,562 + 61,1 \cdot 1,346 = 910,1 \text{ kg}$

- po'latning umumiy og'irligi (39)  $G_{\tilde{o}} = G_c + G_y = 854,9 + 910,1 = 1765 \text{ kg}$

- metal chulg'amning massasi (40)  $G_0 = \frac{C_1}{x^2} = \frac{736,4}{1,346} = 537 \text{ kg}$

- mis chulg'am uchun tok zichligi (41)  $\Delta_i = 0,746 \cdot k_{\tilde{a}} \frac{P_K \cdot U_B}{S \cdot d_{12}} = 0,746 \cdot 0,91 \cdot \frac{18000 \cdot 19,07}{1600 \cdot 39,24} = 3,58 \cdot 10^6$

$$\frac{\text{A}}{\text{i}^2}$$

CHulg'am simlarini mexanik tortilish kuchlanishi(19):

$$\sigma_{\delta} = M \cdot x^3 = 13,89 \cdot 1,562 = 22,1 \text{ MPa}$$

-aktiv qismlarini narxi (43)

$$C'_{\tilde{a},\tilde{v}} = B_1 x^3 + (B_2 + A_2) x^2 + \frac{A_1}{x} + k_{o.c} + k_{\tilde{e},\tilde{d}} \frac{\tilde{N}_1}{\tilde{\sigma}^2} =$$

$$= 532,9 \cdot 1,562 + (63,3 + 122,4) \cdot 1,346 + \frac{825}{1,221} + 2,21 + 1,06 \frac{736,4}{1,346} = 3224$$

Tannarxi va pul ko'rinishida (44)  $C_{\dot{a},\dot{z}} = \tilde{N}'_{\dot{a},\dot{z}} \cdot \tilde{n}_{\dot{n}\dot{o}} \cdot \hat{E}_{\dot{n}\dot{o}} \cdot \hat{E}_{\dot{i}\dot{o}\dot{o}} = 3224 \cdot 1,06 = 3417,4$  so'm

Salt ishlashdagi isrof (45)

$$\dot{D}_o = k'_a (\dot{\delta}_n \cdot G_c + \dot{\delta}_y \cdot G_y) = 1,03 \cdot (1,353 \cdot 854,9 + 1,242 \cdot 910,1) = 3162 \text{ Vt}$$

Salt ishlash toki (46)  $i_{op} = \frac{Q_x}{10 \cdot S} = \frac{18320}{10 \cdot 1600} = 1,145\%$

Salt ishlashdagi magnitlashgan quvvat (47)

$$Q_o = k''_a (q_n \cdot G_c + q_y \cdot G_y) = 1,02 \cdot (1,956 \cdot 854,9 + 1,66 \cdot 910,1) = 18320 \text{ VAr}$$

## 2. CHulg'amlarni hisoblash

### Past kuchlanishli chulg'amlarni hisoblash.

Past kuchlanishli chulg'amning bir fazasiga bo'lgan o'ramlar soni (1)

$$\omega_1 = \frac{U_{\dot{o}1} \cdot 10^4}{4,44 \cdot f \cdot B_c \cdot \dot{I}_c} = \frac{399}{17,18} = 23,22 \approx 24$$

Bitta o'ramning kuchlanishi (2)  $u_B = \frac{U_{\dot{o}1}}{\omega_1} = \frac{399}{24} = 16,63 \text{ V}$

CHulg'amdagi toklarning o'rtacha zichligi,

Mis sim uchun (3)  $\Delta_{Mcp} = 0,746 \cdot k_{\dot{a}} \frac{P_K \cdot u_B}{S \cdot d_{12}} = 0,746 \cdot 0,91 \cdot \frac{18000 \cdot 16,63}{1600 \cdot 0,3645} \cdot 10^4 = 3,48 \text{ A/mm}^2$

O'ram kesimining taxminiy qiymati (5)

$$\dot{I}'_1 = \frac{I_{\dot{o}1}}{\Delta_{\dot{n}\dot{o}}} = \frac{1339}{3,48 \cdot 10^6} = 384,8 \cdot 10^{-6} \text{ i}^2 = 384,8 \text{ i}^2$$

Transformator qavvati  $S = 1600 \text{ VA}$ , bitta sterjendagi toki  $I_{\dot{o}1} = 1339 \text{ A}$ , chulg'amning past kuchlanishi  $U_{\dot{i}\dot{i}} = 690 \text{ V}$  va konstruktiv jixatdan uzluksiz katushka chulg'ami bo'yicha o'ram kesimi  $\dot{I}'_1 = 384,8 \text{ i}^2$  ga asosan [5] 5.8-jadvaldan parallel chulg'am simlarni soni  $n_{B1} = 12$  tanlaymiz. Radial kanalning o'lchamini boshlang'ich o'lchov sifatida  $h_{K1} = 5 \text{ mm}$  deb olamiz.

Bir o'ramli yoki ikki o'ramli (ko'p o'ramli) chulg'amlarni tanlash bitta o'ram o'qli o'lchami (balandligi), sm quyidagi formula bilan aniqlanadi:

Bir o'ramli chulg'am uchun (6)

$$h_{B1} = \frac{l}{\omega_1 + 4} - h_{K1} = \frac{0,635}{24 + 4} - 0,05 = 0,0177 \text{ i} = 17,7 \text{ i}$$

CHulg'am simlarining o'lchamlarini quyidagicha tanlanadi:  $PB \ 12 \times \frac{4,50 \cdot 7,60}{5,00 \cdot 8,00}$

$a = 4,5 \text{ mm}$  [5] 5.9-jadval

$b$  - chulg'am simini bo'yi Mis chulg'am uchun (8)  $b \leq \frac{qk_3}{107 \cdot \Delta_{\dot{i}\dot{n}\dot{o}}^2} = \frac{1200 \cdot 1}{107 \cdot 3,48^2} = 7,60 \text{ i}$

O'ramni to'la kesimi (10)  $\dot{I}'_1 = n_{B1} \dot{I}'_1 = 12 \cdot 32,9 = 394,7 \text{ i}^2 = 394,7 \cdot 10^{-6} \text{ i}^2$

Tok zichligi (11)  $\Delta_1 = \frac{I_{\dot{o}1}}{\dot{I}'_1} = \frac{1339 \cdot 10^6}{394,7} = 3,39 \frac{\dot{I} \text{ A}}{\text{i}^2}$

O'ramlar va o'ramlar orasidagi radial kanallarni  $h_{K1} = 0,5 \text{ sm}$ ; 4 kanal o'rtacha balandligi  $h_{K2} = 1 \text{ sm}$  dan deb olamiz.

Quritilgandan keyin proklatika presslanishini hisobga olib o'ramning to'liq balandligi (12):

$$l_1 = 2b(\omega_1 + 1) + k(2\omega_1 - 3)h_{K1} + 4h_{K2} = 2 \cdot (24 + 1) + 5(2 \cdot 24 - 3) + 4 \cdot 10 = 660 \text{ i} = 0,660 \text{ i}$$

Bitta sterjendagi g'altaklar soni(13)  $n_{\varepsilon\delta\delta 1} = \frac{l \cdot 10^3}{b' + 4h_{K2}} = \frac{0,635 \cdot 10^3}{8,00 + 4 \cdot 10} = 13$

G'altaklardagi o'ramlar soni (14)  $\omega_{\varepsilon\delta\delta 1} = \frac{\omega_1}{n_{\varepsilon\delta\delta 1}} = \frac{24}{13} = 1,85 \approx 2$

CHulg'amni radial o'lchami(15)  $a_1 = \frac{n_{B1}}{2} \cdot a' = \frac{12}{2} \cdot 5 = 30 \text{ } \hat{i} = 0,030 \hat{i}$

CHulg'amni ichki diametri(16)  $D'_1 = d + 2a_{01} = 0,26 + 2 \cdot 0,015 = 0,290 \hat{i}$

CHulg'amni tashqi diametri(17)  $D''_1 = D'_1 + 2a_1 = 0,290 + 2 \cdot 0,030 = 0,350 \hat{i}$

Sovitishni ustki qismi(18)  $\check{I}'_{01} = \check{n}k_3(D'_1 + D''_1) \cdot l_1 = 3 \cdot 0,97(0,290 + 0,350) \cdot 0,66 = 1,23$

### Yuqori kuchlanishli chulg'amlarni hisoblash.

Yuqori kuchlanishli chulg'amning bir fazasiga bo'lgan o'ramlar soni(19):

$$\omega_2 = \omega_1 \frac{U_{\delta 2}}{U_{\delta 1}} = \frac{U_{\delta 2}}{u_{\hat{A}}} = \frac{20207}{16,63} = 1215$$

O'ram kesimining taxminiy qiymati (20)

$$\check{I}'_2 = \frac{I_{\delta 2}}{\Delta_{\check{n}\delta}} = \frac{26,4}{3,57 \cdot 10^6} = 7,39 \cdot 10^{-6} \hat{i}^2 = 7,39 \hat{i} \hat{i}^2$$

Transformator qavvati  $S = 1600 \hat{A}\hat{A}$ , bitta sterjendagi toki  $I_{\delta 2} = 26,4 \hat{A}$ , chulg'amning yuqori kuchlanishi  $U_{\hat{A}f} = 35000 \hat{A}$  va konstruktiv jixatdan uzluksiz katushka chulg'ami bo'yicha o'ram kesimi  $\check{I}'_2 = 7,39 \hat{i}^2$  ga asosan [5] 5.8-jadvaldan parallel chulg'am simlarni soni  $n_{B2} = 1$  tanlaymiz.

$$PB \times 1 \times \frac{1,40 \times 5,60}{1,90 \times 6,10}$$

$a = 1,4 \text{ mm}$  [5] 5.9-jadval

b - chulg'am simini bo'yi (21)  $b = \frac{\omega_2 \check{I}'_2}{l \cdot k_{oc}} = \frac{1215 \cdot 7,39}{0,635 \cdot 2,36} = 5,60$

O'ramni to'la kesimi (22)  $\check{I}'_2 = n_{B2} \check{I}''_2 = 1 \cdot 7,625 \cdot 10^{-6} \hat{i}^2$

Tok zichligi (23)  $\Delta_2 = 2\Delta_{\check{n}\delta} - \Delta_1 = 2 \cdot 3,48 \cdot 10^6 - 3,39 \cdot 10^6 = 3,57 \frac{\hat{i} \hat{A}}{\hat{i}^2}$

Bitta sterjendagi g'altaklar soni (24)  $n_{\varepsilon\delta\delta 2} = \frac{l \cdot 10^3}{b' + 4h_{K2}} = \frac{0,635}{6,1 + 4} = 62,9 \approx 62$

G'altaklardagi o'ramlar soni (25)  $\omega_{\varepsilon\delta\delta 2} = \frac{\omega_2}{n_{\varepsilon\delta\delta 2}} = \frac{1215}{62} = 19,6 \approx 20$

Quriltildan keyin proklatika presslanishini hisobga olib o'ramning to'liq balandligi(26):

$$l_2 = b' n_{\varepsilon\delta\delta 2} + k(4h_{K2}(n_{\varepsilon\delta\delta 2} - 2)) = 6,1 \cdot 62 + 0,95(4 \cdot 10(62 - 2)) \cdot 10^{-3} = 0,660 \hat{i}$$

Qatlamdagi o'ramlar soni(27)  $\omega_{\varepsilon 2} = \frac{l_2}{n_{B2} \cdot b'} - 1 = \frac{0,660}{1 \cdot 6,1} \cdot 10^3 - 1 \approx 107$

CHulg'amdagi qatlam soni (28)  $n_{\varepsilon 2} = \frac{\omega_2}{\omega_{\varepsilon 2}} = \frac{1215}{107} = 11$

Ikki qatlamdagi ishchi kuchlanish (29)  $U_{i \varepsilon} = 2\omega_{\varepsilon 2} u_B = 2 \cdot 107 \cdot 16,63 = 3558,82 \hat{A}$

Ikki qatlamdagi ishchi kuchlanish  $U_{i \varepsilon} = 3558,82 \hat{A}$  ga asosan [5] 4.7-jadvaldan qatlamlar soni  $\delta_{i \check{n}\varepsilon} = 6 \times 0,12 = 0,72 \approx 7$  aniqlanadi

CHulg'amni radial o'lchami ekransiz ikkita katushka (30)



$$a_2 = a' n_{K2} + \delta_{i \bar{n} \bar{e}} (n_{K2} - 1) + a_{22} = 1,9 \cdot 10 + 7 \cdot (10 - 1) + 30 = 112 \text{ i } = 0,112 \text{ i}$$

CHulg'amni radial o'lchami ekranli ikkita katushka (31)

$$a'_2 = a_2 + 0,3 = 11,2 + 0,3 = 11,5 \bar{n} \text{ i} = 0,115 \text{ i}$$

CHulg'amni ichki diametri (33)  $D'_2 = D'_1 + 2a_{12} = 0,290 + 2 \cdot 0,027 = 0,344 \text{ i}$

CHulg'amni tashqi diametri ekransiz (34)  $D'_2 = D'_2 + 2a_2 = 0,344 + 2 \cdot 0,112 = 0,568 \text{ i}$

Ekranli (35)  $D'_2 = D'_2 + 2a'_2 = 0,344 + 2 \cdot 0,115 = 0,574 \text{ i}$

Sovitishni ustki qismi(36)

$$\dot{I}_{02} = cnk\pi(D'_2 + D'_2) \cdot l_2 \cdot 10^{-4} = 3 \cdot 2 \cdot 0,8 \cdot (0,344 + 0,574) \cdot 0,660 = 2,91 \text{ i }^2$$

### 3. Qisqa tutashuv parametrlari hisobi

#### CHulg'amlardagi asosiy isroflarni aniqlash.

Asosiy isrofnani aniqlash uchun quyidagi ifodani olamiz.

Mis sim uchun ( $\gamma_M = 8900 \frac{\text{K}^2}{\text{M}^3}$ ,  $\rho_{M75^0} = 0,02135 \text{ MKOM} \cdot \text{M}$ )

NN uchun (2)  $P_{I \bar{a} \bar{m} \bar{n} 1} = 2,4 \cdot \Delta_1^2 \cdot G_{M1} = 2,4 \cdot 10^{-12} \cdot 3,39^2 \cdot 10^{12} \cdot 254,6 = 7022,1 \text{ Vt}$

VN uchun (2')  $P_{I \bar{a} \bar{m} \bar{n} 2} = 2,4 \cdot \Delta_2^2 \cdot G_{M2} = 2,4 \cdot 10^{-12} \cdot 3,46^2 \cdot 10^{12} \cdot 364,8 = 10481,3 \text{ Vt}$

Bu yerda har bir chulg'amni metall og'irligi

NN uchun (5)  $G_{M1} = 28 \cdot c \cdot D_{\bar{n} \bar{o} 1} \cdot \omega_1 \cdot \dot{I}_1 \cdot 10^{-5} = 28 \cdot 10^3 \cdot 3 \cdot 0,32 \cdot 24 \cdot 394,7 \cdot 10^{-6} = 254,6 \text{ kg}$

VN uchun (5')  $G_{M2} = 28 \cdot c \cdot D_{\bar{n} \bar{o} 2} \cdot \omega_2 \cdot \dot{I}_2 \cdot 10^{-5} = 28 \cdot 10^3 \cdot 3 \cdot 0,918 \cdot 1215 \cdot 7,625 \cdot 10^{-5} = 364,8 \text{ kg}$

To'g'ri simdan iborat o'ram uchun o'rtacha koeffitsient

To'g'ri burchakli mis sim uchun ( $\rho_{M75^0} = 0,02135 \text{ MKOM} \cdot \text{M}$ ) va  $n > 2$  uchun

Past kuchlanishli chulg'ami uchun (11)

$$k_{\bar{a} M 1} = 1 + 0,095 \beta_1^2 a^4 n^2 = 1 + 0,095 \cdot 10^8 \cdot 0,268 \cdot 4,5^4 \cdot 10^{-12} \cdot 6^2 = 1,038$$

Yuqori kuchlanishli chulg'ami uchun (11')

$$k_{\bar{a} M 2} = 1 + 0,095 \beta_2^2 a^4 n^2 = 1 + 0,095 \cdot 10^8 \cdot 0,246 \cdot 1,4^4 \cdot 10^{-12} \cdot 22^2 = 1,005$$

Bu ifodalarda  $\beta$  quyidagi formulalar bilan hisoblash mumkin:

To'g'ri sim uchun

Past kuchlanishli chulg'ami uchun(8)

$$\beta_1^2 = \left( \frac{bn_{\bar{e} \bar{a} \bar{o} 1} k_p}{l_1} \right)^2 = \left( \frac{7,5 \cdot 10^{-3} \cdot 48 \cdot 0,95}{0,660} \right)^2 = 0,518^2 = 0,268$$

Yuqori kuchlanishli chulg'ami uchun (8')

$$\beta_2^2 = \left( \frac{bn_{\bar{e} \bar{a} \bar{o} 2} k_p}{l_2} \right)^2 = \left( \frac{5,6 \cdot 10^{-3} \cdot 62 \cdot 0,95}{0,660} \right)^2 = 0,493^2 = 0,246$$

O'tkazuvchilar kesimi o'rama kesimiga teng deb

Past kuchlanishli chulg'ami uchun(16)  $\dot{I}_{i \bar{o} \bar{a} 1} \approx \dot{I}_{i \bar{a} 1} = 394,7 \cdot 10^{-6} \text{ mm}^2$

Yuqori kuchlanishli chulg'ami uchun (16')  $\dot{I}_{i \bar{o} \bar{a} 2} \approx \dot{I}_{i \bar{a} 2} = 7,625 \cdot 10^{-6} \text{ mm}^2$

va yulduz ulash uchun ketgan simlarning umumiy uzunligi

Past kuchlanishli chulg'ami uchun (17)  $l_{i \bar{o} \bar{a} 1} \approx 7,5 l_1 = 7,5 \cdot 0,660 = 4,95 \text{ m}$

Yuqori kuchlanishli chulg'ami uchun (17')  $l_{i \bar{o} \bar{a} 2} \approx 7,5 l_2 = 7,5 \cdot 0,660 = 4,95 \text{ m}$

O'tkazuvchi simlar massasini quyidagi formulalardan topish mumkin:

Past kuchlanishli chulg'ami uchun (19)

$$G_{i \bar{o} \bar{a} 1} = l_{i \bar{o} \bar{a} 1} \dot{I}_{i \bar{o} \bar{a} 1} \gamma \cdot 10^{-8} = 4,95 \cdot 394,7 \cdot 10^{-6} \cdot 8900 = 17,39 \text{ kg}$$

Yuqori kuchlanishli chulg'ami uchun (19')

$$G_{i \bar{o} \bar{a} 2} = l_{i \bar{o} \bar{a} 2} \dot{I}_{i \bar{o} \bar{a} 2} \gamma \cdot 10^{-8} = 4,95 \cdot 7,625 \cdot 10^{-6} \cdot 8900 = 0,336 \text{ kg}$$

O'tkazgichlarning asosiy sarfini quyidagi formula orqali topamiz.

Past kuchlanishli chulg'ami uchun (20)

$$P_{i\delta a1} = k \cdot \Delta_1^2 \cdot G_{i\delta a1} = 2,4 \cdot 10^{-12} \cdot 3,39^2 \cdot 10^{12} \cdot 17,39 = 479,6 \text{ Vt}$$

Yuqori kuchlanishli chulg'ami uchun(20')

$$P_{i\delta a2} = k \cdot \Delta_2^2 \cdot G_{i\delta a2} = 2,4 \cdot 10^{-12} \cdot 3,46^2 \cdot 10^{12} \cdot 0,336 = 9,66 \approx 10 \text{ Vt}$$

Bakdagi va qismlardagi isrofn quyidagi formula orqali aniqlanadi(21).

$$P_a \approx 10 \cdot kS = 10 \cdot 0,03 \cdot 1600 = 480 \text{ Vt}$$

Umumiy QT isrofi (22)

$$P_K = P_{i\delta a1} k_{aM1} + P_{i\delta a2} k_{aM2} + P_{i\delta a1} + P_{i\delta a2} + P_a = 7022,1 \cdot 1,038 + 10481,3 \cdot 1,005 + 479,6 + 10 + 480 = 18792 \text{ Vt}$$

Yuqori kuchlanishli chulg'ami uchun

$$P_{BHK} = P_K - 0,05 \cdot P_{i\delta a1} k_{a1} = 18792 - 0,05 \cdot 10481,3 \cdot 1,038 = 18265 \text{ Vt}$$

Yoki berilgan qiymat uchun  $\frac{P_{BHK} \cdot 100}{P_{Ka}} \% = \frac{18265 \cdot 100}{18000} = 101,5\%$

Nominal kuchlanishlarni aktiv tashkil etuvchisi (23)

$$u_a = \frac{P_{BHK}}{10S} = \frac{18265}{10 \cdot 1600} = 1,147\%$$

QT kuchlanishining tashkil etuvchisi

$$u_p = \frac{7,92 \cdot f \cdot S' \cdot \beta}{u_B^2} a_p k_p \cdot 10^{-1} = \frac{7,9 \cdot 50 \cdot 533,3 \cdot 1,7945 \cdot 0,051 \cdot 0,95 \cdot 1,031}{16,63^2} \cdot 10^{-1} = 6,828\%$$

(26)

bu yerda  $\beta = \frac{\pi \cdot d_{12}}{l} = \frac{\pi \cdot 0,377}{0,660} = 1,7945$

$$a_p \approx a_{12} + \frac{a_1 + a_2}{3} = 0,027 + \frac{(0,030 + 0,042)}{3} = 0,051 \text{ m}$$

Sochilishning real oqimini ideal parallel oqimdan og'ishini hisobga oluvchi  $k_p$  koefitsienti(29)  $k_p \approx 1 - \sigma \approx 1 - 0,0477 \approx 0,95$ ,

Bu yerda  $\sigma = \frac{a_{12} + a_1 + a_2}{\pi \cdot l} = \frac{0,027 + 0,030 + 0,042}{\pi \cdot 0,660} = 0,0477$

$k_q$  koefitsient quyidagi formula bilan aniqlanadi(31).

$$k_q \approx 1 + \frac{l x^2}{m a_p k_p} = 1 + \frac{0,660 \cdot 0,083^2}{3 \cdot 0,051 \cdot 0,95} = 1,031$$

Qisqa tutashuv kuchlanishi(32):  $u_K = \sqrt{u_a^2 + u_p^2} = \sqrt{6,828^2 + 1,147^2} = 6,92\%$

Yoki berilgan qiymat uchun  $\frac{u_K \cdot 100}{U_K} \% = \frac{6,92 \cdot 100}{6,5} = 106,5\%$

QT tokining tarmoq qarshiligini hisobga olgan xolda tokning ta'sir etuvchi qiymati(33):

$$I_{\epsilon, \delta} = \frac{100 I_{\delta 2}}{u_K \left( 1 + \frac{100 S_{ii}}{u_K S_K} \right)} = \frac{100 \cdot 26,4}{6,92 \left( 1 + \frac{100 \cdot 1600}{6,92 \cdot 2500 \cdot 10^3} \right)} = 349,4 \text{ A}$$

QT tokining oniy maksimal qiymati (34)

$$i_{K \max} = \sqrt{2} k_{\max} I_{\epsilon, \delta} = 1,41 \cdot 1,6 \cdot 349,4 = 786,15 \text{ A}$$

Bu yerda QT tokining aperiodik tashkil etuvchisi(35)

$$k_{\max} = 1 + e^{-\pi u_a / u_p} = 1 + e^{\frac{\pi \cdot 6,828}{1,147}} = 1,6$$

Radial kuch (36)

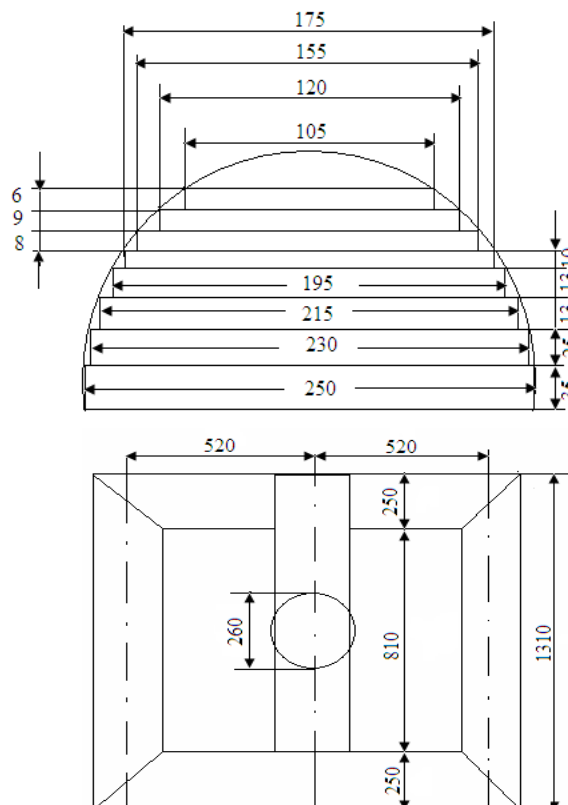
$$F_p = 0,628(i_{K_{\max}} \omega_2)^2 \beta k_p \cdot 10^{-6} = 0,628(786,15 \cdot 1215)^2 \cdot 1,7945 \cdot 0,95 \cdot 10^{-6} = 977034 \text{ N}$$

QT paydo bo'lgandan keyin  $t_K = 5$  sekunddan keyingi xarorati  $\theta_H = 90$  °C da quyidagi formuladan aniqlanadi:

$$\text{Mis sim uchun (37) } \theta_{KM} = \frac{670t_K}{12,5 \left( \frac{u_K}{\Delta_2 \cdot 10^{-6}} \right)^2 - t_K} + \theta_H = \frac{670 \cdot 5}{12,5 \left( \frac{6,92}{3,46 \cdot 10^{-6}} \right)^2 - 5} + 90 = 164,4 \text{ } ^\circ\tilde{N}$$

#### 4. Transformatorni magnit sistemalari hisobi.

Sterjen kesimini paketlarining o'lchovlari (7-rasm)



| № Paket | Sterjen,sm                   |                                | Ko'ndalang kesm yuzasi, $\Pi_{\phi.c.n}$ ,sm <sup>2</sup> |
|---------|------------------------------|--------------------------------|---|
|         | Paket kengligi, $a_{cn}$ ,sm | Paket qalinligi, $b_{cn}$ , sm |   |
| 1       | 250                          | 35                             | 8750  |
| 2       | 230                          | 25                             | 5750  |
| 3       | 215                          | 13                             | 2795  |
| 4       | 195                          | 13                             | 2535  |
| 5       | 175                          | 10                             | 1750  |
| 6       | 155                          | 8                              | 1240  |
| 7       | 120                          | 9                              | 1080  |
| 8       | 105                          | 6                              | 630   |

Sterjen kesimini paketlarining o'lchovlari sterjen diametriga qarab [5] 8.1-jadvaldan aniqlanadi . Sterjen kesimni pog'onali figuralarini maydoni (1):

$$\Pi_{\phi.c} = 2 \cdot \sum a_{cn} \cdot b_{cn} = 2 \cdot (24530) = 49060 \text{ } \dot{\text{u}} \text{ } ^2 = 0,04906 \text{ } \dot{\text{u}} \text{ } ^2$$

Bu yerda  $a_{cn}$  va  $b_{cn}$  -paket kengligi va qalinligi,  $\Pi_{\phi.c}$  qiymati [5] 8.7-jadvalga to'g'ri keladi.

Sterjen aktiv kesimi (2):  $\Pi_c = k_3 \Pi_{\phi.c} = 0,97 \cdot 0,04906 = 0,04759 \text{ m}^2$

Yarmo kesimini paketlarining o'lchovlari [5] (8.2-jadval)

| № Paket | Yarmo, sm                           |                                      | Ko'ndalang kesm yuzasi,<br>$\Pi_{\phi.y.n}, \text{sm}^2$ |
|---------|-------------------------------------|--------------------------------------|--|
|         | Paket kengligi, $a_{yn}, \text{sm}$ | Paket qalinligi, $b_{yn}, \text{sm}$ |  |
| 1       | 250                                 | 35                                   | 8750   |
| 2       | 230                                 | 25                                   | 5750   |
| 3       | 215                                 | 13                                   | 2795   |
| 4       | 195                                 | 13                                   | 2535   |
| 5       | 175                                 | 10                                   | 1750   |
| 6       | 155                                 | 23                                   | 3565   |

Yarmo kesimni pog'onali figuralarini maydoni (3):

$$\Pi_{\phi.y} = \sum a_{yn} \cdot b_{yn} = 2 \cdot 25355 = 50710 \text{ sm}^2 = 0,05071 \text{ m}^2$$

Bu yerda  $a_{yn}$  va  $b_{yn}$  -paket kengligi va qalinligi,  $\Pi_{\phi.y}$  qiymati [5] 8.2-jadvalga to'g'ri keladi.

Yarmo aktiv kesimi (4):  $\Pi_y = k_3 \Pi_{\phi.y} = 0,97 \cdot 0,05071 = 0,04918 \text{ m}^2$

Yarmo kengligi (5)  $b_y = \sum 2 \cdot b_n = 2 \cdot 119 = 238 \text{ mm}$

Sterjen uzunligi (6)  $l_c = l_1 + 2l_0 = 0,660 + 2 \cdot 0,075 = 0,810 \text{ m}$

Sterjen o'qlari orasidagi masofa (7)  $C = D_2'' + a_{22} = 0,488 + 0,032 = 0,520 \text{ m}$

Magnit sistemalari burchagining po'latini og'irligi, kg (8)

$$G_y = 2k_3 \gamma_{cm} \cdot 10^{-9} (a_{1c} a_{1y} b_{1c} + a_{2c} a_{2y} b_{2c} + \dots + a_{nc} a_{ny} b_{nc}) = 2 \cdot 0,97 \cdot 7650 \cdot 10^{-9} \cdot$$

$$\cdot (250 \cdot 250 \cdot 35 + 230 \cdot 230 \cdot 25 + 215 \cdot 215 \cdot 13 + 195 \cdot 195 \cdot 13 + 175 \cdot 175 \cdot 10 + 155 \cdot 155 \cdot 23) = 79,7$$

Yarmodagi po'lat massasi har ikki qo'shiluvchini yig'indisi sifatida aniqlanadi.

CHetki sterjenlar orasidagi yarmolar qismining massasi, kg (9)

$$G'_y = 2(c-1)C\Pi_y \gamma_{cm} = 2 \cdot (3-1) \cdot 0,520 \cdot 7650 \cdot 0,04918 = 784,09 \text{ kg}$$

Ikki yarmoni to'liq massasi (10)  $G_y = G'_y + G''_y$

Yarmo qismlarining massasi (11)  $G''_y = 2G_y = 2 \cdot 79,7 = 159,4 \text{ kg}$

Sterjen po'latini og'irligi, kg (13)  $G_c = G'_c + G''_c = 884,7 + 34 = 918,7 \text{ kg}$

Magnit sistema atrofidagi po'lat sterjenlar massasi, kg (14)

$$G'_c = cl_c \Pi_c \gamma_{cm} = 3 \cdot 0,810 \cdot 0,04759 \cdot 7650 = 884,7 \text{ kg}$$

Sterjen va yarmo paketi birlashish joyidagi po'latlar massasi (15)

$$G''_c = c(a_{1y} \Pi_c \gamma_{cm} - G_y) \beta \cdot (0,250 \cdot 0,04759 \cdot 7650 + 79,7) = 34 \text{ kg}$$

Po'latning umumiy og'irligi (16)  $G_{cm} = G_c + G''_c = 943,5 + 918,7 = 1862,2 \text{ kg}$

Sterjen induktsiyasi (17)  $B_c = \frac{u_B}{4,44 \cdot f \cdot \Pi_c} = \frac{16,63}{4,44 \cdot 50 \cdot 0,04759} = 1,588 \text{ Tl}$

Yarmo induktsiyasi (18)  $B_y = \frac{u_B}{4,44 \cdot f \cdot \Pi_y} = \frac{16,63}{4,44 \cdot 50 \cdot 0,04918} = 1,537 \text{ Tl}$

Egri chiziqli ulanishdagi induktsiya (19)  $B_{cm} = \frac{B_c}{\sqrt{2}} = \frac{1,588}{\sqrt{2}} = 1,123 \text{ Tl}$

Po'lat sterjenlar, yarmo va ulanishi uchun solishtirma isrof [5] 8.10-jadvaldan induktsiyalariga asosan aniqlanadi.

$B_c = 1,588 \text{ Tl}$  uchun  $p_c = 1,269 \frac{\text{Bm}}{\text{K}^2}$  va  $p_{3c} = 974 \frac{\text{Bm}}{\text{M}^2}$  [5] (8.10-jadval)

$B_y = 1,537 \text{ Tl}$  uchun  $p_y = 1,163 \frac{\text{Bm}}{\text{K}^2}$  va  $p_{3y} = 900, \frac{\text{Bm}}{\text{M}^2}$  [5] (8.10-jadval)

$B_{cm} = 1,123 \text{ Tl}$  uchun  $p_{3cm} = 445 \frac{\text{Bm}}{\text{M}^2}$  [5] (8.10-jadval)

Egri chiziqli ulanishdagi sterjen kesimini maydoni (20)

$$\Pi_3 = \sqrt{2}\Pi_c = \sqrt{2} \cdot 0,4759 = 0,0673 \text{ m}^2$$

Salt ishlashdagi isrof (21)

$$P_x = k_{n,\gamma} k_{n,u} k_{n,n} k_{n,3} k_{n,p} \left[ p_c G_c + p_\gamma (G'_\gamma - k_\phi G_\gamma) + \frac{p_c + p_\gamma}{2} G_\gamma k_{\gamma,n} + \sum p_\gamma n_\gamma \Pi_\gamma \right] =$$

$$= 1 \cdot 1,02 \cdot 1,03 \cdot 1 \cdot 1 \cdot \left[ 1,269 \cdot 918,7 + 1,163 \cdot (784,1 - 4 \cdot 79,7) + \frac{1,269 + 1,163}{2} \cdot 79,7 \cdot 10,18 + 4 \cdot 0,0673 \cdot 445 + \right. \\ \left. + 1 \cdot 0,0476 \cdot 974 + 2 \cdot 0,0492 \cdot 900 \right] = 3402 \text{ Bt}$$

Bu yerda  $k_\phi = 2(c-1) = 4$  uch fazali transformatorlar uchun

$$k_{n,\gamma} = 1,0; k_{n,u} = 1,02; k_{n,n} = 1,03; k_{n,3} = 1,0; k_{n,p} = 1,0$$

$$[k_{\gamma,n}] = 10,18 \text{ -koeffitsient [5] (8.6-jadval)}$$

$$\text{yoki berilgan qiymati uchun } \frac{P_{x\phi} - P_x}{P_{x\phi}} \cdot 100\% = \frac{3402}{3100} \cdot 100\% = 109,7\%$$

### Salt ishlash toki hisobi

Po'lat sterjenlar, yarmo va ulanishi uchun magnitlashtirilgan solishtirma quvvati [5] 8.11-jadvaldan induktsiyalariga asosan aniqlanadi.

$$B_c = 1,588 \text{ Tl uchun } q_c = 1,715 \text{ BA}/_{\text{K}^2} \text{ va } q_{3c} = 18480 \text{ BA}/_{\text{M}^2} \text{ [5] (8.17-jadval)}$$

$$B_\gamma = 1,537 \text{ Tl uchun } q_\gamma = 1,474 \text{ BA}/_{\text{K}^2} \text{ va } q_{3\gamma} = 15580 \text{ BA}/_{\text{M}^2} \text{ [5] (8.17-jadval)}$$

$$B_{cm} = 1,123 \text{ Tl uchun } q_{3cm} = 2620 \text{ BA}/_{\text{M}^2} \text{ [5] (8.17-jadval)}$$

Salt ishlashdagi magnitlashgan quvvat (22)

$$Q_x = k_{m,\gamma} k_{m,u} k_{m,n} \left\{ k_{m,3} k_{m,p} \left[ q_c G_c + q_\gamma (G'_\gamma - k_\phi G_\gamma) + \frac{q_c + q_\gamma}{2} G_\gamma k_{\gamma,m} \right] + \sum q_\gamma n_\gamma \Pi_\gamma \right\} =$$

$$= 1 \cdot 1,02 \cdot 1,06 \left\{ 1,1 \cdot 1 \cdot \left[ 1,715 \cdot 918,7 + 1,474 \cdot (784,1 - 4 \cdot 79,7) + \frac{1,715 + 1,474}{2} \cdot 79,4 \cdot 42,40 \right] + \right. \\ \left. \left[ 4 \cdot 2620 \cdot 0,0673 + 1 \cdot 18480 \cdot 0,0476 + 2 \cdot 0,0492 \cdot 15580 \right] \right\} = 15541 \text{ BA}$$

Bu yerda  $k_\phi = 2(c-1) = 4$  uch fazali transformatorlar uchun

$$k_{m,\gamma} = 1,0; k_{m,u} = 1,02; k_{m,n} = 1,06; k_{m,3} = 1,10; k_{m,p} = 1,0$$

$$k_{\gamma,m} = 42,40 \text{ -koeffitsient, [5] (8.12-jadval)}$$

$$\text{Aktiv tuzuvchilari (23) } i_{0a} = \frac{P_x}{10S} = \frac{3402}{10 \cdot 1600} = 0,213\%$$

$$\text{Reaktiv tuzuvchilari (24) } i_{0p} = \frac{Q_x}{10S} = \frac{15541}{10 \cdot 1600} = 0,971\%$$

$$\text{Salt ishlash toki (25) } i_0 = \sqrt{i_{0a}^2 + i_{0p}^2} = \sqrt{0,213^2 + 0,971^2} = 0,994\%$$

$$\text{yoki berilgan qiymati uchun (26) } \frac{i_{0\phi} - i_0}{i_{0\phi}} \cdot 100\% = \frac{1,3 - 0,994}{1,3} \cdot 100\% = 24\%$$

## 5. Transformatorlarni issiqlik hisobi

### 1. CHulg'amlarni issiqlik hisobi

Xaroratni ichki tushishi

$$\text{Past kuchlanishli chulg'am uchun (1) } \theta_{01} = \frac{q_1 \cdot \delta}{\lambda_{u3}} = \frac{839 \cdot 0,25 \cdot 10^{-3}}{0,17} = 1,23^\circ \text{C} \quad \delta = 0,25 \cdot 10^{-3} \text{ m,}$$

$$\lambda_{u3} = 0,17$$

$$q_1 = \frac{107 \cdot \Delta_1 \cdot I_{\phi 1} \cdot \omega_{k1} \cdot k_\delta}{k_\gamma (b' + a_1)} \cdot 10^{-10} = \frac{107 \cdot 3,39 \cdot 10^6 \cdot 1339 \cdot 2 \cdot 0,91}{0,97(0,076 + 0,03)} \cdot 10^{-10} = 839 \text{ Bt/M}^2 \quad (2)$$

$$\text{Yuqori kuchlanishli chulg'am uchun (3) } \theta_{02} = \frac{q_2 \cdot \delta}{\lambda_{u3}} = \frac{587 \cdot 0,25 \cdot 10^{-3}}{0,17} = 0,86^\circ \text{C}$$

$$q_2 = \frac{107 \cdot \Delta_2 \cdot I_{\phi_2} \cdot \omega_{k_2} \cdot k_{\phi}}{k_3 (b' + a_2)} \cdot 10^{-10} = \frac{107 \cdot 3,57 \cdot 26,4 \cdot 20 \cdot 0,91}{0,97(0,0056 + 0,112)} \cdot 10^{-10} = 587 \text{ Вт/м}^2 \quad (4)$$

CHulg'am sirtidagi xarorat tushishi

NN uchun (5)  $\theta_{om1} = k_1 \cdot k_2 \cdot k_3 \cdot 0,35 \cdot q_1^{0,6} = 1 \cdot 1,1 \cdot 0,85 \cdot 0,35 \cdot 839^{0,6} = 18,59^{\circ} \text{C}$

$k_1 = 1; k_2 = 1,1; k_3 = 0,85$  [5] (9.3-jadval)  $\frac{h_k}{a} = 5/30$

VN uchun (6)  $\theta_{om2} = k_1 \cdot k_2 \cdot k_3 \cdot 0,35 \cdot q_2^{0,6} = 1 \cdot 1 \cdot 0,95 \cdot 0,35 \cdot 587^{0,6} = 15,24^{\circ} \text{C}$

$k_1 = 1; k_2 = 1; k_3 = 0,95$  [5] (9.3-jadval)  $\frac{h_k}{a} = 4,5/42$

CHulg'amning moy xaroratlarini to'la va o'rtacha tushishi

NN uchun (7)  $\theta_{omcp1} = \theta_{o1} + \theta_{om1} = 1,23 + 18,59 = 19,82^{\circ} \text{C}$

VN uchun (8)  $\theta_{omcp2} = \theta_{o2} + \theta_{om2} = 0,86 + 15,24 = 16,10^{\circ} \text{C}$

## 2. Bakni issiqlik hisobi

Bakni minimal kengligi (9)

$$B = D_2' + (S_1 + S_2 + d_2 + S_3 + S_4 + d_1) \cdot 10^{-3} = 0,49 + (40 + 42 + 20 + 25 + 90 + 10) \cdot 10^{-3} = 0,717 \text{ m}$$

$S_1 = 40 \text{ mm}$  [5] (4.11-jadval);  $S_2 = 42 \text{ mm}$  [5] (4.11-jadval);  $S_3 = 25 \text{ mm}$  [5] (4.12-jadval)

$S_4 = 90 \text{ mm}$  [5] (4.11-jadval)  $d_1 = 20 \text{ mm}; d_2 = 10 \text{ mm}.$

Bak uzunligi (10)  $A = 2C + B = 2 \cdot 0,52 + 0,76 = 1,800 \text{ m}$

Aktiv qism balandligi (11)  $H_{a,u} = l_c + 2a_{c1} + n \cdot 10^{-3} = 0,81 + 2 \cdot 0,25 + 0,05 = 1,800 \text{ m}$

$n = 50 \text{ mm} = 0,05 \text{ m}$

Bak chuqurligi (12)  $H_{\sigma} = H_{a,u} + H_{y,k} = 1,36 + 0,4 = 1,76 \text{ m}$

$H_{y,k} = 400 \text{ mm} = 0,4 \text{ m}$  [5] (9.5-jadval)

Radiator o'rnatish uchun bak chuqurligi (13)  $H_{\sigma} = A_p + c_1 + c_2 = 1,615 + 0,085 + 0,100 = 1,800 \text{ m}$

$A_p = 1,615 \text{ m}$  [5] (9.9-jadval);  $c_1 = 0,085 \text{ m}$  va  $c_2 = 0,100 \text{ m}$  [5] (9.9-jadval)

Moyni ruxsat etilgan xaroratini o'rab turgan havo xaroratidan ortishi

Qizigan yuqori kuchlanish chulg'ami uchun (14)  $\theta_{m,\sigma} = 65 - \theta_{omcp1} = 65 - 19,82 = 45^{\circ} \text{C}$

Moyni yuqori qatlam xarorati (15)  $\theta_{m,\sigma,\sigma} = 1,2 \cdot \theta_{m,\sigma} = 1,2 \cdot 45 = 54^{\circ} \text{C} < 60^{\circ} \text{C}$

Havo xaroratini bilan bak devorini tashqi xaroratini o'rtacha oshishini topamiz(16) .

$\theta_{\sigma,\sigma} = \theta_{m,\sigma} - \theta_{m,\sigma} - \theta_3 = 45 - 5 - 2 = 38^{\circ} \text{C}$   $\theta_{m,\sigma} = 5^{\circ} \text{C}; \theta_3 = 2^{\circ} \text{C}$

Silliq bak devorini konventsiya yuzasi (17)

$\Pi_{\kappa,zl} = H_{\sigma} [2(A - B) + \pi \cdot B] = 1,8 \cdot [2(1,8 - 0,76) + 3,14 \cdot 0,76] = 8,045 \text{ m}^2$

Radiatorli bakni satxini taxminiy nurlanishi (18):  $\Pi_u = k \cdot \Pi_{\kappa,zl} = 1,5 \cdot 8,045 = 12,06 \text{ m}^2$  Taxminiy

konventsiya yuzasi uchun kerak bo'lgan qiymatlar (19)

$$\Pi'_{\kappa} = \frac{1,05(P_k + P_x)}{2,5 \cdot \theta_{\sigma,\sigma}^{1,25}} - 1,12 \cdot \Pi_u = \frac{1,05 \cdot (18000 + 3400)}{2,5 \cdot 38^{1,25}} - 1,12 \cdot 12,06 = 81,76 \text{ m}^2$$

Bak qopqog'i yuzasi (20)

$\Pi_{\kappa,sp} = 0,5 \left[ (A + B)(B + 0,16) + \pi \frac{(B + 0,16)^2}{4} \right] = 0,5 \cdot \left[ (1,8 - 0,76)(0,76 + 0,16) + 3,14 \frac{(0,76 + 0,16)^2}{4} \right] = 0,809 \text{ m}^2$

Radiator konventsiyasining yuzasi (21)  $\sum \Pi_{\kappa,p} = \Pi'_{\kappa} - \Pi_{\kappa,zl} - \Pi_{\kappa,sp} = 81,76 - 8,45 - 0,809 = 72,91 \text{ m}^2$

Radiator konventsiya yuzasini silliq devor yuzasiga keltirilganligi (22)

$\Pi_{\kappa,p} = \Pi_{\kappa,mp} \cdot k_{\phi} + \Pi_{\kappa,sp} = 1,26 \cdot 4,961 + 0,34 = 6,59 \text{ m}^2$

$k_{\phi} = 4,961$  [5] (9.6-jadval);  $\Pi_{\kappa,mp} = 1,26$  [5] (9.9-jadval);  $\Pi_{\kappa,sp} = 0,34 \text{ m}^2$

Kerak bo'lgan radiator soni (23)  $n_p = \frac{\sum \Pi_{\kappa,p}}{\Pi_{\kappa,p}} = \frac{72,91}{6,59} \approx 11$

Bak konventsiya yuzasi (24)  $\Pi_{\kappa} = \sum \Pi_{\kappa,p} + \Pi_{\kappa,2l} + \Pi_{\kappa,kp} = 10 \cdot 6,59 + 8,045 + 0,81 = 74,8 \text{ } \dot{\text{m}}^2$

Havo xaroratidan trubalarni tashqi xaroratini o'rtacha ortishi (25)  $k = 1,05$

$$\theta_{\delta, \delta} = \left[ \frac{k(P_X + P_K)}{2,8 \cdot \Pi_u + 2,5 \Pi_{\kappa}} \right]^{0,8} = \left[ \frac{1,05(18000 + 3400)}{2,8 \cdot 12,2 + 2,5 \cdot 74,76} \right]^{0,8} = 38,8^{\circ} C$$

Devorlar yaqinidagi xaroratni turdalar devorlari yuzasidagi ichki moy xaroratini o'rtacha ortishi (26)

$$\theta_{m, \delta} = 0,165 \cdot \left[ \frac{k(P_X + P_K)}{\sum \Pi_{kmp} + \Pi_{\kappa,2l} + 0,5 \Pi_{\kappa, \kappa}} \right]^{0,6} = 0,165 \cdot \left[ \frac{1,05(18000 + 3400)}{10 \cdot 4,961 + 8,045 + 0,81} \right]^{0,6} = 5,7^{\circ} C$$

Havo xaroratidan moy xaroratini o'rtacha ortishi (27)

$$\theta_{m, \delta} = \theta_{m, \delta} + \theta_{\delta, \delta} = 5,7 + 38,8 = 44,5^{\circ} C$$

Moy xaroratlarini yuqori qatlamini havo xaroratidan ortishi  $k = 1,2$  (28)

$$\theta_{m, \delta, \delta} = k \cdot \theta_{m, \delta} = 1,2 \cdot 44,5 = 53,4^{\circ} C < 60^{\circ} C$$

CHulg'am xaroratini havo xaroratidan o'rtacha ortishi

NN uchun (29)  $\theta_{o, \delta 1} = \theta_{01} + \theta_{0, mcp1} + \theta_{m, \delta} = 1,23 + 18,59 + 44,5 = 64,32^{\circ} C < 65^{\circ} C$

VN uchun (30)  $\theta_{o, \delta 2} = \theta_{02} + \theta_{0, mcp2} + \theta_{m, \delta} = 0,86 + 15,24 + 44,5 = 60,6^{\circ} C < 65^{\circ} C$

