



Temir yo'l elektr ta'minoti tizimlarida qo'llaniladigan kuch transformatorlarining konstruktiv va ekspluatatsion xususiyatlarini tahlil qilish

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Dolzarbli: Maqola temir yo'l elektr ta'minoti tizimlarida qo'llaniladigan kuch transformatorlarining konstruktiv va ekspluatatsion xususiyatlari tahlil qilishga bag'ishlangan bo'lib, transformatorlarning magnit o'zak, chulg'am, izolyatsiya va sovitish tizimi kabi asosiy elementlari ularning energiya samaradorligi, qisqa tutashuv toklariga chidamliligi va uzoq muddatli barqaror ishlashini belgilashda asosiy omil sifati qarash lozimligi asoslangan. Shuningdek, konstruktiv parametrlar va ekspluatatsion ko'rsatkichlar o'rtasidagi bog'liqlik umumlashtirilgan model holatida shakllantirilgan bo'lib, natijalar temir yo'l sharoitida foydalaniladigan transformatorlarning ishonchligi va samaradorligini oshirishda konstruktiv yechimlar muhim ahamiyatga ega ekanligi aniqlandi.

Maqsad: Temir yo'l elektr ta'minoti tizimlarida qo'llaniladigan kuch transformatorlarining konstruktiv va ekspluatatsion xususiyatlarini tahlil qilish iborat.

Usullar: Maqolada kuch transformatorlarining konstruktiv va ekspluatatsion xususiyatlarini tahlil qilishda elektromagnit maydonlar, elektr mashinalari, issiqlik almashinuvi, izolyatsiya, mexanik mustahkamlik, ishonchlik va energiya samaradorligi nazariyalariga tayanildi. Ushbu nazariyalar va matematik ifodalar kuch transformatorlarining konstruktiv parametrlari bilan ekspluatatsion ko'rsatkichlari o'rtasidagi bog'liqlikni chuqur tahlil qilish imkonini beradi hamda temir yo'l elektr ta'minoti tizimlari uchun optimal texnik yechimlarni asoslashga xizmat qiladi.

Natijalar: Kuch transformatorlarining konstruktiv parametrlaridan kelib chiqadigan fizik jarayonlar bevosita ularning ekspluatatsion ko'rsatkichlarini belgilaydi. Magnit o'zak, chulg'am va izolyatsiya konstruktiviyasi energiya isroflari, tok zichligi va harorat rejimini shakllantiradi. Sovitish va mexanik mustahkamlik esa barqaror ishlash va avariya xavfini kamaytiradi. Shu tariqa, konstruktiv yechimlar va ekspluatatsion natijalar o'rtasidagi umumlashtirilgan model transformatorlarning ishonchligi, samaradorligi va xizmat muddatini optimallashtirishga imkon beradi.

Kalit so'zlar: kuch transformatori, konstruktiv xususiyatlar, ekspluatatsion ko'rsatkichlar, magnit o'zak, chulg'am, izolyatsiya, energiya samaradorlik.

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Анализ конструктивных и эксплуатационных особенностей силовых трансформаторов, используемых в системах электроснабжения железнодорожного транспорта

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Актуальность: Статья посвящена анализу конструктивных и эксплуатационных характеристик силовых трансформаторов, применяемых в системах электроснабжения железных дорог. Основные элементы трансформаторов — магнитопровод, обмотки, изоляция и система охлаждения — являются ключевыми факторами, определяющими их энергетическую эффективность, стойкость к токам короткого замыкания и долгосрочную стабильную работу. Кроме того, взаимосвязь конструктивных параметров и эксплуатационных показателей была сформирована в виде обобщённой модели, и результаты показали, что конструктивные решения имеют важное значение для повышения надёжности и эффективности трансформаторов, используемых в железнодорожных условиях.

Цель: Анализ конструктивных и эксплуатационных характеристик силовых трансформаторов, применяемых в системах электроснабжения железных дорог.

Методы: В статье при анализе конструктивных и эксплуатационных характеристик силовых трансформа-



торов опирались на теории электромагнитных полей, электрических машин, теплообмена, изоляции, механической прочности, надёжности и энергетической эффективности. Эти теории и математические выражения позволяют глубоко исследовать связь между конструктивными параметрами трансформаторов и их эксплуатационными показателями, а также обосновывать оптимальные технические решения для железно-дорожных систем электроснабжения.

Результаты: Физические процессы, обусловленные конструктивными параметрами силовых трансформаторов, напрямую определяют их эксплуатационные показатели. Конструкция магнитопровода, обмоток и изоляции формирует энергетические потери, плотность тока и температурный режим. Системы охлаждения и механическая прочность обеспечивают стабильную работу и снижают риск аварий. Таким образом, обобщённая модель взаимосвязи конструктивных решений и эксплуатационных результатов позволяет оптимизировать надёжность, эффективность и срок службы трансформаторов.

Ключевые слова: силовой трансформатор, конструктивные характеристики, эксплуатационные показатели, магнитопровод, обмотки, изоляция, энергетическая эффективность.

Analysis of Structural and Operational Characteristics of Power Transformers Used in Railway Power Supply Systems

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Relevance: This article is devoted to the analysis of the structural and operational characteristics of power transformers used in railway power supply systems. The main components of transformers — magnetic core, windings, insulation, and cooling system — are key factors determining their energy efficiency, short-circuit withstand capability, and long-term stable operation. Moreover, the relationship between structural parameters and operational performance was formulated as a generalized model, and the results showed that design solutions play a crucial role in enhancing the reliability and efficiency of transformers used under railway conditions.

Objective: To analyze the structural and operational characteristics of power transformers applied in railway power supply systems.

Methods: In analyzing the structural and operational characteristics of power transformers, the study relied on theories of electromagnetic fields, electric machines, heat transfer, insulation, mechanical strength, reliability, and energy efficiency. These theories and mathematical expressions allow for a thorough investigation of the relationship between transformer structural parameters and their operational performance, as well as provide a basis for optimizing technical solutions for railway power supply systems.

Results: Physical processes determined by the structural parameters of power transformers directly influence their operational performance. The design of the magnetic core, windings, and insulation affects energy losses, current density, and temperature regimes. Cooling systems and mechanical strength ensure stable operation and reduce the risk of failures. Thus, the generalized model of the relationship between design solutions and operational outcomes enables the optimization of transformer reliability, efficiency, and service life.

Keywords: power transformer, structural characteristics, operational performance, magnetic core, windings, insulation, energy efficiency.

1. Kirish (Introduction)

Temir yo‘l elektr ta‘minoti tizimlarida kuch transformatorlari energiya uzatishda asosiy vosita hisoblanadi va butun tizimning samaradorligi, ishonchliligi hamda barqaror ishlashini ta‘minlashda asosiy qurilmalardan biri hisoblanadi. Transformatorlarning konstruktiv yechimlari va ekspluatatsion xususiyatlari, jumladan magnit o‘zak, chulg‘am, izolyatsiya va sovitish tizimi, energiya samaradorligini oshirish, qisqa tutashuv toklariga chidamliligini ta‘minlash va uzoq muddatli barqaror ishlashni kafolatlashga xizmat qiladi. Shuningdek, zamonaviy texnologiyalar, jumladan transformator moyini tozalash va holat monitoringi usullari, ekspluatatsion xavfsizlikni oshirish va transformatorlarning ishonchliligini ta‘minlashga yordam beradi. Ushbu maqolada kuch transformatorlarining konstruktiv va ekspluatatsion xususiyatlari batafsil tahlil qilinib, ularning o‘zaro bog‘liqligi umumlashtirilgan model shaklida taqdim etildi. Natijalar shuni ko‘rsatadiki, konstruktiv yechimlar va ekspluatatsion ko‘rsatkichlar o‘rtasidagi o‘zaro ta‘sir temir yo‘l sharoitida ishlatiladigan transformatorlarning samaradorligi, ishonchliligi va uzoq muddatli xizmatini optimallashtirishda muhim ahamiyatga ega. Maqolada kuch transformatorlarining konstruktiv va ekspluatatsion xususiyatlari tahlil qilinib, ularning bog‘liqligi umumlashtirilgan model shaklida taqdim etildi [1-3].



2. Materiallar va usullar (Methods and materials)

Temir yo'l elektr ta'minoti tizimlarida ishlatiladigan kuch transformatorlari ekspluatatsiya jarayonida yuqori yuklama, tez-tez o'zgarib turadigan ish rejimlari, tashqi muhitning ta'sirlari - vibratsiya, changlanish, namlik va haroratning keskin o'zgarish sharoitlarida ishlaydi. Xususan, sovitish tizimlarining samarador ishlashi issiqlik ta'sirini kamaytirish orqali izolyatsiya qismining ishlash vaqtini uzaytirish muhim ahamiyatga ega bo'lib, izolyatsiya qismining dielektrik mustahkamligi yuqori kuchlanishlar ta'sirida xavfsiz ishlashni ta'minlaydi. Mexanik qism va chulg'amlarning konstruktiv mustahkamligi esa qisqa tutashuv holatlarida yuzaga keladigan katta elektrodinamik kuchlanishlarning salbiy ta'sirini kamaytirishga xizmat qiladi [4-5]. Temir yo'l kuch transformatorlarining konstruktiv yechimlari umumiy energetik transformatorlarga nisbatan yanada qat'iy texnik talablarga asoslanadi va bu transformatorlarning asosiy konstruktiv elementlari va ularning ekspluatatsion xususiyatlariga ta'sir etuvchi omillarni tizimli ravishda o'rganish muhim ilmiy-amaliy ahamiyatga ega bo'lib, kuch transformatorlarining tarkibiy qismlari va ularga tegishli asosiy texnik ko'rsatkichlar 1-jadvalda keltirilgan.

1-jadval. Temir yo'l kuch transformatorlarining asosiy elementlari

Table 1. Key elements of railway power transformers

№	Konstruktiv element	Materiallar	Asosiy vazifasi	Konstruktiv talab
1.	Magnit o'zak	Elektrotexnik po'lat	Magnit oqimni yopish	Kam magnit yo'qotish
2.	Yuqori kuchlanish chulg'ami	Mis/Alyuminiy	Elektr energiyasini uzatish	Yuqori izolyatsiya mustahkamligi
3.	Past kuchlanish chulg'ami	Mis	Katta toklarni uzatish	Elektrodinamik barqarorlik
4.	Izolyatsiya tizimi	Qog'oz, presskarton, moy	Elektr ajratish	Namlik va qizishga chidam
5.	Sovitish tizimi	Moy, radiator, ventilyator	Issiqlikni chiqarish	Barqaror termik rejim
6.	Mexanik karkas va bak	Po'lat	Konstruktiv mustahkamlik	Vibratsiyaga chidamlilik

Magnit o'zak yuqorida sanab o'tilgan elementlar orasida transformatorning energiya samaradorligini belgilovchi asosiy element hisoblanadi [6]. Amaliy loyihalarda o'zakning kesim yuzasi quyidagi empirik ifoda orqali baholanadi:

$$S_{o'zak} \approx k \cdot \sqrt{S_{nom}} \quad (1)$$

bu yerda: S_{nom} - transformatorning nominal quvvati (MVA), k - konstruktiv koeffitsiyent ($k = 1,0 \div 1,3$). Bu bog'lanish magnit yo'qotishlarni kamaytirish va shovqinni pasaytirishga xizmat qiladi.

Uch fazali transformatorlarda ularning chulg'amlaridagi tok quyidagicha ifoda yordamida aniqlanadi:

$$I = \frac{S_{nom}}{\sqrt{3} \cdot U} \quad (2)$$

bu yerda: U - chulg'am kuchlanishi.

Chulg'am simining kesimi esa ruxsat etilgan tok zichligiga asosan tanlanadi:

$$A = \frac{I}{j} \quad (3)$$

bu yerda: $j = 2,0 \div 3,0 \text{ A/mm}^2$.

Transformatorlar elektr tarmoqlaridagi qisqa tutashuv vaqtida katta elektrodinamik kuchlarga ta'sirida bo'ladi. Qisqa tutashuv toki quyidagi ifoda bilan baholanadi:

$$I_{qt} = \frac{I_{nom}}{u_k} \quad (4)$$

bu yerda: I_{nom} - nominal tok, u_k - qisqa tutashuv kuchlanishi.

Mazkur tok qiymati chulg'amlarning mexanik mustahkamlik darajasini belgilovchi asosiy omil hisoblanadi.

Transformatorning sovitish tizimi umumiy quvvat yo'qotishlarini chiqarib yuborishi lozim:

$$Q = P_0 + P_k \quad (5)$$

bu yerda Q - umumiy quvvat yo'qotishlari, P_0 - salt yurish yo'qotishlari, P_k - qisqa tutashuv yoki yuklama yo'qotishlari.

Radiator yuzasi soddalashtirilgan holda quyidagi formula orqali hisoblanadi:

$$F = \frac{Q}{\alpha \cdot \Delta T} \quad (6)$$

bu yerda: $\alpha = 6 \div 10 \text{ W/m}^2 \cdot ^\circ\text{C}$, $\Delta T = 40 \div 55^\circ\text{C}$.

Transformatorning ekspluatatsion holati asosan uning yuklama rejimi bilan belgilanadi. Yuklama koeffitsiyenti quyidagi formula orqali aniqlanadi:



$$k_y = \frac{S_{ish}}{S_{nom}} \quad (7)$$

bu yerda: S_{ish} - ishchi quvvat, kVA.

Transformatorning energiya samaradorligini baholash uchun uning foydali ish koeffitsiyenti quyidagicha aniqlanadi:

$$\eta = \frac{P_{chiq}}{P_{chiq} + P_{yo'q}} \times 100\% \quad (8)$$

bu yerda: P_{chiq} - foydali quvvat, kW; $P_{yo'q}$ - umumiy quvvat yo'qotishlari, kW.

Chulg'amlarning qizish darajasi izolyatsiya tizimining xizmat muddatiga bevosita ta'sir ko'rsatadi. Amaliyotda izolyatsiyaning eskirish tezligi Arrenius tenglamasi asosida baholanadi:

$$L = L_0 \cdot e^{-k(T-T_0)} \quad (9)$$

bu yerda: L - xizmat muddati, T - ishchi harorat, T_0 - me'yoriy harorat, k - empirik koeffitsiyent.

Kuch transformatorlarining ekspluatatsion xususiyatlari ularning ishonchligi, xizmat muddati va texnik xizmat ko'rsatish samaradorligi bilan belgilanadi [8]. Temir yo'l elektr ta'minoti tizimlarida transformatorlar ko'pincha o'zgaruvchan yuklama rejimida ishlaydi, bu esa ularning termik va dielektrik holatiga salbiy ta'sir ko'rsatishi mumkin. Ekspluatatsiya jarayonida transformator moyining holati, izolyatsiya qarshiligi, qizish darajasi va vibratsiya ko'rsatkichlari muntazam nazorat qilinishi zarur. Statistik ma'lumotlarga ko'ra, nosozliklarning katta qismi izolyatsiya tizimining eskirishi va sovitish samaradorligining pasayishi bilan bog'liq. Shu sababli ularning ekspluatatsion holatini baholashda asosiy texnik ko'rsatkichlar majmuaviy ravishda tahlil qilinishi zarur. Quyida kuch transformatorlari uchun muhim bo'lgan asosiy ekspluatatsion parametrlar 2-jadvalda keltirilgan.

2-jadval. Kuch transformatorlarining asosiy ekspluatatsion ko'rsatkichlari

Table 2. Key operational characteristics of power transformers

№	Ko'rsatkich nomi	O'lchov birligi	Me'yoriy qiymat	Ekspluatatsion ahamiyati
1.	Nominal quvvat	kVA (MVA)	10 – 40 MVA	Yuklama barqarorligini belgilaydi
2.	Yuklama koeffitsiyenti	–	0,7 – 0,85	Qizish va eskirish darajasini aniqlaydi
3.	Foydali ish koeffitsiyenti (η)	%	98 – 99,5	Energiya samaradorligini ifodalaydi
4.	Qisqa tutashuv kuchlanishi	%	6 – 10	Elektrodinamik barqarorlikni ko'rsatadi
5.	Chulg'am qizish harorati	°C	≤ 65	Izolyatsiya xizmat muddatiga ta'sir qiladi
6.	Transformator moyi namligi	%	≤ 30	Dielektrik mustahkamlikni belgilaydi
7.	Izolyatsiya qarshiligi	MΩ	≥ 1000	Elektr xavfsizligini ta'minlaydi

Temir yo'l elektr ta'minoti tizimlarida qo'llaniladigan kuch transformatorlarining ishonchli va uzoq muddatli ishlashi ularning konstruktiv yechimlari bilan bevosita bog'liq. Har bir konstruktiv parametr ekspluatatsiya jarayonida muayyan texnik ko'rsatkichlarning shakllanishiga sabab bo'ladi [9-13]. Shu bois konstruktiv va ekspluatatsion xususiyatlarni alohida emas, balki yagona tizim sifatida baholash maqsadga muvofiqdir.

“Konstruktiv parametr - fizik jarayon - ekspluatatsion natija” kuch transformatorlarda konstruktiv parametrlar orqali yuzaga keladigan fizik jarayonlar ekspluatatsion natijalarni bevosita shakllantiradi, bu esa temir yo'l elektr ta'minoti tizimlarida transformatorlarni loyihalash va tanlashda ushbu bog'liqlikni majmuaviy hisobga olish zarurligini ko'rsatadi. Kuch transformatorlarining konstruktiv parametrlariga bog'liq fizik jarayonlar ekspluatatsion natijalarni belgilaydi. Bunda, magnit o'zak kesimi va materiali yo'qotishlarni kamaytirib, foydali ish koeffitsiyentini oshiradi, chulg'am simi va izolyatsiya haroratni nazorat qilib, xizmat muddatini uzaytiradi, sovitish va mexanik mustahkamlik barqaror ishlash hamda avariya xavfini kamaytiradi [14-18]. Konstruktiv va ekspluatatsion xususiyatlar o'rtasidagi bog'liqlik 3 - jadvalda keltirilgan.

3-jadval. Konstruktiv va ekspluatatsion xususiyatlar o'rtasidagi bog'liqlik

Table 3. The link between design and operational characteristics

№	Konstruktiv xususiyat	Fizik ta'sir mexanizmi	Ekspluatatsion ko'rsatkich	Natijaviy ta'sir
1.	Magnit o'zak kesimi va materiali	Magnit induksiya kamayadi	Bo'sh yurish yo'qotishlari	FIK oshadi
2.	Chulg'am sim kesimi	Tok zichligi pasayadi	Qizish darajasi	Izolyatsiya muddati uzayadi
3.	Qisqa tutashuv kuchlanishi	Elektrodinamik kuchlar	Mexanik barqarorlik	Avariya xavfi kamayadi



4.	Izolyatsiya tizimi sifati	Dielektrik mustahkamlik	Ishonchlilik	Nosozliklar kamayadi
5.	Sovitish tizimi quvvati	Issiqlik chiqarish	Harorat rejimi	Xizmat muddati oshadi
6.	Mexanik karkas mustahkamligi	Vibratsiya so'nishi	Mexanik eskirish	Barqaror ekspluatatsiya

Tadqiqot jarayonida quyidagi nazariyalardan foydalanildi: Maqolada kuch transformatorlarining konstruktiv va ekspluatatsion xususiyatlarini tahlil qilishda elektromagnit maydonlar, elektr mashinalari, issiqlik almashinuvi, izolyatsiya, mexanik mustahkamlik, ishonchlilik va energiya samaradorligi nazariyalariga tayanildi. Ushbu nazariyalar va matematik ifodalar kuch transformatorlarining konstruktiv parametrlari bilan ekspluatatsion ko'rsatkichlari o'rtasidagi bog'liqlikni chuqur tahlil qilish imkonini beradi hamda temir yo'l elektr ta'minoti tizimlari uchun optimal texnik yechimlarni asoslashga xizmat qiladi [19-22].

3. Natijalar (Results)

Kuch transformatorlarining konstruktiv parametrlaridan kelib chiqadigan fizik jarayonlar bevosita ularning ekspluatatsion ko'rsatkichlarini belgilaydi. Magnit o'zak, chulg'am va izolyatsiya konstruktiv energiya isroflari, tok zichligi va harorat rejimini shakllantiradi. Sovitish va mexanik mustahkamlik esa barqaror ishlash va avariya xavfini kamaytiradi. Shu tariqa, konstruktiv yechimlar va ekspluatatsion natijalar o'rtasidagi umimlashtirilgan model transformatorlarning ishonchliligi, samaradorligi va xizmat muddatini optimallashtirishga imkon beradi.

Konstruktiv - ekspluatatsion bog'liqlikning yakuniy modeli sifatida temir yo'l kuch transformatorlarining asosiy konstruktiv parametrlari (magnit o'zak, chulg'am, izolyatsiya, sovitish tizimi, mexanik karkas) va ularning fizik jarayonlari (magnit induksiya, tok zichligi, issiqlik, deformatsiya) orqali ekspluatatsion natijalariga (salt ishlash yo'qotishi, chulg'am yo'qotishi, moy harorati, foydali ish koefitsiyenti, xizmat muddati) ta'sirini umimlashtirgan tizimli modeldir. Konstruktiv parametrlarning ekspluatatsion ta'siri kuch transformatorlarining ekspluatatsion ko'rsatkichlariga ta'siri 4 - jadvalda keltirilgan.

4 – jadval. Konstruktiv parametrlarning ekspluatatsion ta'siri

Table 4. The Effect of Structural Parameters on Performance

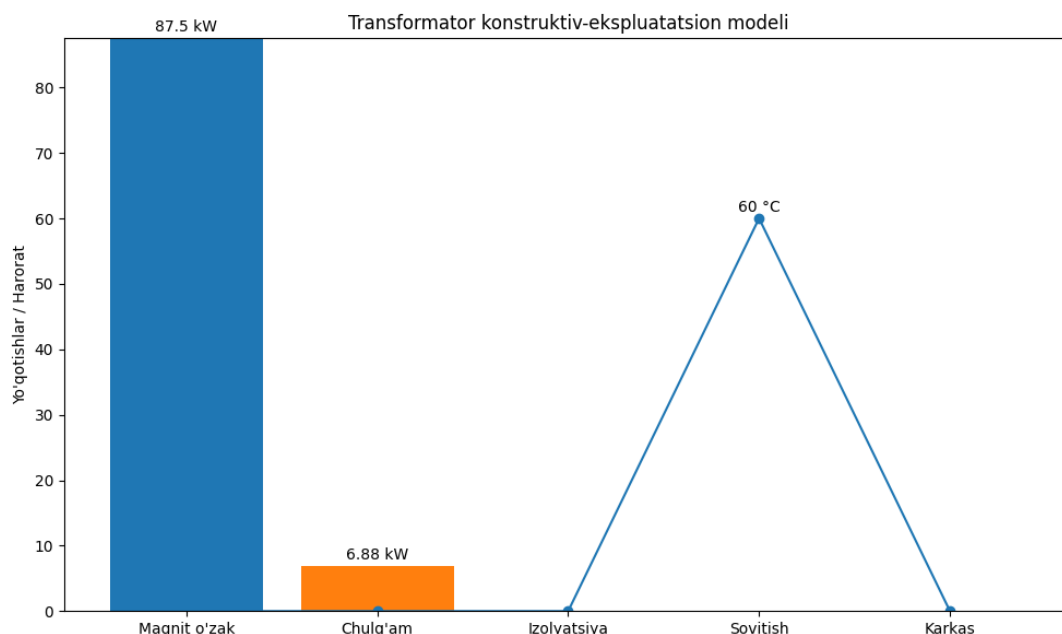
Konstruktiv parametr	Ekspluatatsion ko'rsatkich	Ta'sir darajasi
O'zak materiali	Energiya yo'qotishlari	Yuqori
Sim kesimi	Qizish darajasi	Yuqori
Izolyatsiya sifati	Ishonchlilik	Juda yuqori
Sovitish quvvati	Harorat rejimi	Yuqori
Mexanik mustahkamlik	Avariya xavfi	O'rta - yuqori

Ushbu model yordamida transformatorning konstruktiv xususiyatlarini optimallashtirish orqali ekspluatatsion samaradorlik va ishonchlilikni aniq raqamlar bilan baholash imkoniyati yaratiladi. "Konstruktiv parametrlar - fizik jarayon - ekspluatatsion natija" model ketma-ketligi 5 - jadvalda keltirilgan.

5 – jadval. Konstruktiv parametrlarning foydalanish natijalariga tizimli bo'g'liqligi

Table 5. Systematic correlation between design parameters and operational outcomes

№	Konstruktiv parametr	Qiymati	Fizik jarayon	Ekspluatatsion natija	Izoh / Taqqoslash
1.	Magnit o'zak materiali	Elektrotexnik po'lat, 98% to'yingan	Magnit induksiya, gisterezis yo'qotishlari	Salt ishlash yo'qotishi ($P_s = 87.5 \text{ kW}$), FIK $\approx 99.6 \%$	Chulg'am yo'qotishi bilan solishtiriladi
2.	Chulg'am materiali	Mis, qarshiligi 0.4Ω	Tok zichligi, Joule issiqligi	Chulg'am yo'qotishi ($P_k \approx 6.88 \text{ kW}$)	Maksimal qizish $\leq 75^\circ \text{C}$
3.	Izolyatsiya turi	Mineral moy, 28 kV/mm	Elektr maydon taqsimoti	Razryad ehtimoli $< 1\%$, xizmat muddati 25 yil	Karkas va sovitish bilan xavfsizlikni oshiradi
4.	Sovitish tizimi	Moyli, radiator maydoni 8 m^2 , moy hajmi 500 L	Issiqlik almashinuvi	Moy harorati 60°C	Chulg'am yo'qotishi bilan barqaror ishlashni ta'minlaydi
5.	Mexanik karkas	Po'lat, mustahkamlik 100 kN	Elektrodinamik kuchlarni so'ndiradi	Deformatsiya $\leq 2 \text{ mm}$	Konstruktiv elementlar bilan birgalikda xavfsizlikni oshiradi



1-rasm. Konstruktiv - ekspluatatsion bog'liqlikning yakuniy modeli

Fig.1. Final model of the structural - operational interrelationship

4. Munozara (Discussion)

Hisoblashlarga ko'ra, chulg'am haroratining me'yoriy qiymatdan har 6 - 8 °C ga oshishi izolyatsiya xizmat muddatini ikki martaga qisqarishiga olib keladi. Ushbu holat yuzaga kelmasligi uchun yuklama rejimini optimal darajada ushlab turish, transformator moyining fizik-kimyoviy holatini muntazam nazorat qilish, infraqizil termografiya va onlayn monitoring tizimlaridan foydalanish, profilaktik texnik xizmat ko'rsatishni reja asosida amalga oshirish kabi chora tadbirlarni amalga oshirish lozim bo'ladi. O'tkazilgan tahlil shuni ko'rsatadiki, kuch transformatorlarining ekspluatatsion ko'rsatkichlari to'g'ridan-to'g'ri ularning konstruktiv parametrlariga bog'liq bo'lib, magnit o'zak, chulg'amlar, izolyatsiya va sovitish tizimi konstruksiyasining optimal tanlanishi transformatorlarning energiya samaradorligini oshiradi, issiqlik yuklamalarini kamaytiradi hamda ekspluatatsion ishonchlilikni ta'minlaydi. Shu sababli temir yo'l elektr ta'minoti tizimlari uchun transformatorlarni loyihalash va tanlash jarayonida konstruktiv – ekspluatatsion bog'liqlik majmuaviy tarzda hisobga olgan holda ushbu yo'nalishdagi ilmiy tadqiqotlarni kengaytirish va innovatsion texnologiyalarni joriy etish dolzarb vazifalardan biri ekanligi belgilab olindi. Shuningdek, tahlillar va hisoblashlar natijasiga ko'ra temir yo'l elektr ta'minoti tizimlarida qo'llaniladigan kuch transformatorlarining konstruksiyasi yuqori yuklama, qisqa tutashuv va termik zo'riqishlarga bardoshli qilib ishlab chiqish va magnit o'zak, chulg'amlar va sovitish tizimlarini optimal konstruktiv tanlash orqali transformatorlarning uzoq muddatli ishonchli ishlashini ta'minlashga erishish mumkinligi yan bir bor asoslandi.

5. Xulosa (Conclusion)

1. Temir yo'l elektr ta'minoti tizimlarida qo'llaniladigan kuch transformatorlarining ekspluatatsion samaradorligi ularning magnit o'zak, chulg'am, izolyatsiya va sovitish tizimlarining asosiy konstruktiv parametrlariga bevosita bog'liq ekanligi aniqlandi.
2. Magnit o'zak va chulg'amlarning optimal konstruktiv yechimlari salt ishlash va yuklama isroflarini kamaytirib, transformatorning foydali ish ko'effitsiyentini oshirishga xizmat qiladi.
3. Issiqlik rejimi va izolyatsiya tizimining barqaror ishlashi transformatorning xizmat muddatini uzaytirish hamda temir yo'l sharoitida ishonchli ekspluatatsiyani ta'minlashda muhim omil hisoblanadi.
4. Konstruktiv – ekspluatatsion bog'liqlikning umumlashtirilgan modeli transformatorlarni loyihalash va ekspluatatsiya qilishda energiya tejamlorlik hamda texnik ishonchlilikni oshirish uchun ilmiy asos bo'lib xizmat qiladi.

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