Technical science and innovation

Volume 2023 | Issue 4 Article 7

1-10-2024

EXISTING METHODS FOR MONITORING POWER AUTOTRANSFORMERS

Nurali Berdiyorovich Pyrmatov
Tashkent State Technical University, Tashkent city, Republic of Uzbekistan, npirmatov@mail.ru

Dilafruz Rustamjon qizi Abdullabekova
Tashkent State Technical University, Tashkent city, Republic of Uzbekistan, abdullabekova_94@mail.ru

Recommended Citation
Pyrmatov, Nurali Berdiyorovich and Abdullabekova, Dilafruz Rustamjon qizi (2024) "EXISTING METHODS FOR MONITORING POWER AUTOTRANSFORMERS," *Technical science and innovation*: Vol. 2023: Iss. 4, Article 7.
DOI: https://doi.org/10.59048/2181-0400
E-ISSN: 2181-1180
.1518
Available at: https://btstu.researchcommons.org/journal/vol2023/iss4/7

capacity utilisation of THPSs with a change in the unevenness coefficient from 0.79 to 0.826.

3. To determine the energy characteristics of HEPs, the method of solving the optimisation problem of the daily mode of their operation together with THPSs was used, which allows to determine the distribution of loads between HEPs and THPSs, allowing a minimum of fuel equivalent consumption with available water resources.

Acknowledgements

The work was carried out with the financial support of the Ministry of Innovative Development of the Republic of Uzbekistan under the project F3-OT-2021-235 "Theoretical bases of hydropower development using hydropower complexes".

References

1. Resolution of the President of the Republic of Uzbekistan PP-44 "On additional measures for further development of hydropower" dated 10.12. 2021. http://lex.uz.
2. Energy Efficiency 2020. https://www.iea.org/reports/energy-efficiency-2020.
3. Hydro Equipment Association global technology roadmap. https://www.andritz.com/resource/blob/259432/5487f2c45ab370859ffe8abc26ed72e8/ea-roadmap-data.pdf.
4. Yu. S. Vasilyev, V. V. Elistratov, I. G. Kudryasheva, M. Mukhammadiyev, Urishev B. Use of maneuverable properties of hydroelectric power plants and hydro-accumulating power plants for improving reliability and operating efficiency of electric power systems of commonwealth countries (using example of power plants of russia and the Republic of Uzbekistan). E3S Web of Conferences 216, 01139 (2020), RSES 2020. https://doi.org/10.1051/e3sconf/202021601139
5. Urishev B Microgrid Control Based on the Use and Storage of Renewable Energy Sources. USA, Journal Applied Solar Energy, 2018, Vol. 54, No. 5, pp. 388-391. DOI: 10.3103/S0003701X180 50201
6. Urishev B Decentralised Energy Systems, Based on Renewable Energy Sources. USA, Journal Applied Solar Energy, 2019, Vol. 55, No. 3, pp. 207-212. DOI: 10.3103/S0003701X19030101
7. Sinyugin V.Yu., Magruk V.I., Rodionov V.G. Hydro-storage power plants in modern electric power engineering/ - M. : ENAS, 2008.- 352 p.
8. Zubarev V.V. Accumulating power stations and their use in power systems. -M.: "Informenergo", ser.4, issue 4, 1986.p.34-38
9. Zubakin V.A. It is necessary to develop highly manoeuvrable capacities// Energorynok. 2004. № 9. c. 34-42.
10. Hydropower Special Market Report. Analysis and forecast to 2030. https://iea.blob.core.windows.net/assets/83ff8935-62dd-4150-80a8-c5001b740e21/Hydropower SpecialMarketReport.pdf
11. Energy. Development of thermal power and hydropower (Book 3). History, present and future. Edited by Plachkova S.G., Plachkov. I.V. http://energetika.in.ua/ru/books/book-3/part-2/section-3/3-1;
12. Report of production and technical activities of UE "Talimarjan THPS" for 2017. Nuristan, 2017, 37 p.
13. Hydropower Status Report 2022. Sector trends and insights. https://assets-global.website-files.com/5f749e4b9399c80b5e421384/62c402eb2af8db8431332d62 IHA-2022-Hydropower-Status-Report.pdf
14. Hydropower Status Report 2021. Sector trends and insights. https://assets-global.websiteiles.com/5f749e4b9399c80b5e421384/60c37321987070812596e26a_IHA2021_2405-status-report-02LR.pdf
15. Uzbekhydroenergo JSC. https://uzgidro.uz
16. Ministry of Energy of the Republic of Uzbekistan. https://minenergy.uz

UDC 621.314.223

EXISTING METHODS FOR MONITORING POWER AUTOTRANSFORMERS

N.B.PIRMATOV, D.R.ABDULLABEKOVA (Tashkent State Technical University, Tashkent city, Republic of Uzbekistan)*

Received: November 08, 2023; Accepted: January 10, 2024; Online: January 16, 2024.

Abstract: *This paper presents a review of existing methods for monitoring power autotransformers in power systems. With the growing importance of reliable operation of power equipment, analyzing effective methods is becoming an integral part of ensuring power system stability.*

The paper reviews traditional approaches including temperature, pressure, and current monitoring. These methods undoubtedly have their value, but the focus is on innovative techniques.

* Nurali Berdiyorovich Pirmatov – DSc, Professor, npirmatov@mail.ru, https://orcid.org/0000-0001-5212-2593;
Dilafruz Rustamjon qizi Abdullabekova – Doctoral student, abdullabekova_94@mail.ru, https://orcid.org/0009-0003-8887-6831.

Particular attention is given to analyzing the gas composition of transformer oil, which is a sensitive indicator of various defects such as thermal breakdown and heating.

In addition, methods based on the measurement of external magnetic field strength are discussed. This technique provides a unique opportunity to detect magnetic anomalies associated with possible defects in the structural components of the transformer.

The article emphasizes that successful monitoring requires an integrated approach, combining different techniques. The authors analyze the advantages and limitations of each method and offer practical recommendations for integrating these methods into maintenance systems. In summary, the article provides a valuable overview of modern monitoring techniques that contribute to improving the reliability and service life of power autotransformers in modern power networks.

Keywords: *autotransformers, methods, diagnostics, efficiency, monitoring.*

Annatatsiya: *Ushbu maqolada energiya tizimlarida quvvat avtotransformatorlarini kuzatishning mavjud usullari haqida umumiy ma'lumot berilgan. Elektr energetika qurilmalarining ishonchli ishlashining ahamiyati ortib borayotganini hisobga olib, samarali usullarni tahlil qilish energetika tizimlari barqarorligini ta'minlashning ajralmas qismiga aylanmoqda. Maqolada harorat, bosim va oqimni kuzatish kabi an'anaviy yondashuvlar muhokama qilinadi. Bu usullar, albatta, o'z qiymatiga ega, ammo asosiy e'tibor innovatsion texnologiyalarga qaratilgan. Termik parchalanish va isitish kabi turli nuqsonlarning sezgir ko'rsatkichi bo'lgan transformator moyining gaz tarkibini tahlil qilishga alohida e'tibor beriladi.*

Bundan tashqari, tashqi magnit maydonning kuchini o'lchashga asoslangan usullar ko'rib chiqiladi. Ushbu texnika transformatorning strukturaviy komponentlarida yuzaga kelishi mumkin bo'lgan nuqsonlar bilan bog'liq magnit anomaliyalarni aniqlash uchun noyob imkoniyatni beradi.

Maqolada ta'kidlanadiki, muvaffaqiyatli monitoring turli usullarni birlashtirgan holda kompleks yondashuvni talab qiladi. Mualliflar har bir usulning afzalliklari va cheklovlarini tahlil qiladilar va ushbu usullarni texnik xizmat ko'rsatish tizimlariga integratsiya qilish bo'yicha amaliy tavsiyalar beradilar. Xulosa qilib aytganda, maqola zamonaviy energiya tarmoqlarida quvvat avtotransformatorlarining ishonchliligi va xizmat muddatini yaxshilashga yordam beradigan zamonaviy monitoring texnologiyalarining qimmatli sharhini beradi.

Kalit so'zlar*: avtotransformatorlar, usullar, diagnostika, samaradorlik, monitoring*

Данная статья представляет обзор существующих методов мониторинга силовых автотрансформаторов в энергетических системах. С учетом растущей важности надежной работы электроэнергетического оборудования, анализ эффективных методов становится неотъемлемой частью обеспечения стабильности энергосистем.

В статье рассматриваются традиционные подходы, включая мониторинг температуры, давления, и тока. Эти методы, несомненно, имеют свою ценность, однако основное внимание уделено новаторским технологиям. Особое внимание уделяется анализу газового состава масла трансформаторов, который является чувствительным индикатором различных дефектов, таких как термический разрыв и нагрев.

Кроме того, обсуждаются методы, основанные на измерении напряженности внешнего магнитного поля. Эта техника предоставляет уникальную возможность выявления магнитных аномалий, связанных с возможными дефектами в структурных компонентах трансформатора.

Статья подчеркивает, что успешный мониторинг требует комплексного подхода, объединяя различные методы. Авторы анализируют преимущества и ограничения каждого метода, а также предлагают практические рекомендации для интеграции этих методов в системы технического обслуживания. В итоге, статья предоставляет ценный обзор современных технологий мониторинга, способствующих повышению надежности и продолжительности службы силовых автотрансформаторов в современных энергетических сетях.

Ключевые слова: *автотрансформаторы, методы, диагностика, эффективность, мониторинг.*

Introduction

Power autotransformers play a critical role in reliable and uninterrupted power transmission in power systems. To ensure their longevity and reliable operation, careful monitoring and diagnostics are required. This abstract reviews the existing monitoring methods for power autotransformers and their role in ensuring the stability and reliability of power systems.

Monitoring methods for power autotransformers include measurement of electrical parameters such as voltage and current, temperature monitoring, oil gas analysis, vibration monitoring, insulation inspection, and many others. These methods provide operators and engineers with important information about the condition of transformers, allowing them to identify potential problems before they become critical.

Effective monitoring of power autotransformers helps improve reliability and reduce the risk of accidents. Accurate and timely detection of changes in autotransformer performance allows operators to take maintenance and repair actions, which in turn contributes to cost savings and uninterrupted power.

Research methods and results obtained

Reliable and effective condition monitoring of power autotransformers is critical to ensure continuity of power supply and prevent emergency situations. This paper reviews the existing methods for monitoring power autotransformers.

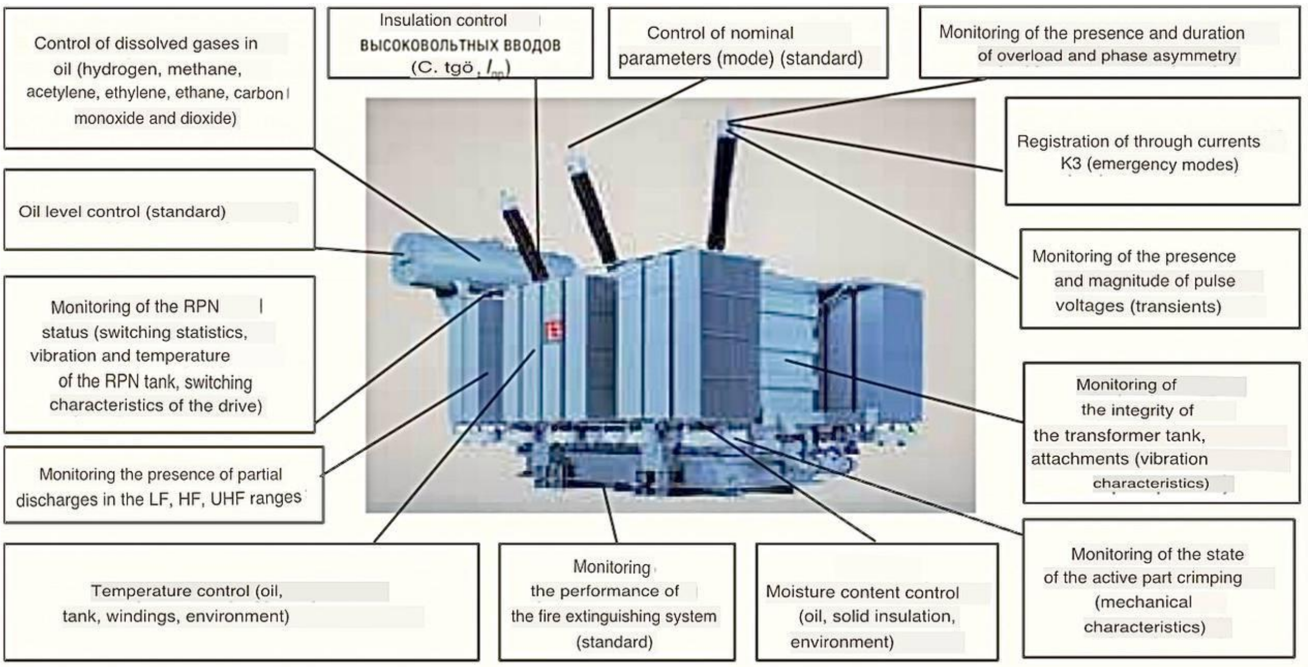

Fig.1. Monitoring of autotransformers

Electrical parameters

One of the most common monitoring methods is to measure the electrical parameters of power autotransformers. This includes measuring voltage, current, active and reactive power, power factor, and harmonic distortion. Changes in electrical parameters can indicate potential problems such as overloads or short circuits.

Temperature Monitoring

Temperature is another important indicator of the condition of power autotransformers. An increase in temperature can indicate overheating or other problems. Temperature sensors can be placed at various points on the transformer for monitoring.

Gas Analysis

Monitoring gas compositions in the oil of an autotransformer is an important method for detecting faults such as insulation breaks. Detection of abnormal concentrations of gases such as methane and acetylene can indicate potential problems.

Vibration Monitoring

Vibration monitoring can be used to detect mechanical problems such as internal defects or uneven oil distribution. Vibration sensors can monitor vibrations and detect anomalies.

Insulation Monitoring

Monitoring the insulation condition of power autotransformers can identify potential insulation problems that could lead to short circuits. This method includes measuring insulation resistance and conducting breakdown tests.

Magnetizing Current Monitoring

The magnetizing current of an autotransformer can be monitored to detect abnormal values that may indicate defects in the transformer core.

Modern monitoring techniques for power autotransformers often include a combination of several of the above methods to improve diagnostic accuracy and early detection of problems. Effective monitoring helps to reduce accident risks, improve transformer efficiency and extend transformer life.

1. Voltage: Measuring the voltage at the input and output of a power autotransformer is the basis of

monitoring. It helps to determine how well the transformer is performing its voltage changing function.

2. Current: Measuring the current at the input and output of the transformer allows an assessment of the current load of the transformer. Excessive loads can lead to overheating and damage.

3. Active and reactive power: These parameters determine how the transformer uses energy. Changes in active and reactive power can indicate efficiency problems.

4. Power Factor: The power factor measures the ratio between active and reactive power. A low power factor can indicate energy efficiency problems.

5. Harmonic Distortion: Measuring harmonic distortion provides a measure of voltage and current quality. High levels of harmonic distortion can affect equipment performance.

6. Frequency: Measuring frequency is important to determine the stability of the network. Changes in frequency can indicate problems in the system.

These electrical parameters can be measured using specialized sensors and equipment. Measurement results can be recorded and analyzed in real time or at regular intervals. Monitoring of electrical parameters allows operators and engineers to monitor the condition of power autotransformers and take action to maintain and prevent potential problems, which helps to improve the reliability and longevity of power systems.

Temperature is another important indicator of the condition of power autotransformers. Measuring and monitoring temperature are critical elements in ensuring reliable operation and preventing transformers from overheating. Here is some information on why temperature is an important parameter and how it is monitored:

The importance of temperature in power autotransformers:

1. Optimal Temperature: Power autotransformers must operate under optimal thermal conditions. This means that the transformer must maintain a certain temperature to ensure efficient power transmission and distribution.

2. Potential Problems: Temperature rise above normal can indicate various problems such as overloading, uneven load distribution, insulation or oil defects. High temperatures can lead to increased wear and tear and even damage to the transformer.

3. Reduced service life: Constant increase in temperature affects the service life of a power autotransformer. Therefore, it is important to monitor temperature readings to maximize the life of the equipment.

Temperature monitoring:

1. Temperature Sensors: Temperature sensors are used to monitor the temperature at various points in the power autotransformer. They can be placed in key areas such as windings, oil and core.

2. Thermal imaging camera: A thermal imaging camera is a tool that allows you to visually monitor temperature changes in real time. It can be used to detect hot spots and abnormal temperature changes.

3. Oil Monitoring: The oil temperature inside a power auto-transformer is an important indicator of its performance. Oil temperature can be monitored using floating sensors placed inside the transformer.

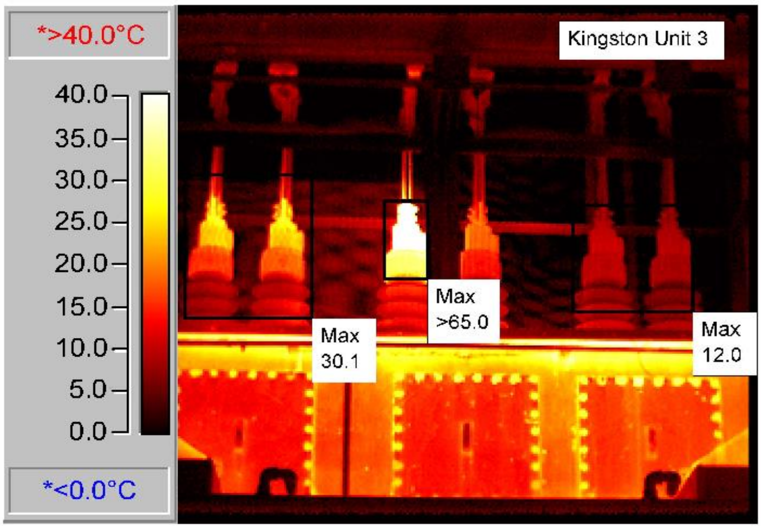

Fig.2. Thermographic survey methodology

Temperature monitoring allows operators and engineers to monitor the condition of power autotransformers and take action to maintain optimal operating conditions. This helps to prevent overheating, extend transformer life and increase the reliability of power systems.

Monitoring the gas compositions in the oil of an autotransformer is an important method for detecting the condition and performance of the transformer. This method is based on analyzing the gases that are released in the oil as a result of various processes and physical phenomena that occur inside the transformer. Here is some information about monitoring gas compositions in oil:

Importance of gas composition monitoring:

1. Fault Detection: Various faults in a power auto transformer such as insulation breaks, short circuits and winding defects can lead to the release of certain gases into the oil. Monitoring of gas compositions allows anomalies to be detected and responded to in a timely manner.

2. Insulation condition assessment: Gases that appear in the oil can indicate the condition of the transformer insulation. Changes in gas composition can indicate potential insulation problems.

3. Accident Prevention: Monitoring gas compositions can help prevent accidents by alerting operators to potential risks and malfunctions.

Analyzing gas compositions:

1. Breath analysis: This method involves collecting gases from the oil and analyzing their composition. Different gases can be associated with different types of defects, and the analysis allows the problem to be identified.

2. Use of gas sensors: Sensors that automatically react to changes in gas composition can be used to continuously monitor the gas compositions in the oil.

3. Interpretation of results: The results of gas analysis require interpretation, and this may include comparison with reference data and assessment of potential risks.

Table 1

Physicochemical analysis of transformer oil

№	Name of gas	Results of the analysis %	Limit value %
1.	Hydrogen (H_2)	0,0022	0,01
2.	Carbon monoxide (CO)	0,018	0,06
3.	Methane (CH_4)	0,00023	0,01
4.	Carbon dioxide (CO_2)	0,21	0,8
5.	Ethylene (C_2H_4)	0,013	0,01
6.	Ethane (C_2H_6)	0,0071	0,005
7.	Acetylene (C_2H_2)	0	0,001

Monitoring of gas compositions in the oil of an auto-transformer is an important tool to ensure transformer reliability and longevity. It helps operators and engineers to monitor the condition of the transformer and take maintenance and repair actions, which helps to prevent accidents and extend the life of the equipment.

Vibration method of power autotransformer diagnostics is an important way to detect mechanical problems and anomalies in transformer operation. Here is the information about the vibration method of diagnosis:

The significance of vibration method:

1. Detection of mechanical problems: Vibration method can detect mechanical problems such as internal defects, uneven oil distribution, winding instability and other transformer anomalies.

2. Damage Prevention: Early detection of mechanical faults allows operators and engineers to take action to prevent serious damage and accidents.

3. Insulation condition assessment: Vibration method can also be used to assess the condition of the insulation inside the transformer, as changes in oil composition and pressure can affect vibrations.

Vibration diagnostic methods:

1.Installation of vibration sensors: Vibration sensors are installed on various parts of a power autotransformer such as windings, core and housing. They record the vibrations that may be caused by various mechanical factors.

2. Frequency Spectrum Analysis: The obtained vibration data is analyzed using frequency spectra. This identifies characteristic frequencies associated with specific mechanical problems.

3.Comparison to baseline data: The results of the analysis are compared to baseline data to determine if the vibrations differ from the normal operating condition.

As faults develop in a machine, dynamic processes change and there are qualitative and quantitative changes in the forces acting on machine parts. As a result, both the level of mechanical vibrations itself and their form change. From the physical point of view, the vibration on the tank surface of a high-power transformer is qualitatively and quantitatively well correlated with the state of the winding and magnet core pressing. Changing the degree of pressing during operation leads to changes in the overall vibration pattern, vibration amplification, changes in its frequency, and the appearance of modulated oscillations. These changes are quite often encountered by maintenance workers who perform transformer inspections.

In practice, quite often the technical condition of the active part of the transformer is controlled by the following vibration characteristics: vibration acceleration, vibration velocity and vibration displacement. For quantitative description of vibration signals, vibration displacement and vibration velocity are most widely used.

To measure vibration, a portable vibration analyzer is used in the vibration acceleration, vibration velocity or vibration displacement RMS measurement mode.

During the survey, the sensor is sequentially installed in each sector, and the instrument readings are taken. The results of vibration survey are summarized in Fig.3 [1].

Vibration-based diagnostics of power autotransformers allows operators and engineers to continuously monitor the mechanical condition of the transformer and respond promptly to detected anomalies. This contributes to maintaining transformer reliability and extending its service life.

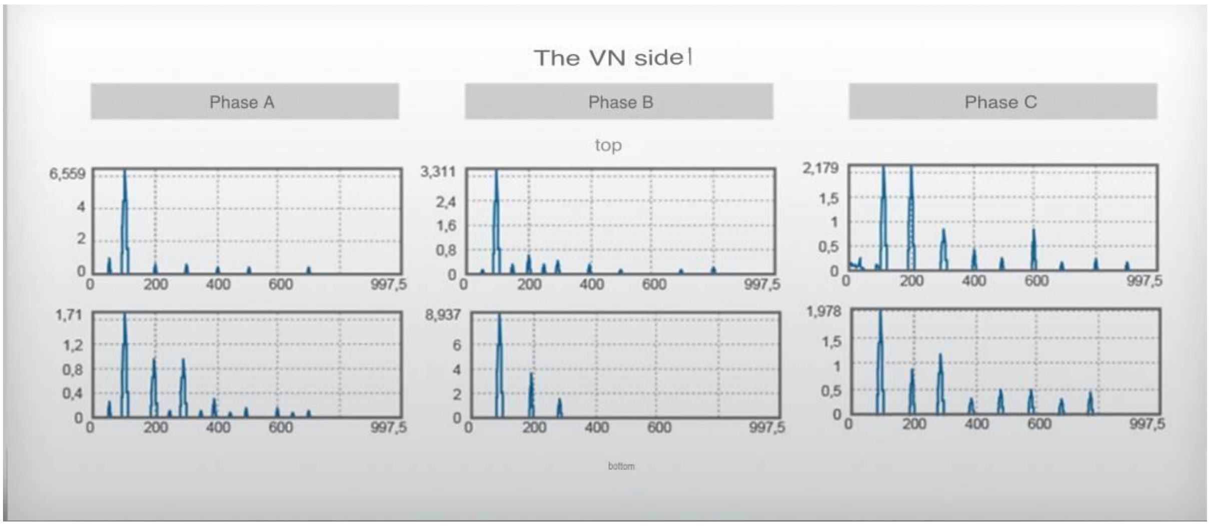

Fig.3. Autotransformer spectra measured at various measurement points

Monitoring the insulation condition of power autotransformers is an important aspect of ensuring their reliable and safe operation. Insulation plays a crucial role in preventing short circuits and ensuring efficient operation of transformers. Here is information about insulation condition monitoring:

Importance of insulation condition monitoring:

1. Identification of insulation defects: Monitoring can detect various defects in insulation such as cracks, punctures, soaking and material degradation. These defects may occur due to aging or external factors.

2. Short Circuit Prevention: Insulation failure can lead to short circuits that can cause emergencies. Monitoring can prevent such incidents by early detection of insulation problems.

3. Maintenance Planning: Regular monitoring of insulation condition allows for the development of a maintenance and repair plan, including replacement of insulating materials and insulation rehabilitation.

Methods for monitoring insulation condition:

1. Insulation Resistance Measurement: This method involves measuring the insulation resistance between the windings and ground. A drop in resistance can indicate insulation problems.

2. Insulation testing: Using a mega-ohmmeter, specific insulation tests are performed to determine the condition of the insulation. These tests may include breakdown voltage and dielectric strength measurements.

3. Oil Degassing Monitoring: The insulation in power autotransformers may contain oil. By monitoring the gases released into the oil, insulation problems can be identified.

The insulation condition is monitored:

when accepting an electrical installation after repair or installation;

periodically during operation, but at least 1-2 times a year, depending on

production conditions (in damp rooms 2-3 times a year);

constantly during operation with the help of special insulation monitoring devices.

According to the “Rules of Electrical Installation” (PUE), the insulation resistance is

measured between two adjacent fuses or behind the last fuses

between any wire and the "ground", as well as between two wires. Insulation resistance

it must be at least 0.5 mOhm.

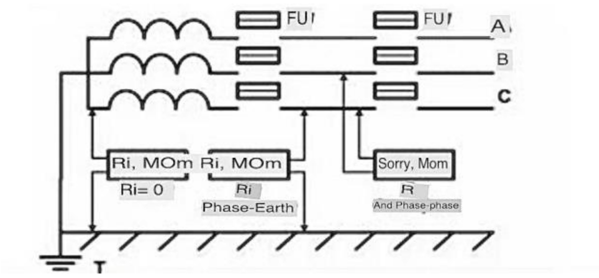

Fig. 4. Insulation condition monitoring

Insulation condition monitoring of power autotransformers is an important part of maintenance and diagnostics of electric power equipment. It allows to keep the insulation in good condition, increase the reliability of transformers and reduce the risk of accidents.

Monitoring the magnetizing current of power autotransformers is an important part of the maintenance and diagnostics of this type of transformers. Magnetizing current, also known as no-load current, reflects the magnetizing current that is delivered to the transformer windings to create a magnetic field. Here is information about magnetizing current monitoring:

Magnetizing current monitoring value:

1. Core Condition Assessment: The magnetizing current is related to the core condition of the power autotransformer. Changes in magnetizing current can indicate potential problems such as disturbance of the magnetic properties of the core.

2- Winding Condition Assessment: Magnetizing current can also affect transformer windings. Monitoring can detect winding anomalies such as overheating, short circuits or breaks.

3. Power Loss Determination: Magnetizing current monitoring allows to estimate the power losses associated with magnetization and optimize transformer performance.

Magnetizing current monitoring methods:

1. Current measurement: Current sensors are used to monitor the magnetizing current, which are installed on the transformer windings. These sensors measure the current supplied for magnetizing current.

2. Harmonic Analysis: Monitoring the harmonic components of the magnetizing current helps to determine the presence of nonlinear magnetizing currents that may be due to faults or problems in the transformer.

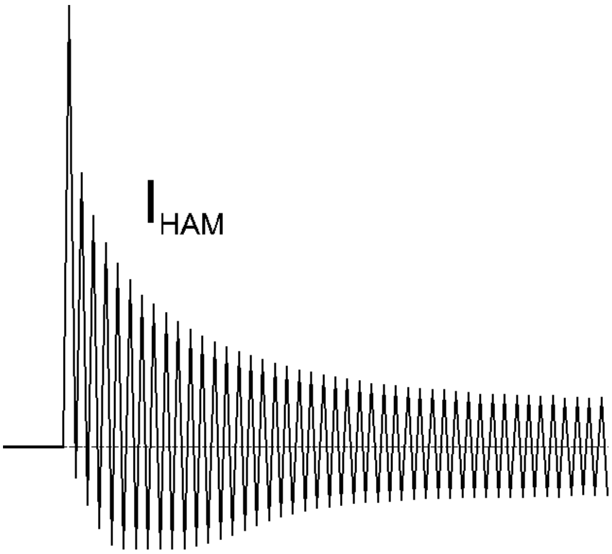

Fig.5. Time variation of the magnetizing current

3. Comparison with baseline data: Monitoring results are compared with baseline data to determine if the current values differ from the normal operating condition.

Magnetizing current monitoring is an important tool for assessing the condition of power autotransformers. It allows operators and engineers to monitor the condition of the transformer and take maintenance and repair actions, which helps to maintain the reliability and efficiency of power systems.

Conclusion

Monitoring the condition of power autotransformers plays a key role in ensuring the reliability and safety of power systems. The existing monitoring methods described in this paper provide important tools for power system engineers and operators to effectively manage and maintain autotransformers. The development and utilization of new monitoring techniques continues to contribute to the development of an efficient and reliable electric power industry.

References

1. Gavrilenko, A.V., Dolin, A.P., Methodology of vibration inspection of power transformers, 2004.

2. Mikheev G.M. Thermal Inspection of High Voltage Equipment: Training Manual, Cheboksary: Izd-vo Chuvash Usta, 2004, 180 p.

3. L.G. Sidelnikov, A.M. Sedunin, A.Y. Sykulev, "TestService" Ltd. Oil diagnostics in power transformers.

4. VILKOV S.A. OBSERVE OF MODERN DIAGNOSTICS OF POWER TRANSFORMERS AND AUTOTRANSFORMERS Modern Scientific Research and Innovations. 2012. No. 9. URL:https://web.snauka.ru/issues/2012/09/16794

5. L. G. Sidelnikov, A. M. Sedunin, A. Y. Sykulev, TestService LLC Vibrodiagnostics and Partial Discharge Measurement in Power Transformer.

6. Bashirov, Z.A.; Voloshanovsky, A.Yu.; Naumov, A.A. A. Sensor arrangement methods for the scalar vibration field estimation in the vibrodiagnostics tasks (in Russian) // Problems of Power Engineering. 2000. № 7-8. C. 86-90.

7. Barkov A.V., Barkova N.A., Azovtsev A.Yu. Monitoring and diagnostics of rotor machines by vibration. Recommendations for users of diagnostic systems. Publishing house of SPbSMTU, St. Petersburg, 2000.

8. Petrishchev L.S., Saltanov V.M., Osotov V.N. et al. Investigation of possibility of diagnostics of transformer winding pressing force by their vibration characteristics. - Electrical Stations 1995, N 8, p. 32-37.