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The "Engineer" publishes the most significant results of scientific and applied research carried out in universities of transport profile, as well as other higher educational institutions, research institutes, and centers of the Republic of Uzbekistan and foreign countries.

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Assessment of dielectric insulation condition of power transformers using Dielectric Absorption Ratio (DAR) and Polarization Index (PI)

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Abstract: The operational reliability and service life of power transformers significantly depend on the condition of their solid dielectric insulation. Moisture ingress, thermal aging, and electrical stress alter the dielectric properties of insulation, reducing its electrical strength and accelerating degradation processes. This paper examines two widely used diagnostic indicators—the Dielectric Absorption Ratio (DAR) and the Polarization Index (PI)—which are employed to assess insulation moisture content and aging degree. The diagnostic criteria, interpretation of measured results, and significance of these indicators in predictive maintenance are presented.

Keywords: Dielectric Absorption Ratio (DAR); Polarization Index (PI); transformer insulation diagnostics; moisture assessment; dielectric response; solid insulation aging; time-domain insulation testing; insulation resistance; transformer condition monitoring; dielectric degradation

1. Introduction

Solid dielectric insulation plays a critical role in ensuring the operational stability and energy efficiency of power transformers and electrical machines. Variations in environmental humidity, temperature, mechanical stress, and prolonged exposure to electric fields cause changes in the insulation's dielectric characteristics. These changes lead to increased leakage current, reduced insulation resistance, higher dielectric losses, and deterioration of electric strength. Therefore, proper diagnostic evaluation of insulation condition is essential for preventing failures and planning maintenance.

Among various insulation diagnostics methods, the most informative and widely applied are the Dielectric Absorption Ratio (DAR) and the Polarization Index (PI). These parameters provide qualitative and quantitative assessments of insulation moisture levels and aging state.

2. Methodology

2.1 Dielectric Absorption Ratio (DAR)

The Dielectric Absorption Ratio (DAR) reflects the polarization processes occurring in the dielectric material and serves as an indicator of moisture content. DAR is determined by comparing insulation resistance values measured after 15 seconds (R_{15}) and 60 seconds (R_{60}):

$$DAR = \frac{R_{60}}{R_{15}}$$

2.2 Polarization Index (PI)

The Polarization Index (PI) reflects the insulation's aging state and slow polarization processes. It is calculated as the ratio of resistance measured at 600 seconds (R_{600}) to resistance at 60 seconds (R_{60}):

$$PI = \frac{R_{600}}{R_{60}}$$

Higher PI values indicate low leakage current and stable dielectric performance, while lower values indicate degradation.

PI provides deeper diagnostic insight compared to DAR because it captures slower polarization phenomena associated with structural insulation aging.

3. Results and Discussion

The presence of moisture significantly lowers insulation resistance due to dissolved ions that increase leakage current and dielectric losses (tgδ). This leads to:

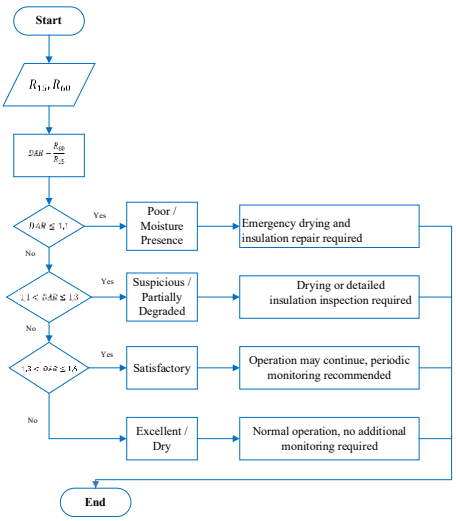

Fig. 1. Diagnostic Flow Chart for Transformer Insulation Evaluation Based on Dielectric Absorption Ratio (DAR)

- Increased heat generation in the insulation

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- Acceleration of thermal aging
- Reduced dielectric breakdown strength

Both DAR and PI decrease when insulation contains moisture, exhibits high ionic conductivity, or undergoes thermal-oxidative aging. This leads to:

- Reduction in electric breakdown strength
- Increase in dielectric losses
- Advancement of aging reactions
- Increased probability of catastrophic insulation failure

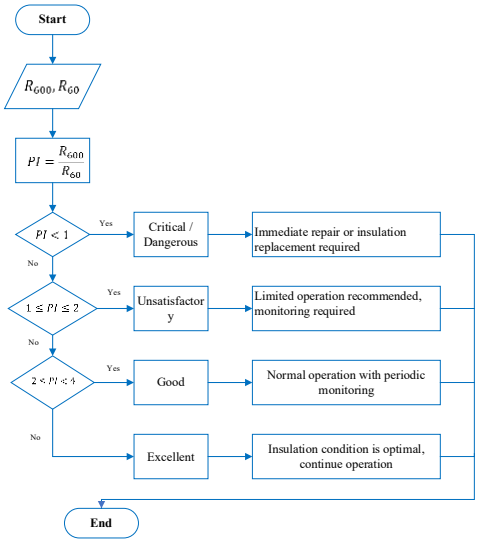

Fig.2. Diagnostic Flow Chart for Transformer Insulation Evaluation Based on Polarization Index (PI)

For comprehensive insulation evaluation, DAR and PI should be analyzed together with additional indicators such as:

- Dielectric loss tangent (tgδ),
- Capacitance variation,
- Temperature correction factors of insulation resistance.

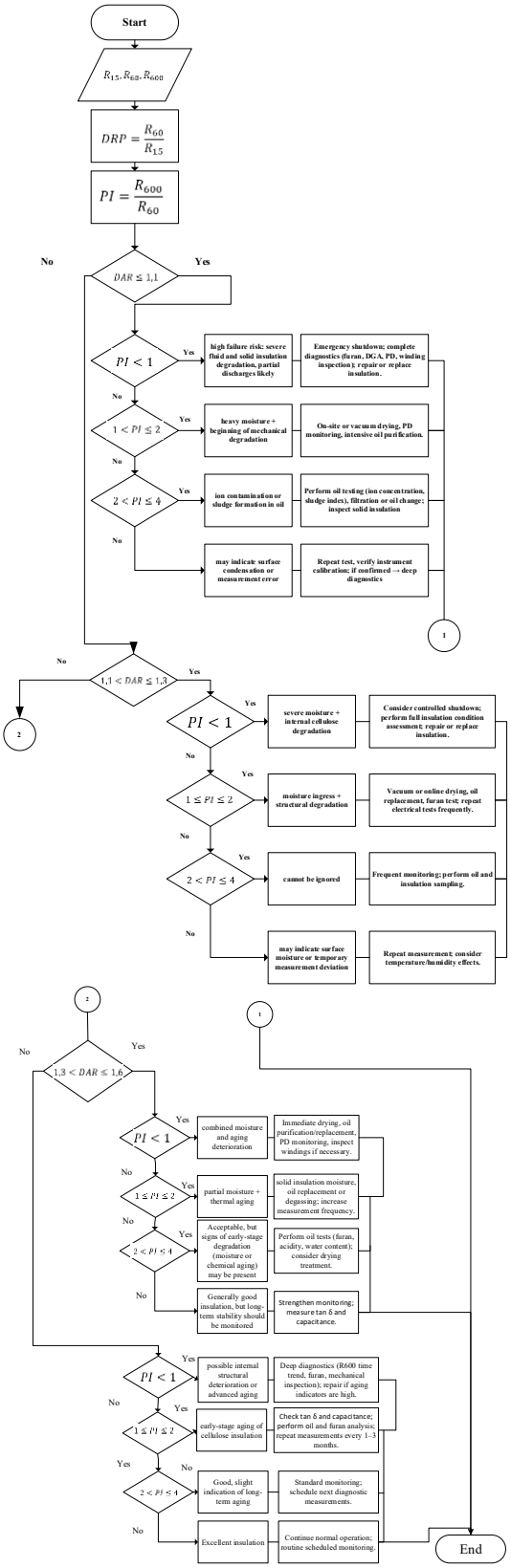

Fig. 3. Combined diagnostic flow chart for insulation condition decision based on DAR and PI

4. Conclusion

The experimental and mathematical investigations conducted in this study provided a comprehensive evaluation of the robustness and data transmission performance of telemetry systems operating in different frequency bands under electronic warfare (EW) conditions. Testing the TBS Crossfire (868 MHz) and LoRa SX1278 (433 MHz) modules—integrated with an STM32 microcontroller—at distances of 50 m, 100 m, and 200 m under a 10 W jamming signal demonstrated that the stability of the telemetry channel is critically dependent on both physical signal attenuation and the interference-induced SINR values.

References

[1] Kutbidinov O.M., Yusupov D.T. Probability of safe operation and failure of the traction transformer // III Международная научная конференция на тему: «Актуальные вопросы прикладной физики и энергетики» Азербайджан, г. Сумгаит, 27-28 октября 2022 г., с. 144-146.

[2] Pankaj Sh., Sood Y.R., Jarial R.K. Experimental Evaluation of Water Content in Transformer Oil // International Journal of Innovative Research in Science, Engineering and Technology. Vol. 2. 2013. pp. 284-291.

[3] Yahya A. A. Assessment of the Efficiency of Transformers Technical Condition Monitoring Based on Dissolved Gas Analysis // J. Sib. Fed. Univ. Eng. Technol. 2020. Vol. 13, №. 4. pp. 438-448.

[4] M. Koch, M. Krüger, and J. Blennow, “Influence of Charging Voltage Magnitude on Time Domain Dielectric Response of Oil-Paper Insulation,” IET Science, Measurement & Technology, vol. 13, no. 6, pp. 870–876, Aug. 2019, doi: 10.1049/iet-smt.2018.5276.

[5] Nnachi, G.U.; Nicolae, D.V. Diagnostic methods of frequency response analysis for power transformer winding a review. In Proceedings of the 2016 IEEE International Power Electronics and Motion Control Conference (PEMC), Varna, Bulgaria, 25–28 September 2016; IEEE: Piscataway, NJ, USA, 2016; pp. 563–568.

[6] Jaiswal, G.C.; Ballal, M.S.; Tutakne, D.R.; Doorwar, A. A Review of Diagnostic Tests and Condition Monitoring Techniques for Improving the Reliability of Power Transformers. In Proceedings of the 2018 International Conference on Smart Electric Drives and Power System (ICSEDPS), Nagpur, India, 12–13 June 2018; IEEE: Piscataway, NJ, USA, 2018; pp. 209–214.

[7] Giri, L.N.; Singh, G.; Kumar, S.; Jaiswal, M.K. Role of Tan Delta Measurement Technique in Power Transformer Moisture Condition Assessment at Factory and Field Level. Int. J. Adv. Res. Electr. Electron. Instrum. Eng. 2025, 14, 51–57.

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