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ASSESSMENT OF CURRENT TRANSFORMER USING HEALTHY INDEX AT ULTG PANAKKUKANG

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***Abstract*— Current transformers (CTs) play a crucial role in the measurement and protection of electrical networks, directly impacting the performance and stability of the distribution system. Over time, the condition of current transformers can degrade due to factors like age, environmental conditions, and overloads. To ensure the health status of these transformers, an assessment method using the Healthy Index (HI) is applied. This research utilizes data from tests on tan delta, insulation resistance, ratio, thermography, excitation, and the age of the current transformer. The data is categorized into two factors: the Conditional Assessment Factor (CAF), which provides a real-time condition overview from tan delta data (where values above 1% indicate poor and values below or equal to 1% indicate good condition), insulation resistance (where values below or equal to 1 Mega Ohm/1kV indicate poor and above 1 Mega Ohm/1kV indicate good), thermography (where temperatures above 4°C are considered poor, temperatures between 1°C and 3°C are medium, and normal temperatures relative to ambient conditions are good), and ratio; and the Performance Assessment Factor (PAF), which assesses equipment performance based on transformer age. Age classifications are 20-35 years as poor, 16-20 years as medium, and below 16 years as good. Following the gathering of CAF and PAF data, a systematic calculation of each factor's weighting is conducted using the Assessment Healthy Index (AHI) Calculation method, resulting in assessment ratings of 1 for poor, 6 for medium, and 9 for good. From these categories, conclusions can be drawn regarding the next steps for the current transformer, determining whether repair or replacement with a new transformer is necessary.**

Keywords—component; Conditional Assessment Factor, Performance Assessment Factor, Assessment Healthy Index

I. Introduction

In an electrical power system, current transformers (CTs) play a crucial role in measurement and protection of the electrical network. The operational reliability of CTs significantly affects the overall performance and stability of the power distribution system. Over time and with continuous use, the condition of CTs can deteriorate due to factors such as age, environmental conditions, and overload. Thus, an effective method to accurately assess the health status of current transformers is essential to ensure operational reliability and efficiency.

One approach used to assess the health condition of CTs is through the implementation of a Healthy Index. This index is an assessment method that combines various operational parameters and inspection results to provide a comprehensive overview of the condition and performance of CTs. By using the Healthy Index, power system operators can anticipate maintenance needs, estimate the remaining service life of transformers, and take proactive steps to prevent unexpected failures.

Failures or malfunctions in current transformers can have serious impacts, not only on the continuity of power supply but also on the safety and reliability of equipment throughout the power system. Undetected damage in CTs can lead to extensive disruptions in the electrical network and increase the cost of unexpected repairs. Therefore, a data-driven approach that enables predictive monitoring and maintenance is essential to maintain a safe and efficient power system operation.

The use of the Healthy Index also supports investment optimization in the maintenance and replacement of CTs. By understanding the health status of CTs in real-time, utility companies can set better maintenance priorities, allocate resources more efficiently, and extend the lifespan of equipment that remains in good condition. This approach not only reduces operational costs but also enhances the reliability and availability of the power network. Additionally, the application of the Healthy Index aligns with sustainability initiatives in the energy sector.

Based on the introduction, the following research problems are identified:

1. How can the health status of a current transformer (CT) be measured and evaluated using an index that provides a comprehensive assessment of the transformer's overall condition?
2. What corrective or maintenance actions should be taken based on the health evaluation results of the current transformer? These questions aim to provide a structured approach for monitoring CT performance and addressing potential issues proactively.

This study is limited to evaluating current transformers within specific substations under the operational area of ULTG Panakkukang. The scope is restricted to eight substations: GI Tanjung Bunga, GI Bolangi, GI Bontoala, GI Borongloe, GI Lanna, GI Panakkukang, GI Sungguminasa, and GI Tallo Lama. Additionally, the study focuses exclusively on assessing the health index of these current transformers to ensure the evaluation aligns with the identified objectives.

The objectives of this research are to accurately measure and evaluate the health of current transformers using an index that offers a comprehensive condition overview. This study aims to enable power system operators to make informed maintenance and corrective decisions based on the health evaluation outcomes. By identifying necessary interventions, the study seeks to contribute to extending the lifespan and maintaining the reliability of current transformers within the power distribution network.

II. Research Methodology

A. Method

This research was conducted at PT. PLN (Persero) Transmission and Substation Service Unit (ULTG) Panakkukang, located at Jalan Hertasning Baru, Panakkukang District, Makassar City, South Sulawesi, beginning in December 2023. The research followed a structured, systematic, and directed procedure. A quantitative approach was employed, where the researcher collected data, performed calculations, and conducted tests according to applicable standards. The steps included identifying problems with the study object, conducting a literature review, performing tests such as thermovision, tan delta, insulation resistance, ratio, anomaly count, and operating age of the current transformer, and compiling data. This was followed by assessing test results based on SK Dir 520, developing a Healthy Index worksheet, and drawing conclusions from the analysis to address the research objectives. The flowchart of this research procedure is illustrated in Figure 17.

B. Figure and Table

The data collection method for this research involved various approaches to gather information on the research variables. Techniques included literature review, interviews, direct observation, and documentation collection. Specifically, the literature review gathered information from PLN’s SK Dir guidelines, books, and journals relevant to the research topic and objectives. Interviews were conducted with qualified sources in the field to clarify any unknown or unclear aspects. Direct observation allowed the researcher to assess the conditions of the research objects, specifically thermovision, tan delta, insulation resistance, and current transformer ratios at ULTG Panakkukang. Data analysis was then performed to process and interpret findings, enabling the researcher to address the formulated research questions.

III. Results and Discussion

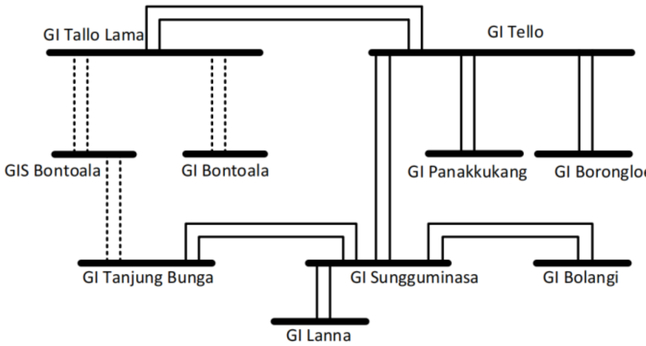

Figure 1 Single Line Diagram of the ULTG Panakkukang System

The data collection methods for this research included literature review, interviews, direct observation, and documentation gathering. The literature review involved consulting PLN's SK Dir guidelines, books, and relevant journals to obtain foundational information aligned with the research topic and objectives. Interviews were conducted with qualified individuals in the field to clarify any ambiguous aspects and gain insights directly related to the research.

Direct observation allowed the researcher to examine the conditions of specific research objects, such as thermovision, tan delta, insulation resistance, and the ratio of current transformers at ULTG Panakkukang. After collecting data, an analysis was conducted to interpret the findings, ensuring that the results provided clear answers to the research questions outlined in the problem formulation.

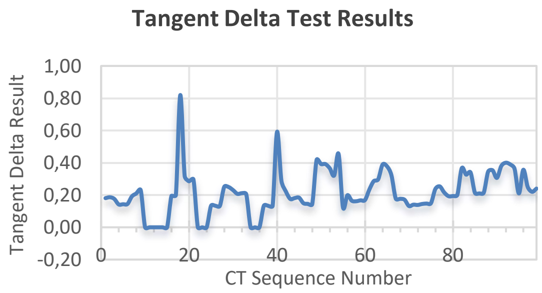

Figure 2 Curve of Tangent Delta Test Data Results

Based on the curve of tangent delta test data in Figure 2, the results show the following distribution of current transformers: 87 current transformers have a tangent delta value of ≤ 1%, 0 current transformers have a tangent delta value > 1% (or 0.01), and 12 current transformers are marked as "N" because testing has not been conducted on them.

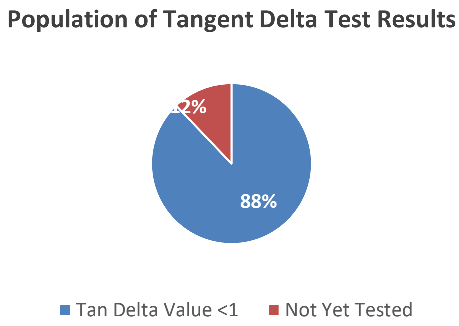

Figure 3 Population Diagram of Tangent Delta Test Results

Based on the diagram above, 88% of current transformers are in good condition with a tangent delta value of <1%, while 12% of the transformers could not be tested due to the lack of a scheduled outage. Overall, the tangent delta test results indicate that the transformers are in good condition. However, there is one current transformer with a tangent delta value of 0.82%—close to the 1% threshold—located at Tanjung Bunga Substation Bay Distribution Transformer #1, which requires attention. To ensure appropriate follow-up, an insulation resistance test should be conducted on this unit. Additionally, there are 12 current transformers pending testing due to the absence of a scheduled power outage for testing purposes.

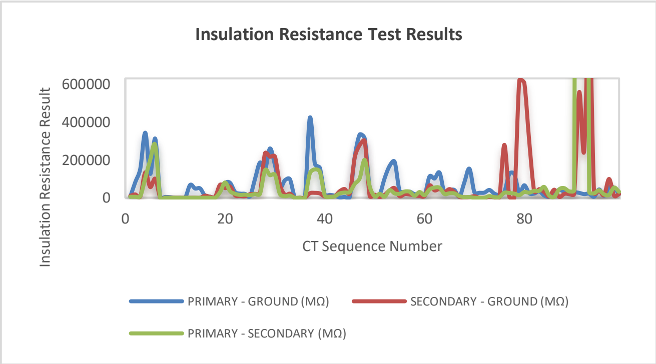

Figure 4 Curve of Insulation Resistance Test Data Results

Based on the data above, the insulation resistance test results show that all values are above 1 Mega Ohm, indicating that the insulation resistance condition of all current transformers is in good condition.

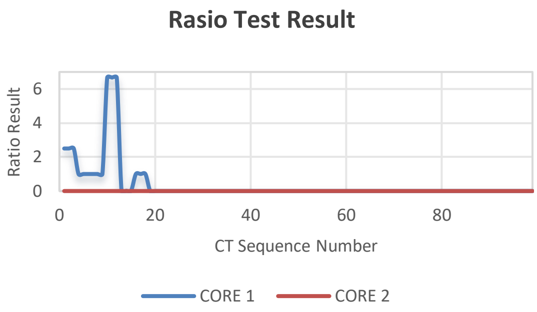

Figure 5 Curve of Ratio Test Data Results

Based on the curve above, the results are as follows: 81 current transformers have a ratio test result below 1, 15 current transformers have a ratio test result above 1, and 3 current transformers have not yet been tested. This distribution provides an overview of the current performance and consistency levels across the transformers.

When these results are compared to the standard ratio testing with a reference error scale of 1%, a more detailed distribution can be illustrated in the following diagram, allowing for a clearer understanding of any deviations and areas requiring attention.

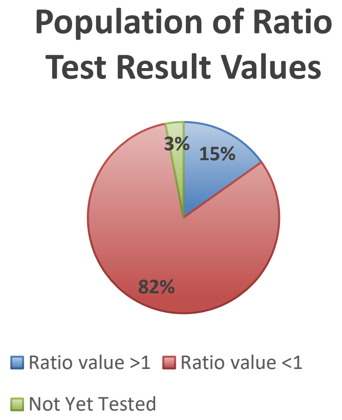

Figure 6 Population Diagram of Ratio Test Results

Based on the diagram in Figure 23 above, the results indicate that 82% of current transformers are in good condition, 15% have suboptimal values and require retesting or repairs, and 3% they have not yet been tested due to the absence of a scheduled outage.

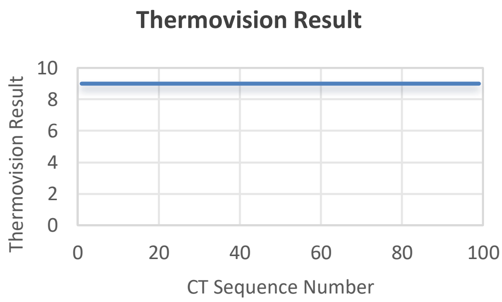

Figure 7 Thermovision Test Data Curve

Based on the curve above, the thermography test results for all 99 current transformers are excellent, as all values are above 9.

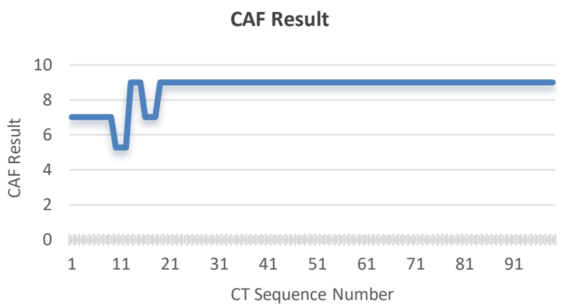

Figure 8 CAF Calculation Data Curve

Based on the curve above, there are 6 current transformers with a CAF value below 50%, detailed as follows: Phase R Bay Transformer #1 GI Panakkukang 150 kV with a CAF value of 5.2778 or 44%, Phase S Bay Transformer #1 GI Panakkukang 150 kV with a CAF value of 5.2778 or 44%, and Phase T Bay Transformer #1 GI Panakkukang 150 kV with a CAF value of 5.2778 or 44%. Additionally, Phase R Bay Line Punagaya #1 GI Tanjung Bunga 150 kV has a CAF value of 9 or 23%, Phase S Bay Line Punagaya #1 GI Tanjung Bunga 150 kV has a CAF value of 9 or 23%, and Phase T Bay Line Punagaya #1 GI Tanjung Bunga 150 kV also has a CAF value of 9 or 23%.

The low CAF values for phases R, S, and T in Bay Transformer #1 GI Panakkukang 150 kV, recorded at 5.2778, are attributed to the absence of test data for tangent delta, insulation resistance, and excitation tests. Similarly, the CAF values of 9 for phases R, S, and T in Bay Line Punagaya #1 GI Tanjung Bunga 150 kV are due to missing data from tangent delta, insulation resistance, ratio, and excitation tests. These missing test results impact the overall assessment of transformer health in these specific units.

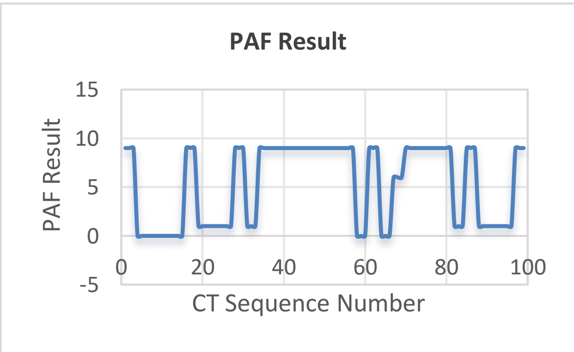

Figure 9 PAF Calculation Data Curve

Based on the curve above, the PAF (Performance Assessment Factor) calculation results are detailed as follows: 54 current transformers have a PAF value of 9 due to an operating age of less than 16 years; 3 current transformers have a PAF value of 6 with an operating age between 16 and 20 years; 24 current transformers have a PAF value of 1, with an operating age ranging from 20 to 35 years; and 18 current transformers have a PAF value of 0, as the operational year data is unavailable, making the operating duration of these transformers unknown.

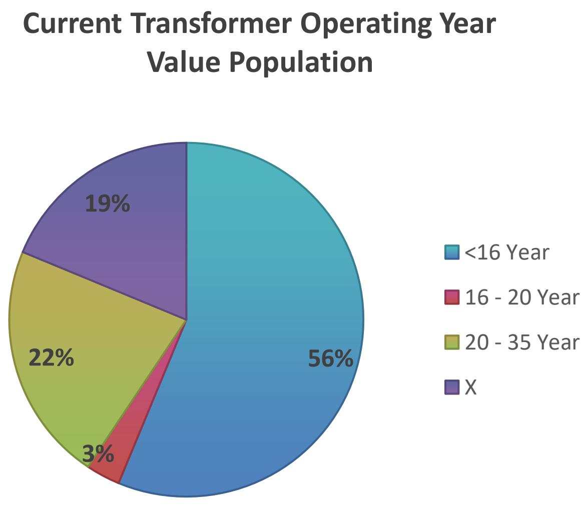

Figure 10 Population of Current Transformer Operating Year Values

Based on the diagram above, the distribution is as follows: 56% of current transformers have been in operation for less than 16 years, 3% have been in operation between 16 and 20 years, 22% have an operational duration of 20 to 35 years, and 19% have an unknown operating duration.

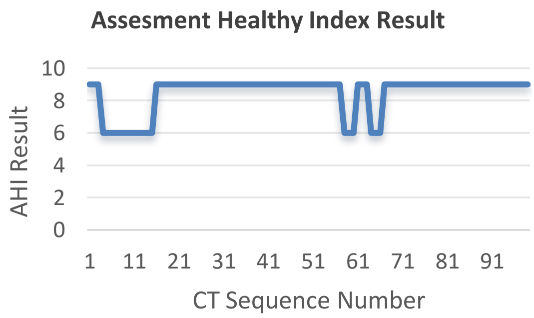

Figure 11 Healthy Index Calculation Data Curve

Based on the data from the curve, there are two levels of certainty in the current transformers: 81 current transformers have a certainty level of 100%, while 18 current transformers have a certainty level below 59%.

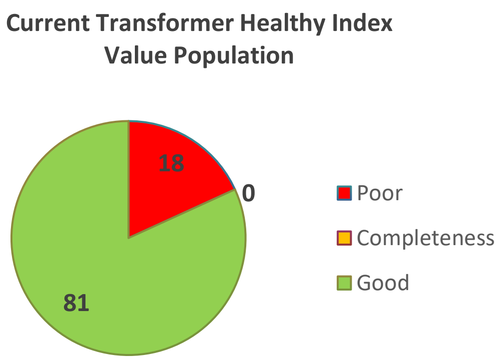

Figure 12 Population of Current Transformer Healthy Index Values

Based on the diagram above, the following can be outlined: 81 current transformers have a Healthy Index assessment indicating good condition; 0 current transformers require additional testing data to complete the assessment; and 18 current transformers have a Healthy Index assessment indicating suboptimal condition, necessitating equipment replacement.

Discussion

Current Transformer Certainty Level

The certainty level of a current transformer (CT) serves as an indicator of how accurately and reliably the transformer can reproduce primary current into secondary current as specified. This level is particularly relevant for ensuring measurement accuracy and performance reliability in various operational conditions. Key factors influencing the certainty level include the accuracy class, which denotes how close the secondary current is to the actual primary current (expressed as percentages like 25%, 50%, or 100%), and the transformation ratio precision, where deviations suggest measurement errors. Additional factors include secondary load, where deviations from recommended load can lead to inaccuracies, environmental conditions (such as temperature, humidity, and electromagnetic interference), and the physical condition and age of the transformer, as material degradation over time can reduce certainty levels.

A high certainty level is crucial in applications demanding precise measurements, such as protection systems and energy monitoring. As the certainty level increases, the likelihood of measurement errors decreases, enhancing the electrical system's reliability and efficiency. Environmental factors, such as extreme temperatures or high humidity, as well as component aging, play significant roles in determining certainty levels, making regular monitoring essential.

Causes of Certainty Level Degradation in Current Transformers and Corrective Actions

Several factors can lead to a reduction in the certainty level of CTs, requiring targeted corrective actions to mitigate this decline. Insulation degradation, often caused by heat, humidity, or excessive voltage, can lead to current leakage and reduced accuracy. Regular insulation tests, like tan delta or high-voltage tests, are recommended, and significant degradation may necessitate insulation repair or replacement. Aging of internal components, including the core or windings, can also affect measurement accuracy. Predictive maintenance programs are beneficial for early detection, and replacing older transformers can prevent issues caused by worn components.

Electromagnetic or environmental interference is another factor, where extreme temperature fluctuations or high humidity levels can impact transformer accuracy. Proper placement, electromagnetic shielding, and environmental controls can help reduce this risk. Mechanical damage, caused by vibration or impact, can lead to structural issues and accuracy decline. Routine visual inspections and physical condition assessments are crucial, with repairs or replacement as needed. Unstable operating conditions, such as excessively high or low voltages, can also create errors, so continuous monitoring and additional protective measures are recommended to maintain operational stability.

In general, for CTs with low certainty levels, the recommended steps include periodic maintenance and inspections to identify and resolve issues before they worsen, replacing degraded or damaged components (such as windings, insulation, or cores), and, if necessary, upgrading older units to newer models with improved specifications and accuracy. Taking these actions can minimize certainty level degradation, ensuring reliable and accurate operation of the electrical system.

Web-Based Healthy Index for Current Transformers on Google Sheets

By maximizing the use of online technology, all maintenance personnel in PT PLN (Persero) UIP3B Sul's substation environment can input, manage, and analyze data periodically using Google-developed software. This approach simplifies data collection, analysis, and decision-making processes, particularly for transformers with lower certainty levels, facilitating timely and accurate maintenance planning.

IV. Conclusion

Based on the research results on the healthy index assessment of current transformers at ULTG Panakkukang, the following conclusions can be drawn:

1. The health measurement and evaluation of current transformers can be effectively conducted using the healthy index assessment method, which provides a quantitative approach to assess the overall condition of transformers by integrating various technical parameters and inspection results, such as tangent delta test data, insulation resistance, ratio, thermography, and transformer age. This method offers a clear and accurate depiction of transformer reliability levels.
2. Corrective or maintenance actions based on the health evaluation of current transformers include predictive maintenance to prevent potential failures, preventive maintenance to ensure optimal performance, replacement of components showing functional decline, and, if necessary, replacing the current transformer with a new one.

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