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A Detailed Description Of Problem Detection In Transformers Using Sweep Transient Response Evaluation

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Abstract

Transformers powered electric pumps, fans, and conveyors. Power and speed affect motor voltage. Transformers create voltage for loads. Unfortunately, daily operation reduces transformer performance. The transformer technical evaluation must be repeated by watching performance. This research periodically inspects a high-power transformer in repair and outage at an Indonesian utility facility. Checking maintains user device performance. SFRA measurements in the 5th unit were checked every six years. Measured in 2007 & 2013. SFRA tests transformer windings and cores by injecting low voltage at a specified frequency. If SFRA finds a winding defect, replace or repair the transformer. The transformer winding & core are in excellent condition after SFRA assessment since shrinkage is less than 20% of the its standard percentage. Thus, PT. YTL East Java's 500 kV power transformer requires less maintenance. Power system lost assets and dependability due to transformer failure. This article describes Sweep Parametric Analysis (SFRA) and its use in transformer testing and maintenance. SFRA tests transformer mechanical integrity electrically. SFRA frequency response changes may indicate physical changes within the transformer, which must be discovered and probed.

Keywords- Power transformer, sweep frequency, signature curve, Sweep Frequency Response Analysis (SFRA), Power Transformer, High Voltage (HV), Low Voltage (LV).

Introduction

Power transformers are essential to distribution and transmission [1]. Transformer insulation strength should increase with transmission voltage transfer capability [2]. Scale up transformers step up power from lower ratings to higher ratings for transmission. Losses arise during power transformation. Transformers may have turn-to-turn, inter-turn, winding, core, insulation, and short-circuit defects. Workdays cause these issues. Transportation from manufacture to installation might cause problems. Transport deforms coil and core.

For standard-compliant transformer dependability, distribution power system transformer performance should be excellent. Electromagnetic vibration analysis measures transformer performance[1]. It detects short circuit flux leakage & electromagnetic force. Acceleration sensors are still needed to detect winding vibrations. Short–Circuit Impedance (SCI) is the next transformer performance test[2]. This approach compares real voltage and current to factory nominal voltage. Short circuit impedance tests only provide power frequency winding information. SCI test cannot identify damaged transformer active components. IFR analysis is another method[3]. This circuit exam is harder than the two. This strategy makes measuring the transformer's thin winding conditions challenging. Impulse signals generate harmonic distortion. Thus, FFT injects impulse signals to acquire winding and core mechanical deformations. Sweep Parametric Analysis (SFRA)[4] detects transformer deformation mechanic structure. SFRA may reveal the winding mechanical structure, core, and clamping structure[5]. Even little winding & core distortion might cause the transformer to fail under fault conditions. Short circuits and shrinking thin transformers may damage cores. SFRA detects mechanical transformer deformation. SFRA may detect mechanical faults such core or winding movement, transformer, and electric faults like short-circuit and partial discharge[6]. SFRA may be impulsive voltage-based, sinusoidal sweep frequency, or other forms depending on the input signal [7]. SFRA sinusoidal sweep signal voltage amplitude is constant from 20 Hz to 20 MHz. Thin transformer terminals receive generator signal. Sweep source-based work uses various frequency ranges. Faults also influence signal bandwidth and level ratio [8]. Multiplication with denominator and refracted result make this error function familiar [9]. Winding transformer injects voltage signal frequency to one end and receives reaction from the other. This approach works when the transformer phase has a fingerprint transfer function that responds to winding, resistance, inductance, & capacitance variations.

Transformers have resistance, capacitance, and inductance networks. Due to current, transformer mechanical deformation generates tremendous force. That force deforms winding racially and axially. Deformation changes R-L-C characteristics. Sweep frequency in the winding allows SFRA to detect that deformation. Faulty transformers have different SFRA findings.

Methods of Study

Collects and tests transformer data in the field. Summarize and compare deformation techniques [10]. The most powerful diagnostic equipment for damaged core and winding transformers is SFRA. Analysis shapes SFRA response tracks frequency thin transformer. The transformer fault location may be tracked throughout core and winding transformer deformation[11]. The transformer winding short circuits due to core shrinkage from long-term operation. Thus, the transformer must be checked before and after repair or relocation. After a defect, cable connections to low voltage (LV) wind, high voltage (HV) coils, tap changer, & bushing malfunction. Spreading transformer vitality protection reduces these problems. Sweep frequency response analysis (SFRA) Sweep Frequency Analysis is a popular transformer deformation winding detection approach (FRA). HV winding problems were common[12]. PT. YTL East Java used this approach to assess transformer use. Maintenance and at least one measurement were done every six years. Comparing phases Besides manufacturing tolerances, transformer coils are likely constructed similarly. Real voltages and currents are occasionally undermeasured. Thus, frequency response measurements in various interphases [13] should be comparable up to 100 kHz. The transformer tank's in-line three coil sets with the tap changer on one side are the limiting issue. Thus, the winding tap leads to the tap changer varied in length for each phase. This affects coil frequency responsiveness. Comparing time Time-based comparison compares frequency response measurements on transformers with comparable manufacture and the same system setup (terminal connections, etc.). The most current results are compared [14]. Besides manufacturing tolerances, they should behave similarly. Almost same. International SFRA experience shows a frequency response of 100 kHz. First, measurement usually just compares phases. Start a time-based comparison with the next SFRA readings. All comparison approaches need measurement repeatability. This necessitates reconstructing the measuring set-up for each measurement as identically as feasible. Taking images of the measurement set-up helps accomplish this purpose. Standardized automated measuring systems execute measurements [15]. SFRA Measurement 2.4 SFRA used basic formulae [16]. A sinusoidal voltage source with changing frequency was attached to one of the three phase terminals or the associated phase terminal in a delta winding[17]. Figure 1 depicts 50 - termination. The frequency response is the ratio of the voltage (U2) measured at a winding terminal to the voltage (U1) applied to the corresponding terminal point. This phase-based comparison at the HV winding may use U, V, or W frequency responses. Other winding connectors are open. SFRA with short-circuited coils or transfer mittance measurements are optional but occasionally useful. Transfer functions were measured from 20 Hz to 2 MHz.

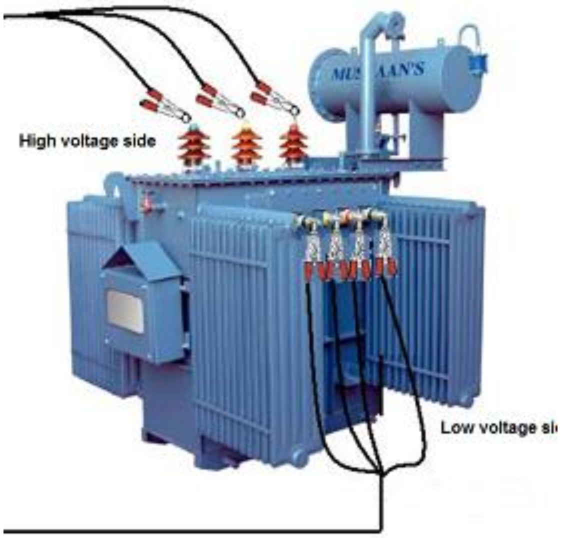

Figure 1. HV terminal connection on the measurement circuit of frequency response winding.

Figure 2 shows the SFRA circuit, which is more accurate below 10 kHz. The core shape causes magnetization up to 2 kHz. Time-based FRA sweeps may vary according on core magnetic flux density. Therefore, start with SFRA measurements. De-magnetization precedes other measures.

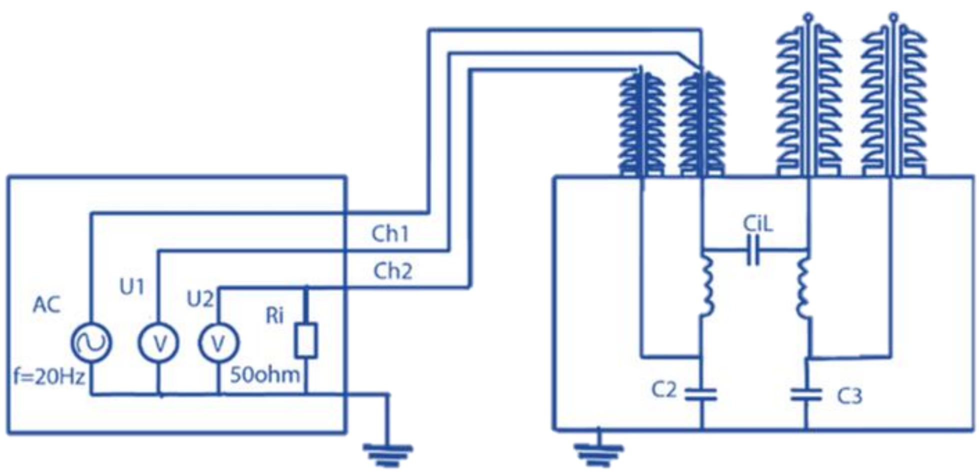

Figure 2. The measurement circuit of frequency response in LV winding.

Same transformer frequency response. A reference measurement compares the same system configurations. The reference measurement came first. This comparative approach permits direct inferences on core-and-coils assembly differences between measurements.

Table 1 shows the examined transformer's nominal voltages and currents. HV side has Y connector, LV side has. It included many load-side voltage taps. Figure 3 shows generator power allocated to load within and outside the facility.

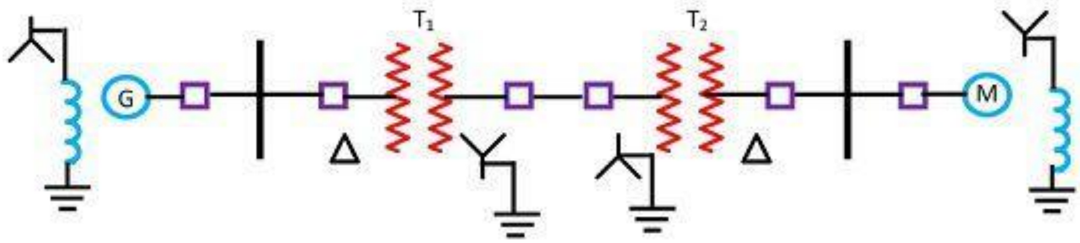

Figure 3. The single line diagram of typical power system.

Short Circuit Forces in Transformer

Short circuits in transformers generate force that might harm them. These forces distort transformer winding radially and axially. Short-circuit Symmetrical current is 6–7 times rated current and may reach 15–18 times at peak time [3].

F = BIL Newton, where B represents flux density in Tesla and I is current in Ampere and Conductor length in metres

Because current squared increases forces, they are quite high. These forces expand the current-carrying conductor radially and axially. Mechanical changes in winding affect impedance.

Identification Analysis Method

There are several ways available for transformer failure detection. nonetheless, dissolve gas analysis and partial discharge technique are the two that are most often used and Analysis of sweep frequency response

I Analysis of Dissolved Gas

Gases are released within transformers and other electrical equipment when insulating materials break down. Both the distribution of these gases and the pace at which they are produced may provide information about the kind and severity of an electrical breakdown. The kind of gases being produced by a certain machine might provide important information concerning faults. Depending on the kind of gas recovered from transformer oil, several fault types exist.

II Partial discharge technique

Micro voids emerged in the transformer's insulation during its first year of operation as a result of faulty manufacturing procedures. Over time, a little hollow might become a large one. Potential difference across the vacuum is caused by electromechanical stress. The partial discharge (PD) that results from this treeing effect on the opposing electrodes signifies that a conducting channel has developed on the surface of the insulating material, resulting in poor insulation. This indicates that the insulation has failed. PD is a significant process that contributes to the deterioration of transformer winding insulation. Numerous approaches, such UHF light emission, chemical procedures, and acoustic emission techniques, may locate the real PD.

III Analysis of sweep frequency response

This technique may provide accurate information on a core movement and winding deformation indicator. There are four phases to this process.

• Measurement in a functional transformer • Once more measurement in a defective sister transformer with a comparable rating

If there is a discrepancy between the two situations, a fault happened. The signature curve of both conditions indicates if a condition is healthy or defective.

Measurements are made using this approach at frequencies ranging from 20 Hz to 20 MHz. In comparison to the DGA and PD methods, it is the most effective defect detection approach. Since fault may be found in both scenarios, the PD approach can only be used to find insulation failure. However, using the SFRA approach, we may identify a variety of transformer-related defects as well as their precise position. Therefore, it is more efficient than DGA and PD techniques.

Results and Discussion of the Study

Fingerprint distortion helps identify the transformer. Short-circuit impedance test and SFRA vary because SFRA short-circuits one transformer terminal. This approach only displayed phase impedance.

Frequency responses in Figures 5–8 are similarly lined. SFRA tests are done at various terminals, although the responses below 10 kHz are similar and mainly impacted by core misalignment. The frequency components should be equal up to 100 kHz. The core shape causes magnetization up to 2 kHz. Time-based FRA sweeps may vary according on core magnetic flux density. Thus, SFRA measurements should commence.

BAT transformer frequency responses reduced in 2013. The HV and LV winding measurements indicated minimal interference and no usual variation. Table 2 shows frequency analysis sub-band sensitivity for transformer BAT. Region 1 has a mean primary focus shrinkage of less than 2 kHz, however measurements reveal no variance.

SFRA measurement in LV winding decreases frequency by 2 kHz. SFRA assessment in PT. YTL East Java limits winding and core damage and shows shrinkage in the main core, bulk winding, and inductance. That statistic also shows that shrinkage is less than 20%. Since 2013, the transformer worked well. The same measuring method was used in 2019. The expected damage is 20%. The 5th unit measured SFRA every six years. To preserve the transformer's viability, maintenance was done again in 2019.

Simulation Results Sweep Frequency

MATLAB/simulink simulates Sweep frequency response analysis. This section explains the same outcomes for various instances. Explained below. Normal: MATLAB/Simulink creates the sweep frequency response transformer model. Normal transformer response. No transformer problem causes this reaction. Transformer winding equivalent circuits include several inductance, resistance, and capacitance parts over large frequency ranges. Mutual capacitive and inductive coupling between winding parts determines winding SFRA response, including multiple resonance & antiresonances. Resonance begins at 414 KHz. After resonance, transformer winding inductance dominates. Winding inductance screens magnetic action after initial resonance point. This technique repeated numerous times to increase medium frequency resonance sites.

Winding series & shunt capacitance cancels inductance effect after medium frequency range. Waveform current is 450.1 A. The initial resonance point shows considerable waveform displacement relative to no fault waveform. First resonance at 424 KHz. The medium frequency waveform is somewhat off from normal. Displacement is large from 2 MHz to 4.23 MHz. Interturn fault current is 500.1 A. 50 Hike. Increased current generates excessive heat that damages transformer insulation and burns windings.

Turn-to-turn fault SFRA behaviour is seen above. Figure 6 shows substantial waveform displacement. Turn-to-turn fault waveforms are compared. Resonance begins at 428 KHz. The waveform recorded during turn-to-turn fault state is entirely displaced between 1.4417 MHz to 4.3697 MHz compared to reference configuration. Turn-to-turn fault current is 562.7. 112.6 A more current than normal stresses transformer winding insulation. Unexpected thermal stress degrades insulation.

PT. YTL East Java Indonesia examined the 500kV power transformer every six years. Standardized SFRA measurement. Switching to the power system will restart the measured transformer after checking. SFRA measurements in 2007 and 2013 indicate a healthy transformer. Before restarting, arrange the inspection and measure transformer damage.

The chart that impacts the transformer's winding and core may also estimate SFRA insulation. SFRA measurement shows that the transformer wire and core are in excellent condition since shrinkage is less than 20% of their standard percentage. Thus, the 500 kV power transformer requires less maintenance.

Conclusion

Power transmission's heart is the transformer. It may develop inter-turn, turn-to-turn, and winding deformation defects during working. Every transformer winding has a signature and is sensitive to winding characteristics. Sweep spectral analysis simulates transformer winding problem diagnosis. Inter turn, turn-to-turn, and ground capacitance defects are simulated and compared to reference Normal state. Comparing defective and healthy conditions, we see that complicated network impedance changes current value. This current change may identify the transformer winding failure.

Thus, in SFRA Testing, each transformer coil has a distinctive look that is sensitive to variations in resistance, inductance, and capacitance. Transformer frequency spectrum is subject to winding deformation. Frequency response analysis helps diagnose transformers. It helps identify mechanical winding damage. This method detects winding short circuits reliably. Several graphical methods may be used to examine measurement results. However, reference improves interpretation. Historical data from the same transformers or sister transformer unit may be used.

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