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# A Review Article of ANN Based Combined Transformer Error Identification in Primary Load Imbalance Conditioning

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**Abstract- The review of Combine transformer is an electrical equipment that needs continuous monitoring and fast protection since it is very expensive and essential element for power system to perform effectively. Various methods for the protection are available. Most of the methods should be known for the protection of the transformer before practically protecting the same. Here a review is presented for various methods available for the protection of transformer. The most common protection technique used is the percentage differential logic, which provides discrimination between different operating conditions and internal fault. Some condition as, inrush current and CT saturation can cause mis-operation of differential protection.**

**Keywords- Transformer health; transformer failures; Combine transformer; real-time assessment.**

## I. INTRODUCTION

With the increase in peak demand and the need to improve grid infrastructure for the ease of operation and management with high reliability, the Combine smart grid is one of the most important elements to accelerate the modernization of the currently aging power system. The Combine grid is also the area that is affected significantly by smart technologies [1].

Automating and controlling the grid remotely will help reduce operating costs, increase information accuracy as well as quickly fix faulty areas in the electricity power system [2].

The Combine transformer is the last component for voltage transformation in the power grid. It is used to convert the medium voltage to the low voltage level that is used for households or for commercial use. Combine transformers are thus one of the most important components of the Combine power system [3].

Moreover, for each HV/MV primary substation, there are tens of secondary substations. As a result, in a medium-sized city with 40 HV/MV primary stations, there is around one thousand Combine transformers. Many of them are damaged every year due to various reasons.

Accelerated degradation and failure of Combine transformers can occur because of several conditions such as oil leakage, overloading, unbalanced loading and harmonics. However, the majority of failures are caused by a combination of these electrical, mechanical and thermal stresses acting upon the power transformer components over time [4, 5, 6, and 7].

Although the manufacturer generally establishes design and operational limits, the impact on service life is non-binary and multi-dimensional in nature [8, 9,10]. For example, exceeding a thermal limit to a moderate extent for a short amount of time will not cause immediate failure, but more severe overloading for an extended period will likely cause irreversible damage [11, 12,13].

## II. TRANSFORMER FAILURE MODES

Different investigations and test analyses have been conducted to identify the root causes and to identify the preventive measures to avoid the breakdown of power transformers. In paper [4], the part that is indicated as the most critical to power transformer health is insulation with an incident rate of about 41%; then, components showing high failure rates are windings, 14%, bushings, 10%, and on-load tap changers at about 10%.

Other components such as the cooling system, core, and operational errors do not have a significant impact. In papers [5–7], the statistical data of component failures are collected from 350 power transformers to establish a three-level model of failure mechanism, failure linkages, and failure modes. Even though power transformer and

Combine transformer have the same main working principles and key components such as insulation, windings, core, etc, these transformers differ in complexity and size. In this Section, the author will reference failure modes that pertain to these common working principles and components, investigate the reasons for Combine transformer failure from literature to identify the components that are most critical to combine transformer health.

## III. LITERATURE REVIEW

**Jiefu Zhang,** Research on the Influence of Primary Load Imbalance on the Combined Transformer's Error: According to the procedure, measurement of the error of three-phase three-element combined transformer should adopt three-phase detecting method that could detect the actual error. A three-phase three-element combined transformer has both current transformer and voltage transformer, and the distance between each of them is quite close, thus, the electromagnetic interference is unavoidable. Imbalanced primary load occurs frequently in power system operation.

In order to study the effect of electromagnetic field in this complex situation on the error characteristics of combined transformers, the following work is carried out in this paper: developing a three-phase detecting test platform and working on the platform to carry out an experiment about the influence of primary load imbalance on the error of the three-phase three-element combined transformers. The experimental results show that the imbalance of the primary load will lead to great impact on the error of voltage transformer in combined transformer, the maximum ratio error is 0.25 and the phase difference could be up to 4.9'. The primary load imbalance has rare effect on the error of current transformer.

In order to further verify the influences of the primary load imbalance on the three-phase three-element combined transformers' error characteristics, a three-phase three-element combined transformer model is to be established and the error characteristics of three-phase three-element combined transformer will be simulated and analyzed under the imbalanced primary load. The proportion of combined transformer in power grid measurement is very large. It is of great engineering value and academic significance to study the error characteristics of combined transformer and ensure that it can accurately carry out electric energy measurement during operation.

**Cong Lin,** Research on Error Characteristics of Three-phase Two-element Combined Transformer under Simulation Operating Conditions: Based on the three-phase detection method, a three-phase combined transformer error verification platform is designed and the error properties of three-phase two-element combined instrument transformers, including the interaction between voltage transformer unit and current transformer unit are studied systematically.

The experimental results show that the error characteristics of CT and PT are greatly influenced by rated current percentage of CT and rated voltage percentage of PT, the size of secondary load and whether the CT unit and PT unit are excited at the same time. Especially when the current transformer unit and the voltage transformer unit are excited at the same time, due to the strong electromagnetic interaction between them, even the test point of the current transformer below 20% of the rated current is out of tolerance.

The use of 3-D electric field analysis and the analytical approach for improvement of a combined instrument transformer insulation system: In this paper, the algorithm of design for an insulation system of a high-voltage combined instrument transformer using the field method is considered. The commercial software OPERA 3D was used to compute field distribution and the author's software SHIELDS was used to optimize the number, dimensions, and position of each electrostatic control shield in the insulation of the voltage and current parts. The programs interact with each other. This work presents the results of the use of numerical methods in the designing process.

**Gang Liu,** Voltage Error Analysis of Three-phase Combined Transformer Based on Real Test Platform: The voltage error of three-phase combined transformer is detected according to the single-phase method, but this situation is not consistent with the actual operation state, thus the single-phase method can not accurately detect the actual voltage error characteristics of the three-phase combined transformer. In this paper, the three-phase combined transformer composed by three-column is treated as the object, using the real test platform to simulate the actual operation condition of the three-phase combined transformer, which carries out the test and in-depth analysis of its voltage error under different primary current conditions.

The main conclusions are as follows: the three-phase combined transformer qualified in single-phase method may not be qualified in three-phase method, the current makes a linear influence on the voltage error of three-phase combined transformer, with the increase of current, the algebraic sum of error variation of three-phase voltage transformer is approximately equal to zero.

**Liu Gang,** Simulation of the Magnetic Field Distribution and Voltage Error Characteristics of the Three-Phase Three-Component Combined Transformer With New Three-Cylinder Core Structure: The disadvantages of the traditional three-column core structure three-phase three-component (TPTC) transformer are its incomplete symmetry, the different magnetic circuit length, and the coupling parameters, which lead to each phase voltage error varying differently. In this article, a new structure optimization design of a new type of three-phase three-element combined transformer with a new three-cylinder core structure was proposed. The simulation analysis of the magnetic field distribution and the voltage error characteristics of the voltage transformer with the new three-cylinder core structure was carried out. Compared with the traditional three-column core structure TPTC

transformer, the magnetic induction intensity distribution of the voltage transformer with the new three-cylinder core structure is more uniform. The simulation results of the voltage error characteristics under normal load condition also show that with the increase in voltage, the voltage error of the voltage transformer with the three-cylinder core structure changes gently, and the error difference between the three phases is smaller. The TPTC combined transformer with the new three-cylinder core structure has better error characteristics under normal load conditions.

**Cong Lin,** Research on Error properties and Influence Factors of Three-phase Combined Instrument Transformers under Different Operating Conditions: Based on the three-phase detection method, a three-phase combined transformer error verification platform is designed and the error properties of three-phase three-element combined instrument transformers, including the interaction between the voltage and current parts are studied systematically. The experimental results show that the percentage of rated voltage/current and the secondary load have a great impact on the error properties of three-phase combined transformers.

When the current and voltage parts of three-phase combined transformer are excited at the same time, it is found that due to the strong electromagnetic coupling, the mutual influence between the voltage and current transformer is large. Especially under the condition of 20% of the rated current, the influence of voltage transformer on current transformer error properties has exceeded the allowable range and cannot be ignored.

**Bingliang Shan,** Breakdown strength of transformer oil modified by TiO2 nanoparticles under AC-DC combined voltage: The dielectric strength of transformer oil can be greatly improved by the modification of nanoparticles under AC, DC and positive impulse voltage, respectively. In comparison with the certain voltage, the combined voltage is more complicated and important for the safe operation of the converter transformer. However, the modification effect of nanoparticles on the breakdown characteristic of transformer oil is still not clear under the AC-DC combined voltage. In this paper, Titania (TiO 2 ) nanoparticles were prepared and used to modify the mineral transformer oil.

The breakdown characteristics of transformer oil before and after modification were measured under the AC-DC combined voltage with a needle-sphere electrode configuration. In order to systematically study the modification effect of TiO 2 nanoparticles, the influence of proportion of AC to DC was also investigated. The results showed that TiO 2 nanoparticles have an improvement on the breakdown strength of transformer oil under combined AC-DC voltage. It can be found that the positive DC breakdown voltage of the nanofluid is similar to that of pure oil. While as the pre-applied AC voltage increases from 10 kV to 20 kV, the breakdown strengths of the nanofluid are increased by 12.9% and 21.8% respectively, in comparison with that of pure oil under combined voltage.

**Alexey Stulov,** The Combined Model for Design Single-Phase Transformer with Amorphous Steel Wound Core: The paper presents a developed adjusted combined model for the simulation of steady-state and transient processes in the distribution transformers. The structure and the operating principle of the model are described. The elements of the technology of a numerical simulation of transient physical processes in the CAE system of single-phase transformers are considered.

The main results of the start-up simulation of the single-phase transformer with amorphous steel wound core are considered. The requirements to the losses in the distribution transformers are described. The combined model is applicable to investigate the steady-state and transient processes in single-phase transformers and creating computer-aided engineering subsystems with generative design elements. The model is efficient to design common and special transformers.

**Jian Qin,** A Three-phase Combined Transformer with Characteristics of Anti-leakage current and Anti-electromagnetic Interference: The three-phase combined transformer is a frequently-used metering equipment in distribution network, so it is of great significance to ensure its metering accuracy. Researches show that if a three-phase combined transformer is qualified when using the single-phase detection method; it may not be qualified according to the three-phase detection method, so the metering performance of the three-phase combined transformer must be improved.

In this paper, the designs of anti-leakage current and anti-electromagnetic interference are proposed to improve the error performance of the three-phase two-element combined transformer and its metering performance before and after the improvement are compared. It can be found from the results that the anti-leakage current and anti-electromagnetic interference design can effectively reduce the effect caused by leakage current and inter-phase electromagnetic interference, and the three-phase two-element combined transformer with this design has better metering performance.

**D.V. Topolskiy,** Development of Technical Solutions for Digital Substations Using Ddigital Instrument Combined Current and Voltage Transformers: The paper discusses technical solutions for the development of instrument transformers for digital substations. A new combination of current and voltage measurement converters for combined transformer voltage class 110 kV and higher is considered. The possibilities of creating digital instrument

transformers based on the principles of open architecture are analyzed. In the authors' opinion, such an approach will ensure independence from hardware and software manufacturers. Computer modeling, experimental studies and experimental exploitation of a prototype of the digital instrument combined current and voltage transformer confirm the results presented in the paper.

**E. A. Mackenzie,** On-line monitoring and diagnostics for power transformers: Transformers are a critical part of an electrical utility's asset base. Loss of a transformer in a utility, generation plant or process can cost many millions of dollars, depending on how long it is out-of-service. On-line monitoring and diagnostics is a useful tool to help operators to manage their assets and make decisions on continuing operation, maintenance or replacement. This paper illustrates how Dissolved Gas Analysis (DGA) is the heart of on-line monitoring as it is a well-established method of transformer diagnosis.

Experience has shown that DGA can detect and give warning of 70% of the most common failures in power transformers. Some aspects of ongoing developments in DGA and its diagnosis are described. Most of the knowledge built up over the last 40 years on DGA has been based on mineral oil/paper insulation systems in transformers and other static equipment such as bushings and instrument transformers.

In these types of equipment, the causes and mechanisms of gassing have been established and the diagnosis of faults is well documented. The other transformer-related equipment that has largely been ignored in the past is on-load tap-changer diverters or combined diverter-selectors. In oil-filled diverters, it was generally assumed that because arcing was taking place in the oil, large quantities of fault gases were being produced and therefore conventional DGA diagnosis could not be applied. In recent years, various parties have investigated tap-changer oil analysis. Several organizations have also been investigating onload tap-changer analysis based on ratios rather than discrete gas concentrations. This paper describes an example of on-load tapchanger condition assessment based on DGA measurements.

**Om Prakash Mahela,** Detection of Open Circuiting of Secondary Winding of Current Transformer Using Combined Feature of Hilbert Transform and Stockwell Transform: This paper presents a technique based on combined application of the Hilbert Transform and Stockwell Transform for the detection of open circuiting of secondary winding of the current transformer. The proposed algorithm has been tested in the presence of the resistive inductive as well as capacitive loads. The proposed study is performed in MATLAB/Simulink environment. The simulation results show effectiveness of the proposed algorithm for detection of open circuiting of the secondary winding of the current transformer core.

**B C Sujatha,** Design of 100kVA energy efficient three phase hybrid transformer for combined application of solar and wind: Increased power demand, depletion of nonrenewable energy sources and intermittent nature of availability of renewable energy sources has led to the development of hybrid energy systems. A wind-solar hybrid system is one such hybrid system which is reliable as it converts both solar and wind energy into electrical energy. A wind-solar hybrid transformer is used to step-up voltage generated from solar and wind sources to the grid voltage. This paper discusses the design of 100 kVA energy efficient three phase hybrid transformer for combined application of solar and wind.

**Alexey Stulov,** Model of Special Transformer for Transient Processes Analysis in Three-Phase Mode: The main transient processes in a special transformer operation mode are considered. Circuit models closed to field models in terms of accuracy and significantly exceeding computation speed are used. The adjusted model for simulation and investigation transient processes in the three-phase special transformer is developed. The structure and the operating principle of the model are described. Technology of a numerical simulation of transient physical processes in the CAE system of power transformers is considered. The main results and conclusions of the investigation transient processes in the special transformer are provided. The model is efficient for modern designing of special transformers.

**Hyunjin Ahn,** A highly efficient WLAN CMOS PA with two-winding and single-winding combined transformer: In this paper, a fully integrated high-efficiency linear CMOS power amplifier (PA) is developed for 802.11g WLAN applications with the proposed power combining transformer. In comparison with conventional power combining transformers, the proposed power combining transformer can offer high-efficiency performances with a smaller die size. The fabricated two-stage PA using a 65nm CMOS technology achieves a saturated output power of 26.7 dBm with a drain efficiency (DE) of 47.7% at 2.48 GHz. The PA is tested with 54Mbps WLAN 802.11g signal and it meets the stringent error vector magnitude (EVM) and spectral mask requirements at a 20.13-dBm output power with a DE of 21.4%.

## IV. CONCLUSIONS

The paper presented a study to determine the most significant influencing indicators on Combine transformer operation and service life. The health assessment techniques were reviewed based on up-to-date literature.

This is to provide more information to transformer operators about the important parameters of Combine transformers that need to be considered. This also gives the other researchers an overview of the development process of transformer condition assessment technologies,

thereby continuing to develop new effective evaluation techniques. Real-time monitoring has become a very important technology in the field of Combine transformer maintenance and has attracted more and more attention worldwide, especially with high penetration of PV systems in the Combine power grid.

The potential functions of failure prediction, defection identification, and life estimation bring a series of advantages for utility companies: reducing maintenance cost, lengthening the transformer's life, enhancing the safety of operators, minimizing accidents and the severity of destruction, as well as improving power quality.

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