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Survey of Quality Analysis of Transformer Oil using Image Processing Technique

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Abstract:- Electrical energy is the paramount need in a nation's development. To cater for large demand for electricity there is a need for reliable and proficient power system. The role of Transformers is critical for a power system to work reliably. Health of the transformer mainly depends on its insulation. Among the different insulating material used in transformers, mineral oil is the most widely used as insulating medium in oil filled transformers. The performance key factor is quality of the insulating oil of the transformer. Hence, the oil quality analysis becomes essential. Traditionally chemical diagnostic criteria are used for oil quality evaluation. However, this conventional method is expensive and time consuming. Extensive experimental evaluation has been fruitful to establish the acidity and tanδ of the transformer oil. Here, we are proposing Image processing technique to estimate the oil properties, which is inexpensive and an effective technique namely Texture Entropy is extended to compute the Neutralization Number (NN) or Acidity and tanδ (Dissipation factor).
Keywords:- Acidity, Entropy(E), Image Processing(IP), tanδ (Dissipation factor), Oil analysis, Transformer oil.

I. INTRODUCTION

Oil serves as both cooling and insulating agent in transformer, so health of the oil is very important. Oil degrades because of gases dissolved in it due to the occurrence of various faults and deterioration with respect to age. Increase in dissolved fault gases concentration in oil, results in oil losing its effectiveness; this will influence the transformer performance. Variation in transformer performance will ultimately affect on power supplying company's revenue and consumers. Hence, to prevent the transformer failure, oil analysis is very essential and there are several methods to diagnose the health of the oil. Currently, in the practice of chemical diagnostic criteria, it has the following significant observation such as, dangerous to operate during oil transaction, time consuming and expensive. As per the literature and practice of electrical system, oil changes have been modifying the colour as time varies. In other words, the changing of oil colour attempts to indicate its life cycle. Hence, we are able to notice the drastic change in oil colour and subjected to the testing. As oil gets aged, color of the oil changes which indicates the transformer oil condition. Here, the prominent oil characteristics are Acidity, Interfacial Tension (IFT), power factor and tanδ. They are quite interrelated to each other. Due to the ageing of the oil, these two properties values also remarks through the change. Increasing of acidity will raise the tanδ of the oil. In view of the overcoming the pitfalls of conventional practice, the most convenient strategy through appearance based automation with the help of Image Processing concept. An explorative experiment has been conducted with image processing technique namely Texture Entropy, subsequently compared the performance with conventional methods [1].

Electrical energy plays an important role in a nation's development. A reliable and proficient power system is needed to meet large demand for electricity. Transformer is an integral part of power system whose role is critical for a reliable power system. Periodically the health of transformer has to be checked which primarily depends on the type of insulation used. Out of different insulators used in transformer, mineral oil so as to say transformer oil is used as an insulation material in almost all transformers. Transformer oil not is only used for insulation purpose, but also for cooling purpose. Its dielectric strength, different chemical properties determine the type of insulator it is which in turn determines the health state of a transformer. Thus its performance mainly depends on characteristics of mineral oil used. Thus it is very important to perform oil analysis periodically to check transformer health. There are a number of traditional methods available. But these methods are very time consuming and expensive. The method of image processing is a quick simple method to analyze transformer oil and thus to check transformer health from the image of a transformer oil sample.

Power transformers play an important role in both the transmission and distribution of electrical power. Since a fault in a transformer can have a huge repercussion when failures occur, and as the number of old transformers and of those that are difficult to operate in overload conditions is on the rise, it is important to detect incipient faults in a transformer and forecast and prevent failures. In operation, transformers are subject to electrical and thermal stresses, which can cause the degradation of the insulating materials. Generally the degradation products are gases, which will get dissolved in the oil entirely or partially. The gases dissolved in the oil are easily detected through dissolved gas analysis as the ppm level changes. Dissolved gas analysis (DGA) is a widely used most powerful method to detect incipient faults in oil filled electrical equipment. The electrical equipment may be a transformer, a load tap changer or a cable [3].

It is generally believed that the failure occurs when a transformer component or structure is no longer able to withstand the stress imposed on it during operation. During the course of its life, the distribution transformer as whole has been suffering the impact of thermal, mechanical, electrical, chemical and electromagnetic stress during normal and transient loading conditions. The normal causes of transformer failure are-

- Insulation Failures: Insulation failures were the leading cause of failure in this study. This category excludes those failures where there was evidence of a lightning or a line surge. There are actually four factors that are responsible for insulation deterioration are pyrolosis (heat),oxidation, acidity, and moisture. But moisture is reported separately. The average age of the transformers that failed due to insulation was 18 years.
- Design / Manufacturing Errors: This category includes conditions such as loose or unsupported leads, loose blocking, poor brazing, inadequate core insulation, inferior short circuit strength, and foreign objects left in the tank.
- Oil Contamination: This category pertains to those cases where oil contamination can be established as the cause of the failure. This includes sludging and carbon tracking.
- Overloading: This category pertains to those cases where actual overloading could be established as the cause of the failure. It includes only those transformers that experienced a sustained load that exceeded the nameplate capacity.
- Fire / Explosion: This category pertains to those cases where a fire or explosion outside the transformer can be established as the cause of the failure. This does not include internal failures that resulted in a fire or explosion.
- Line Surge: This category includes switching surges, voltage spikes, line faults/flashovers, and other T&D abnormalities. This significant portion of transformer failures suggests that more attention should be given to surge protection, or the adequacy of coil clamping and short circuit strength.
- Maintenance / Operation: Inadequate or improper maintenance and operation were a major cause of transformer failures, when you include overloading, loose connections and moisture. This category includes disconnected or improperly set controls, loss of coolant, accumulation of dirt & oil, and corrosion. Inadequate maintenance has to bear the blame for not discovering incipient troubles when there was ample time to correct it.
- Lightning: Lightning surges are considerably fewer in number than previous studies we have published. Unless there is confirmation of a lightning strike, a surge type failure is categorized as “Line Surge”.
- Moisture: The moisture category includes failures caused by leaky pipes, leaking roofs, water entering the tanks through leaking bushings or fittings, and confirmed presence of moisture in the insulating oil. Moisture could be included in the inadequate maintenance or the insulation failure category above, but we customarily report it separately [4].

II. LITERATURE REVIEW

2.1 Chemical Diagnostic Methods

2.1.1 Dissolved Gas Analysis: The main causes of transformer insulation break down are thermal and electrical disturbances. When the mineral oil is subjected to high thermal and electrical stress, gases are generated from the decomposition of the mineral oil. Different type of faults will generate different gases, and the analysis of these gases will provide useful information about the condition of the oil and the identification of the type of fault in the transformer. There are mainly two types of insulation; paper insulation which consists of cellulose and oil which is a mixture of hydrocarbons. Due to excessive thermal and electrical stress, cellulose and hydrocarbon undergoes various chemical reaction to form different gases as byproduct. These gases are hydrogen , ethane, methane, ethane, ethyne, nitrogen dioxide, carbon dioxide, carbon monoxide (CO). The DGA will require the removal of an oil sample from the transformer and this can be done without de-energization of the transformer. The oil sample is analyzed in the laboratory using gas chromatography technique. In Dissolved Gas-in-Oil Analysis (DGA) method these gases are analyzed quantitatively to infer existence of any faults which are mainly incipient faults. There are conventional standards through which dissolved gas analysis is done. The concentrations of gases and in the transformer oil can be used to diagnose faults in the transformer. The evaluation of the measuring results can be performed according to different standards and methods. The most important standards are IEEE C57.104-1991, IEC 60599, MSS-Schema, Dornenburg, Rogers and Duval.

2.1.2 Electrical Diagnostics: Winding Power Factor is due to thermal and electrical stress windings are deformed (e.g. buckling of transformer winding), insulation get deteriorated etc. This results into increase in the power loss in insulations and thus the winding power factor varies. Thus winding power factor is a parameter for diagnostics of transformer oil. Bushing Power Factor provide insulations to electrically separate conductors from transformer tank. Bushing insulations also get deteriorated due to thermal and electrical stress and thus bushing power factor has been used over years to save transformers from faults by detection of bushing power factor. Leakage Reactance, in adverse cases the coil displaces from their original position and this causes a change in the flux linked and there is a change in the leakage reactance. Thus leakage reactance is taken into consideration in diagnosing the transformer oil analysis. Transformer Turns Ratio gets changed when there is a short circuit of windings and thus TTR is included in the diagnostics of transformer oil. DC Winding Resistance due weak contact of windings, weak joints and short circuit of winding the dc resistance of the winding get changed. Thus dc winding resistance is a required oil diagnostic tool. Core Excitation Current the current which is required to excite the core of transformer changes with core deformation, core damage and winding shorting. Thus this factor also added in diagnostics of transformer oil. Core Ground is grounding of core results into circulating current and which leads to overheating thus where core ground is accessible this test should be performed. Sweep Frequency Response Analysis (SFRA) in this test a signal with varying frequency is injected into the transformer coil and the output response is analyzed numerically and FFTs are used to detect any core/coil anomalies. Deformation of coil, damage of core, winding short circuiting can be detected in this method [4].

2.2 Thermal and Optical Diagnostic Method

Both thermal and optical diagnostic methods using the electromagnetic spectrum between 104 Hz up to 1016 Hz as information source. Either the transformer produces a signal which get detected (for instance heat produces infrared signals) or the transformer reflect signal (for instance surface temperature sensors which reflect high frequency impulses in dependence of the transformer temperature). Temperature monitoring can be performed with the help of PT-100 elements, by using fiber optics or thermography. The best optical diagnostic method is the human optical inspection for inner inspection with the help of the endoscopy [13].

2.3 Mechanical Diagnostic Method

The tension force of the transformer windings is important for the avoidance of deformation in the case of short-circuit. This tension force decrease during operation so a monitoring is useful for transformer where the risk of short-circuit is high. A possibility for determination of the existing tension force is the measuring of the transient oil pressure after applying of a current surge. The lower the tension force the higher transient oil pressure. Another mechanical diagnostic method is the stream analysis for controlling the cooling system. With this method also mechanical deformation in case of a short-circuit which influence the cooling system can be detected [13].

2.4 Taguchi-Artificial Neural Network Approach

Taguchi-Artificial Neural Network can be used to detect incipient faults in oil-immersed power transformer. It involved the development of Artificial Neural Network (ANN) designs and embedding Taguchi methodology to fine tune the parameters of a backpropagation feed-forward ANN. Detection of incipient faults in power transformer is essential because it is one of the fundamental equipments in the power system. Dissolved gas analysis technique was used as it has been found as a reliable technique to detect incipient faults as it provides wealth of information in analyzing transformer condition. This study is based on IEC 60599 (2007) standard and historical data were used in the training and testing processes. Comparative studies were conducted between heuristic ANN design and optimized hybrid Taguchi-Neural Network. Taguchi proposed eight standard procedures for optimizing any process:

- Identify the main function, side effects and failure mode.
- Identify noise factors, testing conditions and quality characteristics.
- Identify the objective function to be optimized
- Identify the control factors (CF) and their levels
- Select the orthogonal array matrix experiment
- Conduct the matrix experiment
- Analyze the data, predict the optimum levels and performance
- Perform the verification experiment and plan future action.

2.5 Adaptive Neural-Fuzzy Interference System

In these algorithms, the type of fault is diagnosed first, and the fault is then located using the ratio of the concentrations of and CO dissolved in the transformer oil. The algorithms are not entirely satisfactory. The wavelet network has high efficiency but low convergence, the fuzzy logic method has a limited number of inputs and, in some cases, it is very difficult to derive the logic rules, and the ANN need reliable training patterns to improve their fault diagnosis performance. The Adaptive Neuro Fuzzy Inference System network consists of a number of nodes connected by directional links. The nodes can be adaptive or fixed; the output of an adaptive node depends on the parameters forming its input, but the output of a fixed node depends only on the output of the previous layer. (A layer consists of all nodes that have the same inputs [11, 12].

The ANFIS system is trained using separate input data sets for each fault listed in each standard. The input data sets are the gas ratios required by a given standard, and the output is 1 if the input data match the standard for the specific fault being investigated, and 0 otherwise. In this, the fuzzy rules used in ANFIS, based on an extended range of input data, improved the fault diagnosis capability of the standard. In an ANFIS network with n inputs, layer 1 consists of nodes, so the two-input network have four nodes . Each of these nodes is a fuzzy set. A fuzzy set is a set of elements, which can be numbers, letters of the alphabet, other sets, etc. The transition from an element belonging to a set to the same element not belonging to the same set is gradual. In the fuzzy system, a membership function of 1 (the maximum) indicates full membership of an element in a set, and a membership function of 0 (the minimum) indicates zero membership. The output of each node of layer 1 is the Membership of its input to the fuzzy sets. Any continuous and differentiable function, e.g, triangular, trapezoidal, could be a suitable membership function. Fault diagnosis and its location finding can be done by two main stages, namely, training and testing.

- The Training Stage: The initial values of the parameters are specified. These parameters include the ANFIS parameters for each standard and gas chromatography data for different transformers. The latter allow the initial training data set to be calculated for each standard. The ANFIS network is then trained for each training data fault. The input consists of four or five gas ratios, and the output is a binary number. Thus the training data for fault1 of the IEC.

- The Testing Stage: The performance of the ANFIS method can be evaluated for each fault in the standards. When ANFIS is trained through multiple iterations, the error may increase between successive iterations if the training data is noisy or the quantity of training data is insufficient [14].

2.6 Genetic Algorithm Approach

Genetic algorithm can impose a series of genetic operations such as selection, crossover and mutation on the current population, which will generates the new population and gradually evolves to the optimal solution. Genetic Algorithm is defined as proceeds to initialize a population of solutions randomly, and then improves itself through iterations of selection, crossover and mutation. Genetic algorithm is a search technique used in computing to find exact or approximate solutions to optimization and search problems. In short, it is a very efficient and widely used technique to determine dissolved gases due to deterioration of the insulating oil of transformers. GA has been applied to search the optimal parameter of new technique grey model. In gray system some part of the information is known and some information is unknown. The main advantage of this system utilize only a few know data points by such a way of accumulated Generating Operation (AGO) to established the more effective model for diagnosis to power transformer. In such method has the main advantage, not to pursue large sample size and not require special data distribution. In regression analysis, calculation is very easy & smaller than other methods. The GA determined the dilation and translation parameters and the weighting values of the most accurate diagnosis DGA model. The information hidden in the many DGA diagnostic records was efficiently extracted by the GA without heavy human involvement, because of the self-tuning, multiscale, multiresolution, and localization of the method [2,11].

2.7 Proposed Quality Analysis Using Image Processing

There are numerous investigating methods to determine the transformer oil quality. Chemical method is most enlightening technique to examine the oil properties. To evaluate the oil properties, chemical method is sub divided in to two types namely DGA and Oil analysis [5]. DGA furnishes information about fault in transformer and oil analysis assesses the oil properties like NN, viscosity, tanδ, IFT and power factor. To determine the acidity of oil, potentiometric titration with potassium hydroxide is used and for tanδ measurement Schering Bridge is utilized. These conventional diagnostic methods are devouring much time to estimate the oil properties. To overcome the disadvantages of traditional method, an image processing technique of Entropy method is proposed.

The image processing technique involves preprocessing of the taken image of transformer oil in which first the noises are removed using median and weinner2 filter and histogram enhancement technique is used for better visibility. Now entropy which is the statistical measure of randomness is calculated which depends mainly on the deterioration of the taken oil sample. Thus using regression method from the knowledge of entropy and learned data the state properties of oil can be predicted. Similarly the concentration of gases present in transformer oil can be calculated. This project also provides a tool to predict for the different faults in the transformer using Key Gas Analysis method and IEC basic ration method.

This analytic method is useful to detect the fault caused by presence of a single gas predominantly. The range of ppm level presence of a particular gas leads to different characteristic faults in transformer oil. This method indicates the fault level from the comparison of the concentration of the key gas. The microscopic image obtained from oil sample contains noises which can interrupt in image processing detection and may lead to erroneous results. Noise is the presence of any unwanted signal which degrades the image signal and are removed through filters. In the microscopic images the majority of pixels possess a luminescence less than average which results into poor visual effect. Histogram modification is a tool which pixels will be rescaled to values where there is a well distinguish between their pixel values and thus better to analyze it [1].

Here two methods are applied to find the kind of fault from the concentration of CO and . These are as follows:

- Key Gas Analysis Method
  This analytic method is useful to detect the fault caused by presence of a single gas predominantly. The range of ppm level presence of a particular gas leads to different characteristic faults in transformer oil. This method indicates the fault level from the comparison of the concentration of the key gas with the reference.
- IEC Basic Ratio Method
  Though there are many gases to indicate different faults in transform primarily there are 5 gases which can indicate almost all kind of fault. In this method these 5 gases are taken into consideration. This method compares the ratio of gases with the reference ratio to detect the kind of fault exist in transformer oil. Here only 3 ratios are important [6].

III. CONCLUSION

Image processing technique for transformer oil analysis is software based analytic technique which is fast, reliable and user friendly. The image quality can be enhanced for better visibility and analysis through histogram modification techniques. Entropy technique was used to find out different oil properties like NN, dissipation factor, power factor etc. to determine the performance of transformer. Further, it emphasizes the inference as the outcome of experimentation. It enhances the acidity with respect to increase of tanδ. Image processing technique namely texture entropy is much better when compared with conventional practices. Subsequently, image processing provides an easy and fast method to check the transformer health from the image of transformer oil.

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