A COMPARATIVE STUDY OF DIFFERENT FAULT DIAGNOSTIC METHODS OF POWER TRANSFORMER USING DISSOVED GAS ANALYSIS

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Abstract:

Dissolved Gas Analysis is an important analysis for fault diagnosis and condition monitoring of power transformer. The various technique such as conventional methods, Artificial Intelligence, Artificial Neural network, Fuzzy Expert system, Genetic algorithm etc can be used to increase the efficiency and accuracy of diagnostics system. Failures of power transformer can cause malfunction of system device or damage to apparatus. This paper presents the review of different techniques with their relative advantages and shortcomings. Dissolved Gas Analysis of the oil samples has been widely used fault diagnostic tool.

Keywords- Dissolved Gas Analysis, Power Transformer, Fuzzy Logic, Fuzzy inference system, Artificial Neural Network, Expert System.

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1. INTRODUCTION:

Transformer is one of the most important and costly equipment in power system. In transformer oil and paper insulation degrades due to different types of stresses like thermal, electrical, chemical, mechanical and environmental during its operation. When power transformer is subject to electrical and thermal stresses, characteristic gases such as H_2, CH_4, C_2H_4 , C_2H_6 , CO & CO_2 generated in transformer oil. These are known as dissolved gas.[1].Degree of Polymerization [2-3] and furan analysis[4] are very commonly used by electric utilities to indicate degradation. DGA is one of the most powerful techniques to detect the incipient faults of power transformer. The different fault diagnostic methods include the conventional key gas method, ratio method [5]-[8], and recently, the expert system[9], neural network [10] and fuzzy logic approaches [12]-[15].Fuzzy logic is a sophisticated analysis method which can also detect multiple fault condition. Since in the multiple fault condition gases from different faults are mixed up resulting in the confusing gas ratio between different gases. Knowledge based approach which can utilize artificial intelligence. By using artificial intelligence methods the rules can be generated automatically and the decision would be made. Artificial neural network and fuzzy logic are the most commonly used artificial intelligence technique for transformer insulation condition assessment. The hybrid tool has been developed to diagnose fault in power transformers through the analysis of dissolved gases in oil. The traditional criteria of the dissolved gas analysis, artificial neural network and fuzzy logic have been used for fault diagnosis [9]. The results obtained with this tool in the diagnosis of the incipient fault in transformers were 80%. A two - step neural network method has been used to detect faults in oil filled power transformer based on dissolved gas analysis with or without cellulose involved [10]. Good diagnosis accuracy has been obtained here. However, the accuracy of fault diagnosis could be improved choosing the proper value of learning rate, momentum factor and activation functions.

In this paper, artificial intelligent techniques like fuzzy logic and neural network applied to conventional Dissolved Gas Analysis have been discussed. Also, an expert system is formulated combining these techniques has been discussed.

2. FUZZY LOGIC APPLICATIONS TO DGA:

When there are abnormal phenomenons such as overheating or arcing in transformer, degradation of transformer insulating oil result in the formation of many by products. The combustible gases like H_2, CO_2, CH_4 , C_2H_2 , C_2H_4 and C_2H_6 are these by-products. And they are closely related to type of abnormality. The patter and degree of abnormality can be determined by monitoring the concentrations and growth of these combustible gases and fault can be prevented from deterioration consequently. Four particular ratios of these combustible gases are translated into four independent codes according to their values. Different combinations of these four codes represent different fault patterns like overheating, arcing and corona [5]. This data is present in crisp form. The fuzzy logic analysis involves three successive processes, namely: Fuzzification, Fuzzy Inference and Deffuzification. Fuzzification converts crisp data into a fuzzy input membership. A Fuzzy Inference System draws conclusions from the knowledge –based fuzzy rule set or if –then linguistic statements. Defuzzification then converts the fuzzy output back into crisp outputs. A Fuzzy DGA system was proposed in [13], which represents both IEC 599 and critical key-gas levels for monitoring the time trend and local insulation of each transformer.

Work has been done for the diagnosis of multiple incipient faults in a transformer using a fuzzy logic technique which can diagnose multiple faults in a transformer and quantitatively indicates the likelihood or severity of each fault. Insulation deterioration at each fault location can then be monitored closely according to its trend, which is important for a transformer in critical situation. Tests using this technique on a number of transformers have given promising results [13]. Adaptive fuzzy system for incipient fault recognition through evolution enhanced the fault diagnosis abilities for the dissolved gas analysis (DGA)[19].An advantage of fuzzy diagnosis system is that it is insensitive to the errors in the data collection, storage and testing process. One drawback is that it is bonded with conventional DGA methods, cannot learn directly from data samples. This drawback is taken care by the use of Artificial Neural Network in the diagnostic procedure.

3. ARTIFICIAL NEURAL NETWORK APPLICATION TO DGA:

The ANN's are tools particularly adapted to help the specialist in maintenance in the activities of classification, diagnosis and decision makings, prediction etc. An important advantage of ANN based fault diagnosis is that it can learn directly from the training samples and update its knowledge when necessary. The highly non-linear mapping capability of neurons provides a comparable and often superior performance over fuzzy system solutions. ANN computational complexity is not too high, especially in testing (diagnosis) process. For these reasons, many studies are undertaken in the field of maintenance to evaluate the contributions of neural networks before their operational implementation. The application of ANN makes possible to reduce considerably the laboratory experiment time while networks learn how to predict properties of insulation for duration longer than those of the test. Thus constituting a tool making more economic the tests of high voltage in general. ANN method is more accurately applied to Dissolved Gas Analysis since the hidden relationship between fault types and dissolved gases can be recognized by ANN through training process .The neural network consist of number of neurons connected by links divided into two layers. A set of inputs is applied from outside or from previous layer. Each of these is multiplied by a corresponding weight w. The sum of the weighted inputs and the bias forms the input to the transfer/ activation function.

Work has been done using Adaptive Back propagation learning algorithm for the fault diagnosis of power transformer. The training algorithm of both multi-layer feed-forward neural network (MNN) and recurrent neural networks (RNN) are usually based on a back propagation (BP) algorithm, as were the first neural networks used for non-linear system identification.The BP algorithm for MNN's are better understood than RNN's . As such there has been much more success in using MNN's for non-linear system identification, pattern recognition, controls and signal processing than there has been using RNN's. Over the years many improvements have been made on the standard BP algorithm, such that it would have a faster convergence. Despite the improvements, the major disadvantage of BP based neural networks is the slow convergence and the susceptibility to falling in a local minimum. An extension neural network (ENN)-based diagnosis system for power transformer incipient fault detection is presented. In the extended neural network proposed is a combination of extension distance instead of Euclidean distance (ED) to measure the similarity between tested data and the cluster centre, it can effect supervised learning and achieve shorter learning times than traditional neural networks. Morover, the ENN has the advantage of height accuracy and error tolerance. Thus the incipient faults of power transformer can be diagnosed quickly and accurately.

4. NEURO-FUZZY APPLICATION TO DGA:

There are many different types of neural network architectures that can be used for non-linear system identification. When choosing the appropriate algorithm, there are two properties that are crucial. First the training algorithm should be fast and the parameters space must not be too large that the architecture cannot be implemented in a real-time scenario.Through experimental study with a refrigerator diagnostics and distribution transformer systems; it was found that MLPNN has a tendency to fall into local minima. The RBFNN performed comparatively with the TNFIN with respect to accuracy. However, the RBFNN requires nearly three times s many parameters as the TNFIN. This is computationally expensive and undesirable for the purposes of non-linear system identification for the transformer. Due to the results with the small distribution transformer, the TNFIN is used for this research, where a larger transformer is being identified. Experience with non-linear system has shown that the TNFIN does not have the tendency to fall into local minima as is the case for the MLPNN. The training algorithm for the TNFIN has also been improved to make it comparable with the RBFNN. With this fast training capability of the TNFIN, non-linear system identification became possible. In [20], the adaptive neuro-fuzzy system identification is applied to predict moisture characteristic of oil. The comparison of the measured and predicted values of average moisture content in paper oil insulation system is presented. The accurate evaluation of moisture content is extremely important when it is necessary to determine the dryness of the solid insulation during both the factory drying process and refurbishment of the transformer in field. The dry-out termination criteria based on the measurement of dielectric characteristic and classification of the dryness state by using the neuro fuzzy pattern clustering is suggested for this purpose. Further the work has been done in developing a neuro-fuzzy based expert system for characterizing various incipient fault based on Dissolved Gas Analysis and various other parameters like moisture content and degree of polymerization.

5. NEURO- FUZZY BASED EXPERT SYSTEM:

A transformer diagnostic system that utilized both an expert system and a neural network to detect failures in a transformer must be developed. The knowledge of the expert system has many uncertainties and therefore fuzzy logic is employed. In this case the neural network employs sampled learning to complement the knowledge based diagnosis of the expert system. The two techniques are integrated by comparing the expert system conclusion with the neural network reasoning using a consultative mechanism. A block diagram for this type of hybrid system is given in figure 2. [21] Depicts an expert system for fault diagnosis of large power transformers and finds a deficiency in periodic testing while the transformer is still in service. An expert system s developed with ANN to combat more difficult diagnosis cases [22]. To avoid "No diagnosis case" experts develop the self learning design using ANN to give probability of fault in future borderline cases. Further the work has been done in developing a combined ANN and Expert System Tool Transformer Fault Diagnosis[19] which showed that a combined Neural Network and fuzzy Logic approach provides a best guess method avoiding the "No Decision" with a very high training and testing accuracy.

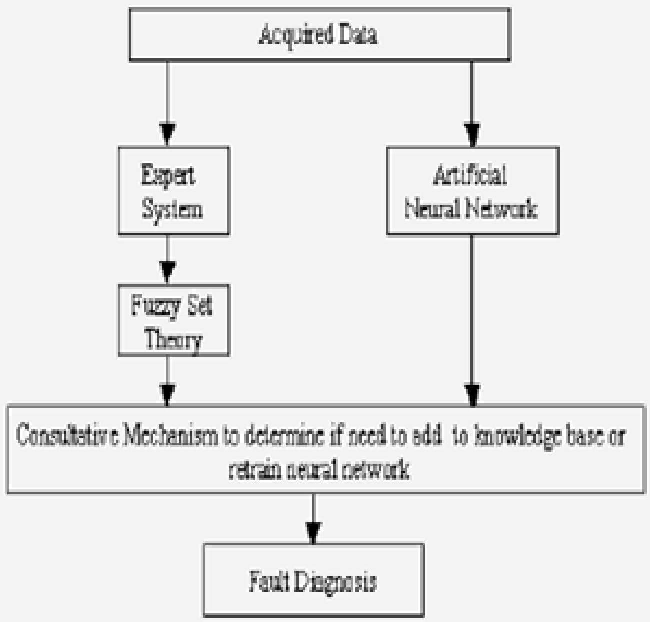

Figure 4: Strategy for combined fuzzy logic, expert system, and neural network

6. CONCLUSIONS:

An attempt has been made in this paper to review the modern intelligent diagnostic techniques for transformer insulation assessment based on Dissolved Gas Analysis (DGA) Firstly, the intelligent methods utilizing fuzzy logic implementation and neural network are discussed separately. Further the emphasis has been laid on the expert system developed using the combined fuzzy neural approach. Limitations of conventational DGA methods with frequent non-decision are addressed by fuzzy logic based diagnosis of power transformer incipient faults. The expert system using combined ANN fuzzy approach is expected to be useful to even inexperienced maintenance engineers for quick and reliable insulation condition assessment of transformers based on Dissolved Gas Analysis.

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