

Prediction of Fault in Distribution Transformer Using Adaptive Neural-Fuzzy Interference System

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Abstract: A distribution transformer is one of the most expensive pieces of equipment in an electricity system. The condition of a distribution transformer is crucial for its successful operation and, as a consequence, for the reliability of the distribution system as whole. The detection of incipient faults which may be caused by insulation weakness, malfunction, defects or deterioration is of fundamental importance. Monitoring the performance of a transformer is crucial in minimizing distribution outages through appropriate maintenance thereby reducing the total cost of operation. Diagnosis techniques based on the Dissolved Gas Analysis (DGA) have been developed to detect incipient faults in distribution transformers. The quantity of the dissolved gas depends fundamentally on the types of faults occurring within distribution transformers. By considering these characteristics, Dissolved Gas Analysis (DGA) methods make it possible to detect the abnormality of the transformers. This can be done by comparing the Dissolved Gas Analysis (DGA) of the transformer under surveillance with the standard one. This idea provides the use of adaptive neural fuzzy technique in order to better predict oil conditions of a transformer. The proposed method can forecast the possible faults which can be occurred in the transformer. This idea can be used for maintenance purpose in the technology where distributed transformer plays a significant role such as when the energy is to be distributed in a large region.

Keywords: Dissolved Gas Analysis (DGA), Adaptive Neuro Fuzzy Interference System (ANFIS).

1. Introduction

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-

1. Insulation Failures.
2. Design / Manufacturing Errors.
3. Oil Contamination.
4. Overloading.
5. Fire / Explosion.
6. Line Surge.
7. Maintenance / Operation.
8. Lightning.
9. Moisture.

- **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: pyrolysis(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. In this study, this is the second leading cause of transformer failures.

- **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.

Distribution transformers are of prime importance for electrical distribution systems. The condition of a distribution transformer is crucial for its successful operation and, as a consequence, for the reliability of the distribution system as whole. The detection of incipient faults which may be caused by insulation weakness, malfunction, defects or deterioration is of fundamental importance. A set of modern diagnostic methods is available and applied for oil filled distribution transformers. These methods allow the operators to plan adequate corrective actions at an early stage. For many years the Dissolved Gas Analysis (DGA) method has been used as a tool in transformer diagnostic. The main idea behind the use of Dissolved Gas Analysis (DGA) is based on the fact that during its lifetime, all oil cellulose insulated systems generate decomposition gases under the influence of various stresses, both normal and abnormal. The method has been used for several purposes to detect incipient faults, to supervise suspect transformers, to test a hypothesis or explanation for the probable cause of failures or disturbance which have already occurred and to ensure that new transformer are healthy.

Conventional DGA interpretation methods are: Individual and total dissolved key-gas concentration method (not universally accepted), Rogers ratio method, IEC Method and Duval triangle method (Graphical representation method). However, the identification of fault types by the conventional methods is not always an easy task due to the variability of gas data and operational nature. These methods often give different fault diagnosis results for the same input data. In recent years several AI techniques have been used in order to obtain unique and accurate diagnostic results, such as fuzzy logic (FL), expert systems (ES), artificial neural networks (ANNs) and self-organizing maps.

Thermal and electrical stresses result in fracture of the insulating materials and the release of several gases. Analysis of these gases may provide information on the type of fault. Various standards have been suggested for the identification of transformer faults based on the ratio of dissolved gases in the transformer oil, e.g., International Electro technical Commission (IEC) standards. However, they are incomplete in the sense that, in some cases, the fault cannot be diagnosed or located accurately. {Intelligent algorithms, e.g., wavelet networks, neuro-fuzzy networks fuzzy logic and artificial neural networks (ANN) have been used to improve their liability of the diagnosis.} In these algorithms, the type of fault is diagnosed first, and the fault is then located using the ratio of the concentrations of CO₂ 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.

2. DGS Standards-

The Three Conventional Standards dissolved gas analysis has following standards. The concentrations of H₂, CH₄, C₂H₄, C₂H₆, and C₂H₂ in the transformer oil can be used to diagnose faults in the transformer. The concentration ratios between some of these gases are used in some standards. Details on the three conventional standards are as follows.

- A. IEC Standard [3]: A three-digit code (X, Y, Z) is used to indicate the fault type. Each digit indicates a gas concentration ratio ($X = C_2H_2/C_2H_4$; $Y = CH_4/H_2$; and $Z = C_2H_4/C_2H_6$).
- B. Rogers Ratio Method [7]; Three gas ratios are used, namely, CH_4/H_2 , C_2H_4/C_2H_6 , and C_2H_2/C_2H_4 . Table 3 shows the fault diagnosis corresponding to various combinations of these ratios.
- C. Doernenburg Ratio Method [7]: In this method, four gas ratios, namely, CH_4/H_2 , C_2H_2/C_2H_4 , C_2H_2/CH_4 , and C_2H_6/C_2H_2 , are used to diagnose the fault.

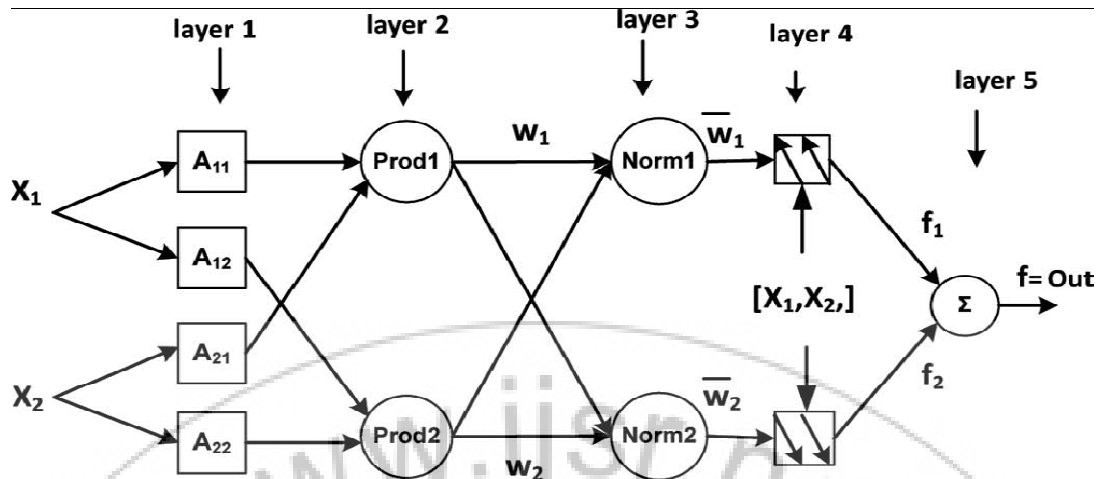
3. Adaptive Neuro Fuzzy Interference System-

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.)

4. Methodology

In this work the ANFIS system was 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 work, 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 n^2 nodes, so the two-input network in Figure 1 have four nodes, A₁₁, A₁₂, A₂₁, and A₂₂. 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 (A_{11} , A_{12} , A_{21} , A_{22}). 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.

A. **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 fault 1 of the IEC.

B. **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 are noisy or the quantity of training data is insufficient.

5. Conclusion

This paper is an attempt to predict fault in distribution transformer using Adaptive Neuro Fuzzy Interference System (ANFIS). The proposed system will be implemented using Dissolved Gas Analysis (DGS).

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