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Ageing Diagnostic Method for Analysis of Transformer

Anil Kumar Kori[1], A.K. Sharma[1] and A.K.S. Bhadoriya[2]

[1]Department of Electrical Engineering,
Jabalpur Engineering College, Jabalpur (M.P.), India
[2]Rajiv Gandhi Technical University, Bhopal (M.P.), India
E-mail: akkori1@rediffmail.com, arvindksharma_2000@rediffmail.com, dr.aksbhadoria@yahoo.co.in

Abstract

Transformers are critical and capital intensive assets for utility industry. It is broadly accepted that the life of a power transformer is the life of the oil/ paper insulating system, also the fact that most failures in their final on electro-mechanical base such as a short circuit condition or a mechanical failure. The ageing of insulation in Transformers is influenced by short term and long term over loads, intensity of short circuit, incidence of lightning, and internal faults. The ageing behavior is likely to be different for different types of transformers. The life span of the transformer, thus, depends initially on the design, and quality of manufacture, and later on service conditions and maintenance standard these factors vary considerably and affect the useful span of service life which therefore needs to be taken into account for residual life assessment. During the natural ageing of transformers, the insulation of winding, which is cellulose paper, deteriorates. Cellulose insulation degrades due to heating or electrical Breakdown, resulting in the production of furfural derivatives, which dissolve in oil. Hence, the chemical analysis of the Transformer oil gives evidence of changes that are taking Place in the winding insulation during operating. Deterioration in transformer cellulose decreases both its electrical and mechanical strength. In this paper a novel fuzzy based algorithm has been developed for ageing analysis of power transformer and implemented on three samples of transformer oil.

Keywords: Transformer oil, Paper insulation, Electrical breakdown, Aging analysis, Fuzzy logic.

Introduction
In power transformer paper ageing is a process involving both chemical and physical changes causing a loss of both mechanical and electrical strength. Deterioration of both the paper and transformer oil is caused by oxidation accelerated by high temperatures, air and moisture. The oil oxidation will lead to acids and par oxides production. These compounds are introduced into the transformer oil. The main requirements of insulating oil are to provide insulation, to withstand electric stresses imposed in service as the oil has high dielectric strength and low dissipation factor, to transfer heat and to provide cooling. The oil must have viscosity and pour point that are sufficiently low to ensure that the oil circulation is not impaired at the most extreme low temperature conditions for the equipment. To meet the arc quenching function, the oil requires a combination of high dielectric strength, low viscosity and high flash point to provide sufficient insulation and cooling to ensure arc is extinguished. The more general requirements are, in many cases, related to and interdependent with the three main functional requirements, and oil needs to have the general following properties:

The Moisture content of the oil must be low, otherwise the electric strength of the oil will be impaired and moisture will be absorbed in any insulating paper, reducing insulation life and increasing the risk of dielectric breakdown. The Oxidation Stability of the oil must be high to reduce oxidation process in service, which degrades the oil, producing sludge and acids. These can reduce the effectiveness of cooling and cause general internal deterioration and eventual failure. The oil must have a low Particle Size and Count and low fiber content as the presence of such contaminants, especially in the presence of moisture, can considerably reduce the electric strength. The oil must have undetectable Polychlorinated Biphenyl (PCB) content to meet the requirements of healthy and safety legislation. The oil must have low Polycyclic Aromatic (PCA) carbon content to meet the requirements of healthy and safety legislation. The Pour Point is related to viscosity and needs to be low enough to ensure that oil flows satisfactorily under low temperature conditions.

In this analysis we collected oil sample for ageing analysis of power transformer. The rating of Power Transformer was 40 MVA, 132/33kV. Following tests have been performed on sampled oil.

Chemical tests
- Moisture Content test
- Viscosity test

Electrical tests
- Breakdown Voltage test
- Particles Analysis test

Brief Description of Tests to be Performed
Moisture Content Analysis
Deterioration in transformer cellulose decreases both its electrical and mechanical

strength. In general, the greater the water content the more the mechanical strength reduces. Mineral oil has a very limited capacity to absorb moisture. Most of the water produced during ageing remains in the windings, reducing the insulation resistance of the transformer. It also reduces the transformer's ability to withstand the mechanical and electrical stresses that occur in operation additionally, high levels of moisture can effectively reduce the dielectric strength of the mineral oil. Over time this will result in outages and/or the necessary down rating of the transformer and ultimately could result in complete failure. While preparing this study we have used 831 KF Coulometer The coulometric Karl Fischer titration is as version of the classical water determination method by Carl Fischer. The traditional method utilizes a methanolic solution of iodine, sulpher dioxide and a base as buffer. Several reactions run in the titration of water containing sample and can be summarized by the following overall equation:

$$H2O + I2 + [RNH]\ SO3CH3 + 2\ RN \leftrightarrow [RNH]\ SO4CH3 + 2\ [RNH]$$

According to the above equation, I2 reacts quantitatively with H2O.This chemical relation forms the basis of the water determination. In the coulometric Karl Fischer titration, the iodine needed is generated directly in the electrolyte by electrochemical means ("electronic buret").the rigorously quantitative relationship between the electric charge and the amount of iodine generated is used for high-precision dispensing of the iodine. As the coulometer Karl Fischer is an absolute determination no titer need be determined. It is necessary only to ensure that the reaction which generates the iodine runs with 100% current efficiency. With the reagents available today this is always the case.

The end point is indicated voltameterically by applying an alternating current of constant strength to strength to a double Pt electrode. This results in a voltage difference between the Pt wires of the indicator electrodes which is drastically lowered in the presence of minimal quantities of free iodine. This fact is used to determine the end point of the titration.

Analysis of Suspended Particles Size

In case of deteriorated or waste oil their may be some dissolved particles. The larger the size and no of conducting particles decrease the break down voltage Spectrex laser particle Counter utilizes the principle of "near angle light scatter"; a revolving laser beam passes through the walls of a glass container of a flow-thru cell. When it is directed through a central "sensitive zone" the PC-2200 not only counts the particle in suspension, but tabulates their size as well.

Viscosity

The Viscosity of oil needs to be low enough to ensure the oil flows under all temperature (particularly low) conditions thus providing necessary cooling and arc quenching.

Breakdown Strength Test

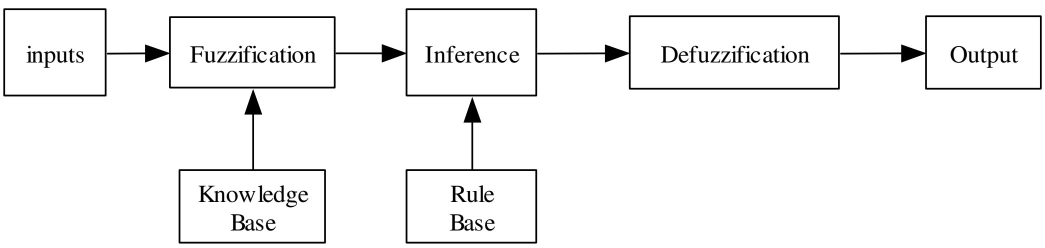
Breakdown test are normally conducted using test cells. For testing pure liquids, the test cells used are small so that less quantity of liquid is used during testing .The electrodes used for breakdown voltage measurements are usually spheres of 10 to 20cm in diameter with gap spacing of about 0.4 -1cm. The gap is accurately controlled by using a micrometer. Sometimes parallel plane uniform field electrode systems are also used. Electrode separation is very critical in measurements with liquids, and also the electrode surface smoothness and the presence of oxide films have a marked influence on the breakdown strength .The test voltages required for these tests are usually low, of the order of 50-100kV, because of small electrode spacing .The breakdown strengths is obtained in pure liquid of the order of 40KV/4mm-100KV/4mm.

Overview of Fuzzy Logic Ageing Dignosis of Power Transformer

A fuzzy expert system is an expert system that uses a collection of fuzzy membership functions and rules, instead of Boolean logic, to reason about data. The rules in a fuzzy expert system are usually of a form similar to the following:

If x is low and y is high then z = medium

where x and y are input variables (names for know data values), z is an output variable (a name for a data value to be computed), low is a membership function (fuzzy subset) defined on x, high is a membership function defined on y, and medium is a membership function defined on z. The antecedent (the rule's premise) describes to what degree the rule applies, while the conclusion (the rule's consequent) assigns a membership function to each of one or more output variables. Most tools for working with fuzzy expert systems allow more than one conclusion per rule. The set of rules in a fuzzy expert system is known as the rule base or knowledge base. The block diagram of fuzzy system is like this.



Block diagram of typical fuzzy logic system and the general inference process

The general inference process proceeds in four steps.

1. **Fuzzification:** Under fuzzyfication the membership functions defined on the

input variables are applied to their actual values, to determine the degree of truth for each rule premise.

2. **Inference:** Under inference, the truth value for the premise of each rule is computed, and applied to the conclusion part of each rule. This results in one fuzzy subset to be assigned to each output variable for each rule. Usually only MIN or PRODUCT is used as inference rules. In MIN inference, the output membership function is clipped off at a height corresponding to the rule premise's computed degree of truth (fuzzy logic AND). In PRODUCT inference, the output membership function is scaled by the rule premise's computed degree of truth.
3. **Composition:** Under composition, all the fuzzy subsets assigned to each output variable are combined together to form a single fuzzy subset for each output variable. Again, usually MAX or SUM is used. In MAX composition, the combined output fuzzy subset is constructed by taking the point wise maximum over all of the fuzzy subsets assigned to variable by the inference rule (fuzzy logic OR). In SUM composition, the combined output fuzzy subset is constructed by taking the point wise sum over all of the fuzzy subsets assigned to the output variable by the inference rule.
4. **Defuzzification:** Finally the (optional) defuzzification is used when it is useful to convert the fuzzy output set to a crisp number. There are more defuzzification methods than you can shake a stick (at least 30). Two of the more common techniques are the CENTROID and MAXIMUM methods. In the CENTROID method, the crisp value of the output variable is computed by finding the variable value of the center of gravity of the membership function for the fuzzy value. In the MAXIMUM method, one of the variable values at which the fuzzy subset has its maximum truth value is chosen as the crisp value for the output variable.

Presence of moisture, dissolved particles, acidity, resistivity and viscosity has serious impact on the asset performance and life, ignoring one could mislead the estimation. The fuzzy logic modeling and analysis has been carried out to get better asset's remnant life estimation. Figure 1 represents FIS editor showing 3-input variables and 1-output variable, figure 2, 3, & 4 represents the moisture, particle size, and viscosity represents membership function plot for input variable and figure 6 represents the membership function plot for output variable age.

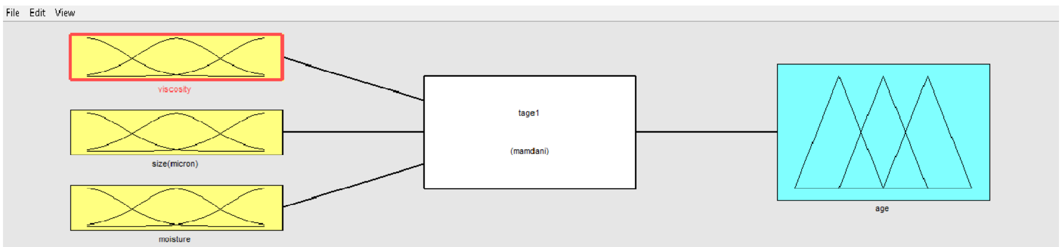


Figure 1: FIS Editor showing 3-input variables and 1-output Variable.

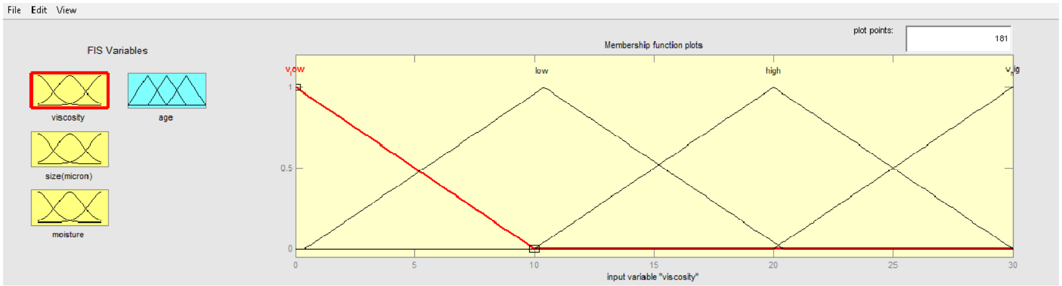


Figure 2: FIS Editor Showing membership function plot of viscosity.

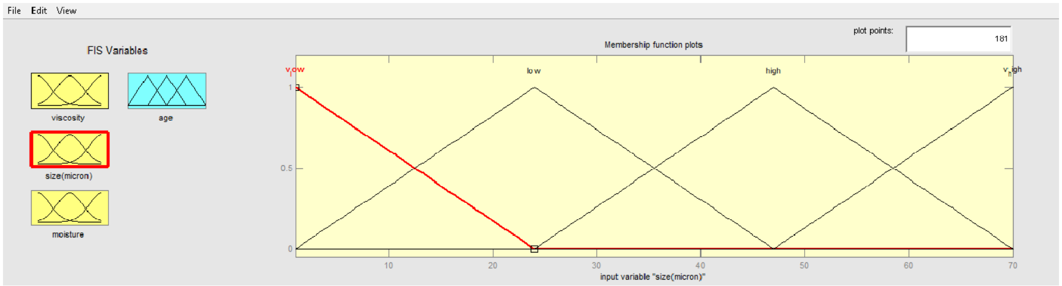


Figure 3: FIS showing membership function plot of size.

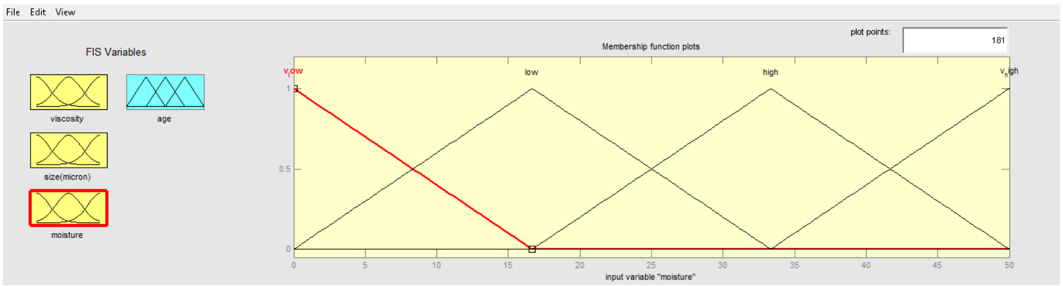


Figure 4: FIS Editor showing Membership function plot for moisture.

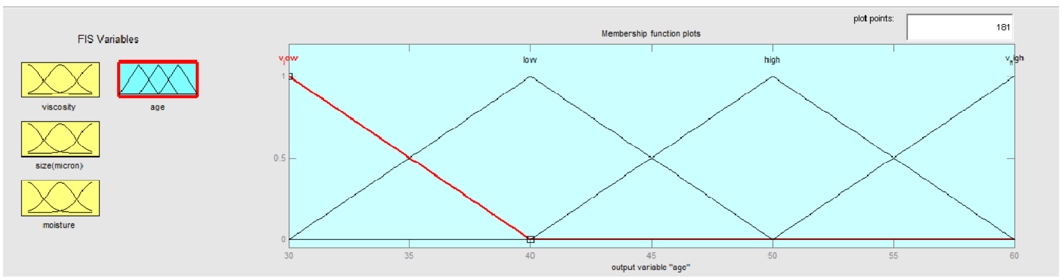
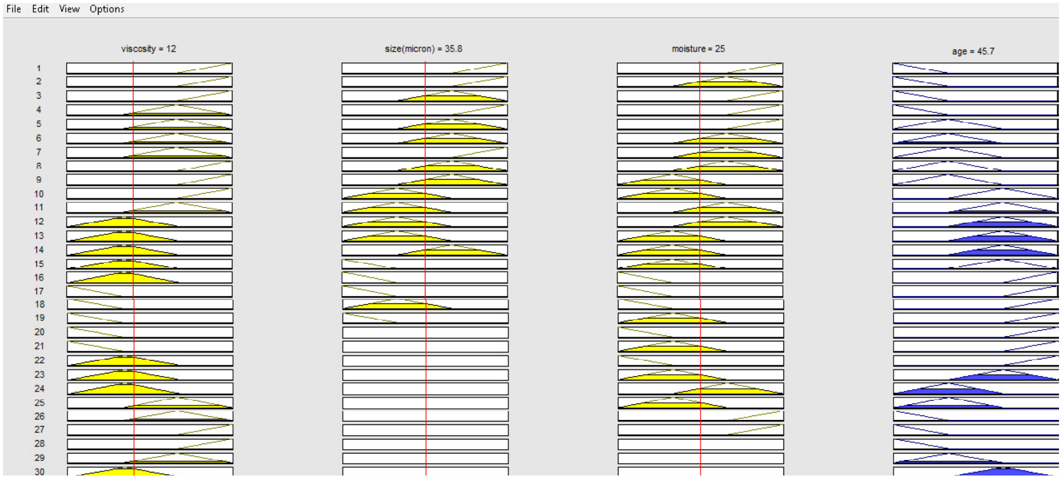


Figure 5: FIS Editor showing Membership function plot for output variable age
RULE VIEW



Conclusion

The transformer life is extended, and the risks are eliminated by Residual life Assessment. The user in meeting system demand, satisfactory operation of large power transformers can be achieved only if the condition of the coolant oil is maintained. Considerable experience exists worldwide where lack of attention to oil condition has led to shorter operational lives.

Moisture is the most dangerous contaminant of insulating oils. As small as ten parts per million by volume can lower the dielectric strength of the oil below its acceptable value. The resistivity of a liquid is a measure of its electrical insulating properties under conditions comparable to those of the test. High resistivity reflects low content of free ions and ion-forming particles and normally indicates a low concentration of conductive contaminants.

High acidity leads to advanced degradation and sludge formation. This in turn can lead to power cooling conditions and higher temperature leading to shorter lives. The Viscosity of oil needs to be low enough to ensure the oil flows under all temperature (particularly low) conditions.

The oil must have a low Particle Size and Count and low fiber content as the presence of such contaminants, especially in the presence of moisture, can considerably reduce the electric strength.

The life estimation model of transformer presented here with the use of fuzzy logic controller. The fuzzy method has been proposed in this work due to its simplicity and accuracy.

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