A NOVEL METHOD TO MEASURE THE LOL OF OIP OF TRANSFORMER

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Abstract - This paper provides an analysis of varied methods for estimating the remaining lifetime of in-service power transformer. Degree of Polymerization (DP) value is the most effective value for determining the remaining life of an Oil-Impregnated-Paper insulation system. Commercial equipment makes it relatively easy to obtain the values of paper-moisture and tanδ. Hence, these parameters have become popular among utilities. In the present paper, paper-moisture and tanδ, are wont to obtain several important dielectric properties (like lastingness, Degree of Polymerization, hotspot temperature) which are subsequently used for estimating the remaining life of several real-life power transformers. Efforts also are made to spot the tactic which is capable of identifying the remaining lifetime of power transformer with minimum error.

Key Words: Paper moisture, Oil Insulated Paper (OIP***)***, hotspot temperature (HST), dielectric dissipation factor, degree of polymerization (DP), loss of life (LOL), tensile strength.

1. INTRODUCTION

Power transformer plays an important role in ensuring reliable and efficient electricity supply. Power transformer being one among the foremost expensive equipment within the network, it's beneficial to increase its operational life by implementing proper policies. Formulations of such policies are often hooked in to the worth of Remaining lifetime of the transformer concerned. Available literature shows that various non-invasive techniques are available for estimating the worth of remaining life [1]. The accuracy provided by each of those available methods is restricted by the methodology opted and assumptions made during their formulations. Therefore, it is often observed that application of various Real-Life assessment technique results indifferent results for an equivalent unit (as shown later within the paper) thus resulting in errors. it's become a standard practice among utilities to think about paper moisture and dielectric dissipation factors as aging sensitive performance parameters. It is reported in literature that over time because the operational age of the unit increases, %pm and tanδ also increases. Therefore, it seems logical to incorporate these parameters in RLA calculations. Hence, this paper focuses on determination of RLA of power transformer using %pm and tanδ. Assuming these two aging parameters because the key factors there in influencing the worth of RLA assessment, four methods for estimation of remaining lifetime of transformer has been discussed within the paper. an attempt is additionally made to work out the tactic which is best suited (among the four methods) for RLA calculation.

It is a known that Degree of polymerization (DP) value are often used as a reliable indicator ageing in cellulosic parts of transformer insulation. Needless to say, DP value depends on this value of %pm additionally to DP, available literature shows that %pm also influences other performance parameters of insulation diagnosis like (Hot Spot Temperature) HST of transformer windings, lastingness of paper insulation. In recent times, availability of economic equipment's has made it possible to gauge %pm easily using non-invasive method as compared to analysis of DP value which necessitates analysis of actual paper samples. Recent advances within the field of insulation diagnosis show that it's also possible to predict %pm and dissipation factor (tan δ) by using data obtained through non-invasive technique like measurement and analysis of polarization-depolarization current. In the present paper four available methods of RLA calculations are compared. it's already mentioned that determination of %pm and tanδ now each day is comparatively easy. Hence, altogether these four methods %pm and tanδ (evaluated using available commercial equipment) are utilized in various capacities to gauge RLA. it's worth mentioning here that the four methods are tested with data collected from several in-service power transformers. The power ratings of these units are given in Table 1.

Table 1. Details of transformers used for experimental purpose

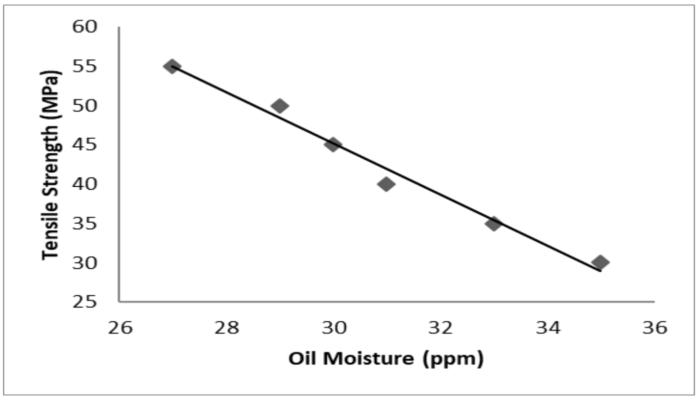
Transformer Name	Transformer Rating
Tran1	200 MVA; 400 kV
Tran2	63 MVA; 420 kV
Tran3	125 MVA; 220 kV

2. VARIOUS METHODS FOR EVALUATING REMAINING LIFE OF OIP INSULATION SYSTEMS

2.1 DEGREE OF POLYMERIZATION AND % MOISTURE

In this method, the estimation of RLA is completed by relating the three ageing sensitive parameters which are percentage moisture of oil, lastingness and DP value of paper insulation. Lastingness (tensile strength) indicates the amount of intact hydrogen bonds in cellulose molecule of paper insulation. With increase in moisture in paper the no of hydrogen bonds decreases and hence lastingness (tensile strength) decreases. Figure 1 shows the plot between tensile strength and oil-moisture (applicable to different units under equilibrium) that is reported in existing literature.

Figure. 1 Tensile strength reduction as a result of increase in oil moisture

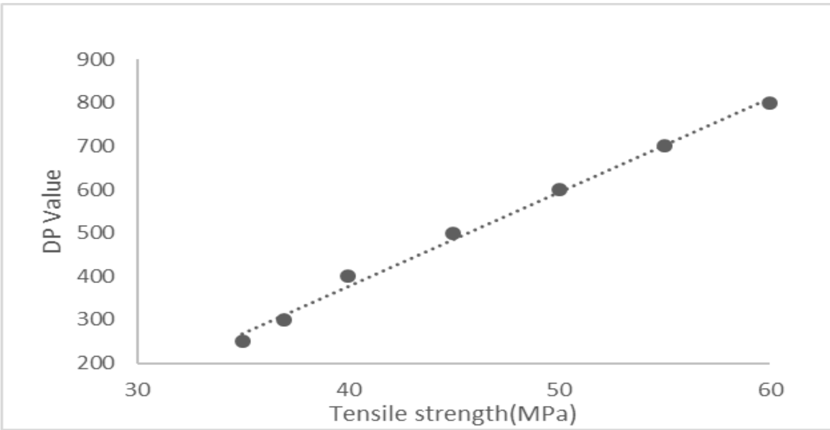


It is observed that equation (1) best describe the relationship that exists between tensile strength and oil-moisture.

TENSILE STRENTH= $84.78\times e^{0.02565\times oil\_ppm}$ (1)

The degree of polymerization is an indicator of ageing of transformer paper insulation. In equation (1) lastingness in MPa and oil ppm denotes oil moisture content in ppm. The equation (1), shows the exponential relation between tensile strength and oil moisture. Over time,the lastingness decreases because of reduction in hydrogen bond in cellulose structure. As a result, decrease in tensile strength is additionally amid associated reduction in DP value [4]. it's a known proven fact that the DP value of 200 is usually considered to be the top of Life (EOL). Hence,it is observed that when this DP value is known, calculation of remaining life is comparatively simple . Available literature shows that DP value and tensile strength of paper maintains a decent correlation with one another .The equation which best describes the connection between DP value and tensile strength is shown by equation (2). in order to know the ability of equation (2) to predict relationship between DP value and tensile strength Figure 2 also show the relationship predicted by equation (2).

Figure. 2 linear relation between DP value a tensile strength of paper insulation



In the present paper, *%pm* (measured using IDAX 300) and moisture equilibrium curves are used to determine the value of oil-moisture content. Thereafter, equation (1) is used to calculate the value of tensile strength. Once the value of tensile strength is evaluated, equation (2a) is used to compute the present DP value. Finally, equation (2b) is used for evaluation of the RL value.

DP = 21.71× Tensile Strength− 491.5 (2a)

Elapsed Life =20.5ln 1100 (2b)

DP

It can be understood that the drawback of this method in prediction of RLA is the cumulative error which affect the final result.

2.2 DISSIPATION FACTOR BASED METHOD

Dielectric dissipation factor (tanδ) measured at power frequency has always been a commonly used parameter for assessing the general health of transformer insulation condition. Dielectric dissipation factor being less sensitive to insulation geometry provides additional advantage. As per the report of CIGRE WG A2.3%pm of an in-service power transformer increases by 0.2% yearly. A rise in %pm results in decrease in desirable insulation property and increase in overall leakage current. These factors successively contribute in incrementing the general dielectric loss of the insulation concerned. It's worth mentioning here that tanδ measured at power frequency represents the entire dielectric loss and hence in influenced by both %pm also as by thermal/aging conductive by-products that accumulates within the OIP insulation over time. Figure 3 shows the variation of tanδ with operational age observed within the case of various transformers. Equation (3) is found to be best fitted to describing the relationship that exists between data presented in Figure 3.

Age = −9787 × $e^{51.26\tan\delta}$ + 9794× $e^{51.26\tan\delta}$ (3)

In equation (3) tanδ is expressed in percentage. so as to enhance clarity, Figure 4 also shows the mean characteristics (obtained through equation (3)) used for approximating the relationship between tanδ and aging of OIP insulation system. As per IEC 60216 and other literatures the lifetime (in years) of cellulose, considering an average winding temperature of 70˚C, is between 43 to 35 years. Within the present work, it's assumed that transformers reported during this paper have a lifetime of 37 years. Hence, within the present method, the worth of remaining life is obtained by subtracting the worth of elapsed life (obtained using equation (3) and measured tanδ) from 37.

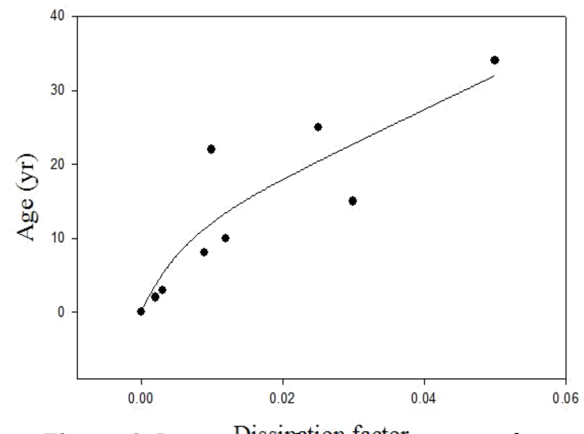


Figure 3. Dissipation factor increases with ageing

3. PERFORMANCE OF DIFFERENT METHODS FOR RLA OF REAL-LIFE UNITS

The above two methods are used to evaluate the remaining life of power transformers whose details are provided in Table 1. Values of paper-moisture and *%tanδ* for the tested transformers are given in Table 2. It is worth mentioning here that the value of *%pm* mentioned in Table 2 is obtained using IDAX 300.

Table 2. %$tan\delta$ and paper-moisture values measured for different power transformers.

Transformer Name	% paper- moisture	% $tan\delta$
Tran1	0.9	0.0025
Tran2	0.78	0.0028
Tran3	1.5	0.0031

Table 3. Remaining Life evaluated for various transformers.

Transformer Name	RLA (Years)	
	Equation (2)	Equation (3)
Trafo1	33.5	26.9
Trafo2	33.0	26.8
Trafo3	31.0	26.0

It is understood from the analysis presented above that the data obtained using equation (3) is at risk of less error as RLA estimation using equation (3) involves less number of equations. Hence, within the present paper the value of RLA obtained using equation (3) is assumed to be accurate. The results obtained using equation (2b) are expressed are normalized using results of equation (3). Table4 represents the normalized value of RLA obtained for various transformers tested. Considering the value of RLA (obtained from equation (3)) to be accurate, it is observed from Figure 4 that the error in RLA estimation is high for units having low paper-moisture which is usually the case for newly commissioned transformers.

4. CONCLUSION

In this paper two available methods of Remaining Life assessment is compared. In this paper, paper-moisture *%pm* and $tan\delta$ are used to obtain several important dielectric parameters like lastingness (tensile strength), DP value. These values are finally used to evaluate RLA of several power transformers. Results represented in this paper suggest that RLA methods provide less accuracy for new units having low-moisture content.

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