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Review article

Lifetime estimation methods in power transformer insulation

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ABSTRACT

Mineral oil in the power transformer has an important role in the cooling, insulation aging and chemical reactions such as oxidation. Oil temperature increases will cause quality loss. The oil should be regularly control in necessary time. Studies have been done on power transformers oils that are used in different age in Iranian power grid to identify the true relationship between age and other characteristics of power transformer oil. In this paper the first method to estimate the life of power transformer insulation (oil) is based on Arrhenius law. The Arrhenius law can provide loss of power transformer oil quality and estimates remaining life. The second method that is studies to estimate the life of power transformer is the paper insulation life prediction at temperature160 ° C.

1. Introduction

Different stresses including thermal, electrical and chemical influence on insulation of the power transformer. Life of a transformer is equal to its insulation life which depends on mechanical and electrical reliability. The main factors that determine the insulation life of oil-immersed liquid-cooled transformers are the transformer load, ambient temperature, moisture content and oxygen content in oil (Taghikhani and Rafiei, 2011). If the winding hottest spot temperature is increased 6 ° C related to the nominal value, the age of the power transformer is reduced by half and its electrical properties is changed (IEEE Standard, 2000).

Accelerated degradation examination that be called acidity value examination or neutral value examination is test of acid in oil or oxidation resulting in oil. Acid content is expressed as the amount of milligrams of potassium hydroxide (KOH) that making neutralize of acids in one gram oil sample. In an alternative method to acidity measuring 20 ml of oil sample is replaced into a cylinder and potassium hydroxide solution added to the oil (Emsley and Stevens, 1994). The solution color will change after became emotionless. Paper insulation deterioration with 1% moisture is ten times faster than the 0.1% moisture. The acids that by oxidation oil have been produced can help to rising metal corrosion in the power transformer (Lundgaard et al., 2004). Moisture in oil service should be monitored at least once a year. Many methods have been investigated to measure the quantity of moisture in oil (Emsley et al., 2000). Accelerated corrosion testing of power transformer is used to show the effect of temperature on oil paper insulation systems of power transformer (Crine, 2005; Saha and Purkait, 2004, 2008; Pradhan and Ramu, 2005; Muthanna et al., 2006). Several samples prepared for 24 hours at 120 ° C temperature and vacuum pressure in the drying ovens. Carbon monoxide and carbon dioxide are produced at high temperatures and have a lot of influences on the corrosion rate of oil.

2. Carbon monoxide concentration in oil

To measure carbon monoxide in oil in certain prescribed times and according to IEC 60567 standard gas chromatographic analysis was performed to determine the concentration. Fig. 1 shows result of this measurement. According to Fig. 1 with increasing temperature the aging time is increased due to paper thermal degradation. Fig. 2 shows paper destruction with decreasing mechanical strength when monoxide carbon concentration increases in oil.

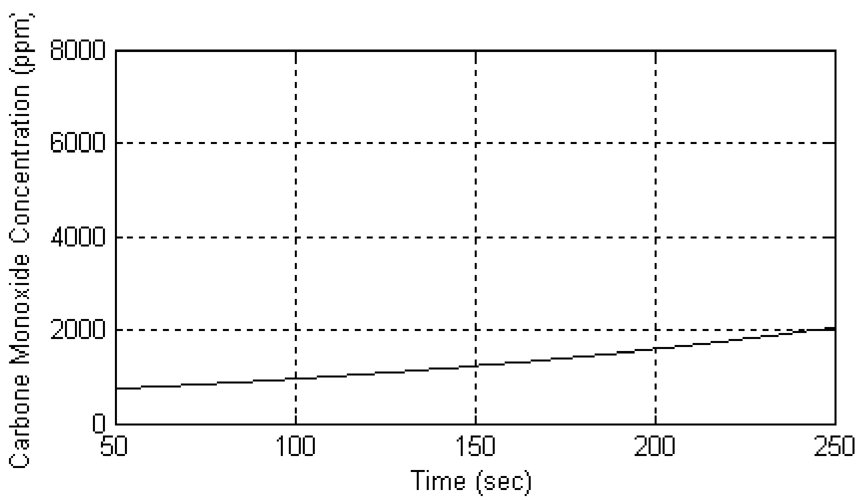

Fig. 1. Changing of the carbon monoxide concentration dissolved in oil.

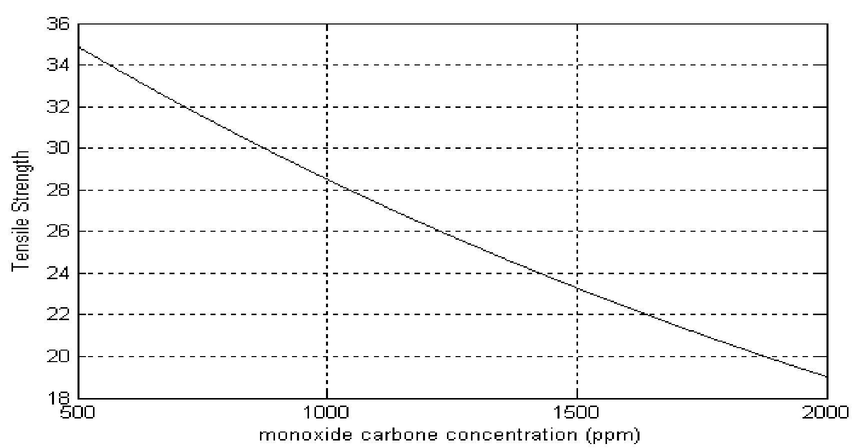

Fig. 2. Paper tensile strength verses monoxide carbon concentration of oil in temperature $160°C$.

3. Carbon dioxide concentration in oil

Fig. 3 shows measurement result of solution carbon dioxide in the oil and gas chromatography (IEC 60567). Carbon dioxide concentration in old oil to new oil has increased during heat stress. The aging time is increased due to increasing temperature. Fig. 4 shows paper destruction with decreasing mechanical strength when dioxide carbon concentration increases in oil.

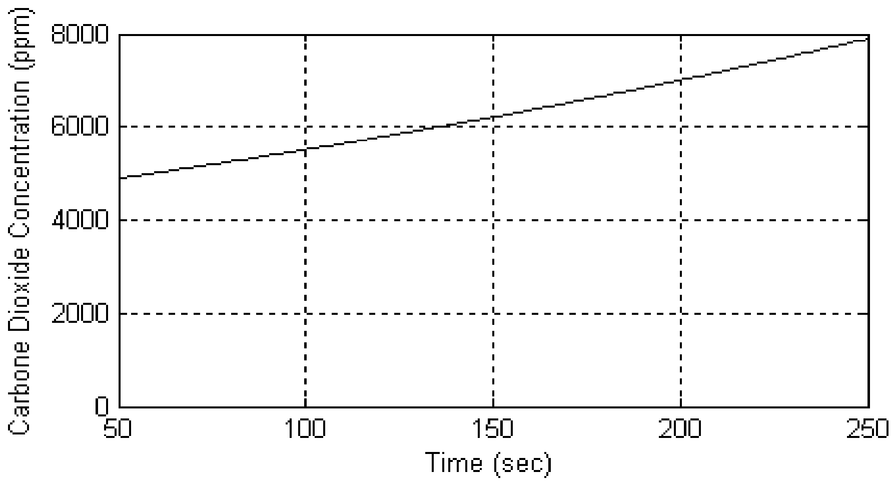

Fig. 3. Changing of the carbon dioxide concentration dissolved in oil.

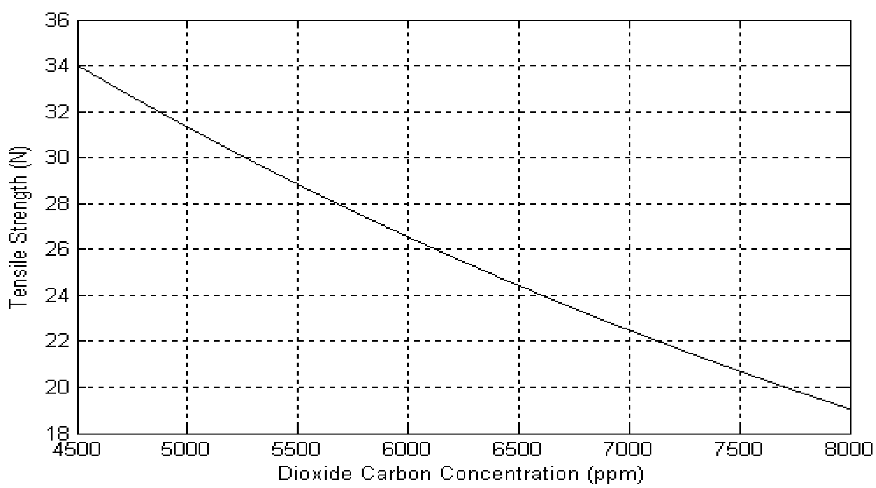

Fig. 4. Paper tensile strength verses dioxide carbon concentration of oil in temperature $160°C$.

4. Arrhenius law

Arrhenius law is an experience-mathematically law which is dependent on temperatures effects on chemical reaction rate. According to this law, the reactions are dependent on temperature (Lundgaard et al., 2004):

$$t = A \cdot e^{\frac{B}{T}} \tag{1}$$

Where t is time, T is temperature, A and B are constants(based on testing and reaction conditions).For example, can accelerate corrosion tests on the insulation by Montsinger over 70 weeks in temperature7-110°C, Dakin over 100 weeks at temperature100-135°C, Shroff over 16 weeks in temperature 110-140°C, Moser during the 57 weeks at temperature 90-135°C , And again by Moser in 3 weeks at the temperature 145-190°C and finally Oomen during one week at the temperatures of 120-180°C. Figure 5 shows lifetime logarithmic graph. If from both sides of the equation (1) take the logarithm will have a linear function of 1 / T. Power transformer remaining life (insulating) is earned using this method in the conventional temperature.

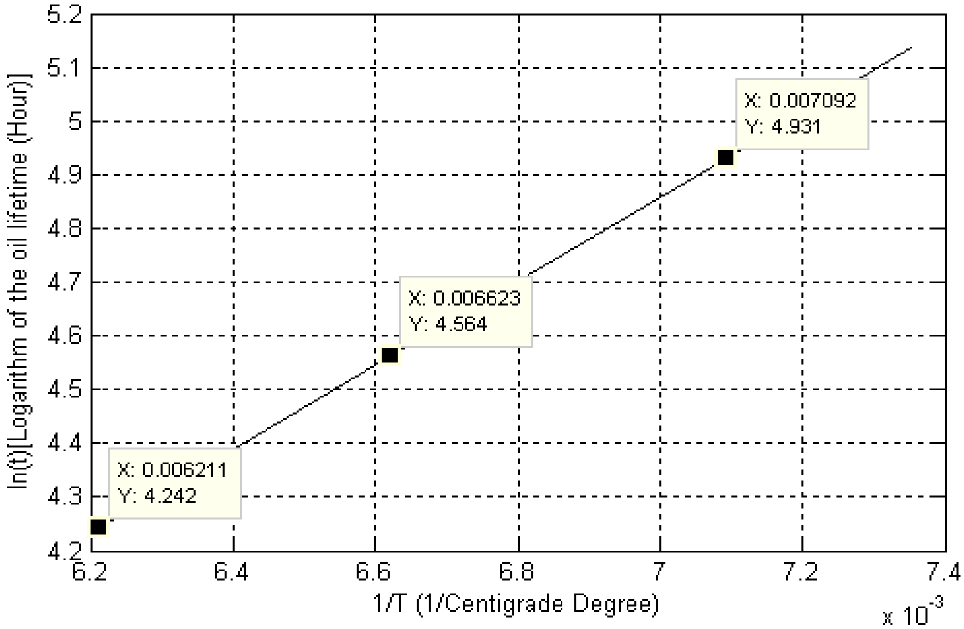

Fig. 5. Arrhenius diagram to accelerate aging in an oil sample at different temperatures.

As an example a 230kV, 18 years old power transformer reached to our degradation criterion limit (the acidity number equal to 0.3 mg KOH in one gram of oil) after 145 h at 140°C, 100h at 150°C and 66h at 166°C respectively. We observed that the degradation time and the applied temperatures (three points reached on a straight line) has been repeated in this manner for various oil samples to prove the Arrhenius law for transformer oil. The life of the oil samples in the normal working temperature (80°C) using Fig. 5 is the natural logarithm with the following relationship:

$$t = 0.5374 \cdot \exp(\frac{782.9}{T}) \tag{2}$$

We can obtain the remaining lifetime of this used oil specimen at 60°C equal to 249526 hours which is 28.5 years and in temperature 80°C it will reach to non-acceptable acidity limit in 9559 hours (one year). This method can easily estimate the oil remaining life of power transformers.

5. Prediction of paper insulation life at temperature 160 °C

One of the important mechanical parameters for cellulose insulation (paper) in the power transformers is tensile strength (the loss of mechanical strength) that causes the short circuit fault (Emsley et al., 2000). Therefore, this parameter can be an important criterion in determining the end of life of paper insulation. Paper tensile strength change verses the per unit life at temperature 160°C is shown in Fig.6. Low paper tensile strength (50% of its initial value) is considered end of its life. Therefore the remaining life of the paper at temperature160° C would:

$$\mathrm{Re}\,maining - lifetime = 1 + 1.441 \cdot \ln(\frac{Tensile - Strength(\%)}{100}) \tag{3}$$

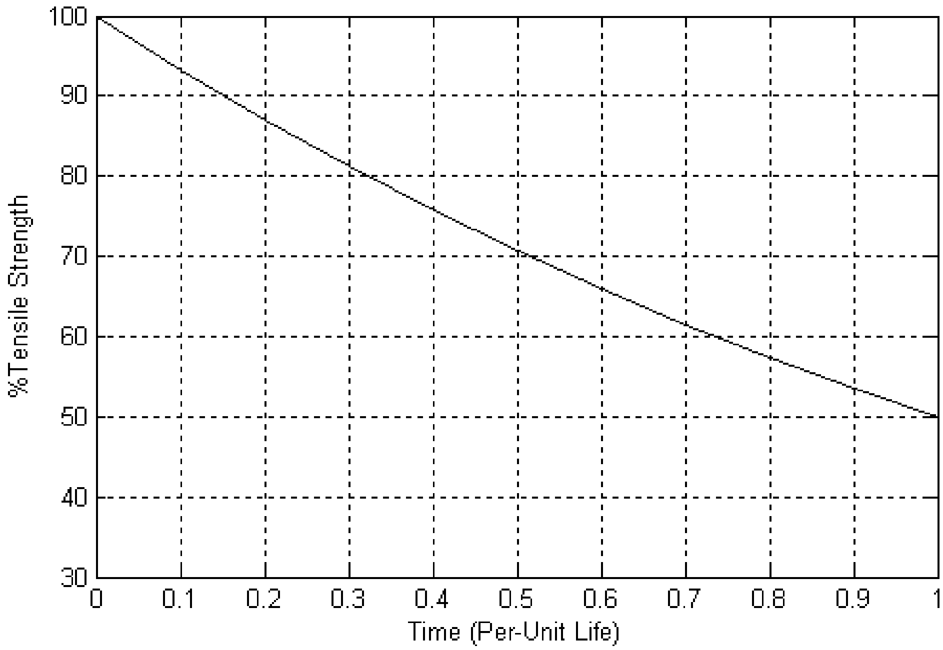

Fig. 6. Paper tensile strength verses time at temperature 160°C.

6. Conclusion

In this paper have been measured acidity and moisture content of power transformer insulating oil - paper under thermal stress. Most experiments conducted in accordance with changes in electrical properties. The first method to estimate the life of the power transformer insulation (oil) is based on Arrhenius law. The Arrhenius law can provide loss of power transformer oil quality and estimates remaining life. The second method that estimates the life of the power transformer insulation is the paper insulation life prediction at temperature 160 ° C.

Acknowledgements

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