Energy Saving Methods for Transformer Oven

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Abstract

The drying time of distribution transformer core-winding assembly, at the transformer plant, Lanka Transformers Limited is presently based on the high voltage rating and the oven consumes larger proportion of total energy consumption. It is the normal practice to dry out the transformer core-winding assembly for twenty-four hours for 11 kV distribution transformers and thirty-six hours for 33 kV distribution transformers, irrespective of the capacity. This has been decided considering the total capacity of transformers kept in the oven during the drying process. This achieves a larger than required drying time, which has been considered to have a higher safety margin. But, if the exact drying time can be found by means of an acceptable method and by implementing a user friendly temperature control system we can save energy and achieve efficient & effective drying.

Index Terms

Transformer, drying time, insulation, winding, core, loss factor

1.0 Introduction

Figure 1 – Core-winding assembly ready for ovening

Drying out of the transformer core-winding assembly (shown in figure 1) is an extremely important aspect in transformer manufacturing. This should be done in order to remove moisture from the core-winding assembly.

This mainly consists of insulation materials such as pressboard, paper, wood and insulating tape.

Degradation of transformer insulation which reduces the withstand capability of insulation for mechanical and electrical stresses is the main factor for transformer failures, and presence of moisture leads to increase the rate of degradation.

Figure 2 – Transformer Oven

The transformer core-winding assembly is put into the oven (figure 2) for up to 36 hours to remove this moisture.

It is required that the temperature inside the oven should be kept at a defined value through out the drying process in order to get complete bonding between windings and insulation and also to remove the moisture inside the core-winding assembly.

Since moisture evaporates at over 100^{o}C, the oven temperature is set between 112^{o}C to 120^{o}C. It is heated up to a temperature above the ambient before loading the transformer core assemblies.

1.1 Loss Factor of Insulation

The loss factor of the transformer Insulation is a measure of its dielectric power loss. With the removal of moisture the dielectric power loss decreases and the insulation resistance will increase. It thus provides information about the quality of the insulation. The loss factor is independent of insulation area or thickness, and increase with contamination by moisture. In practice, however, it is difficult to measure the loss factor during the drying out process. Thus the decrease in the moisture content of the insulation is assessed by measuring insulation resistance.

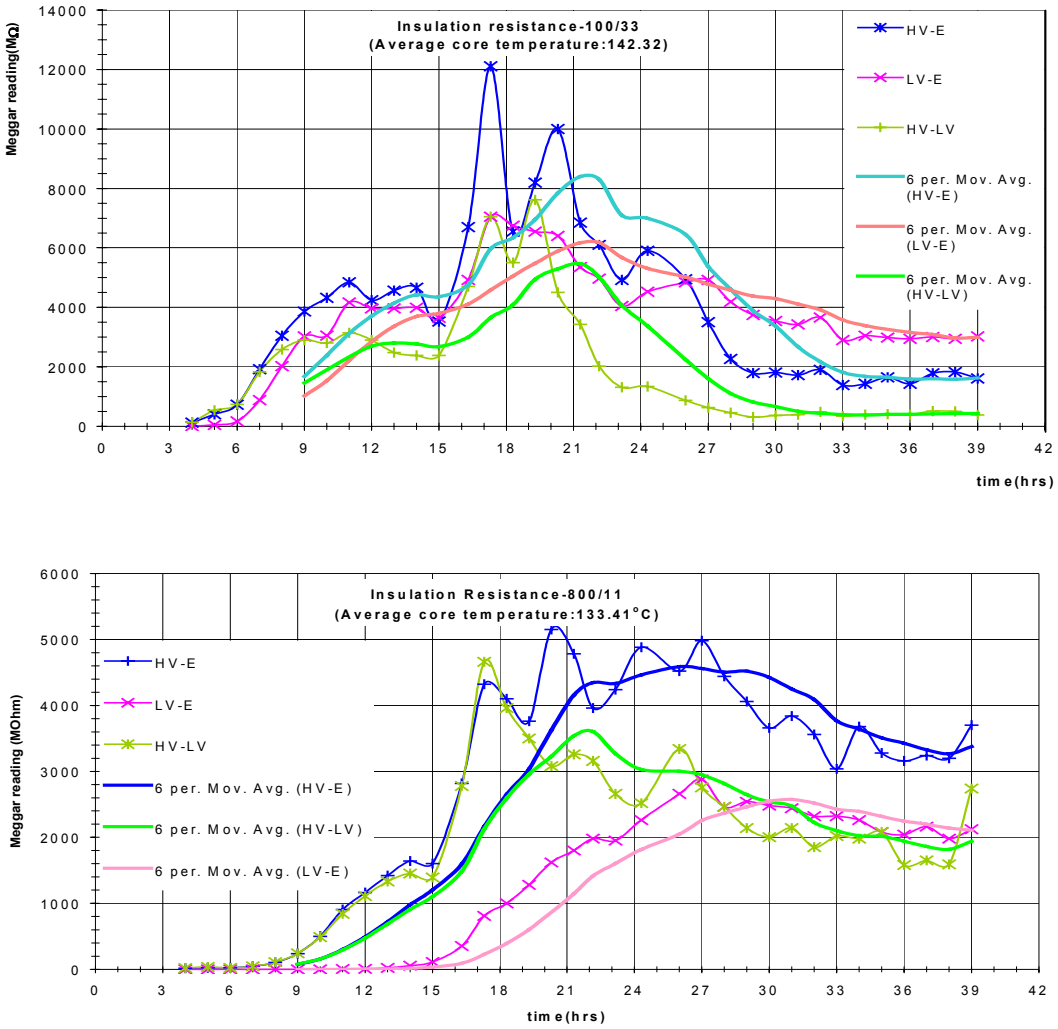

Figure 3a: Insulation Resistance variation for 100 kVA/33 kV and 800 kVA/11 kV transformers

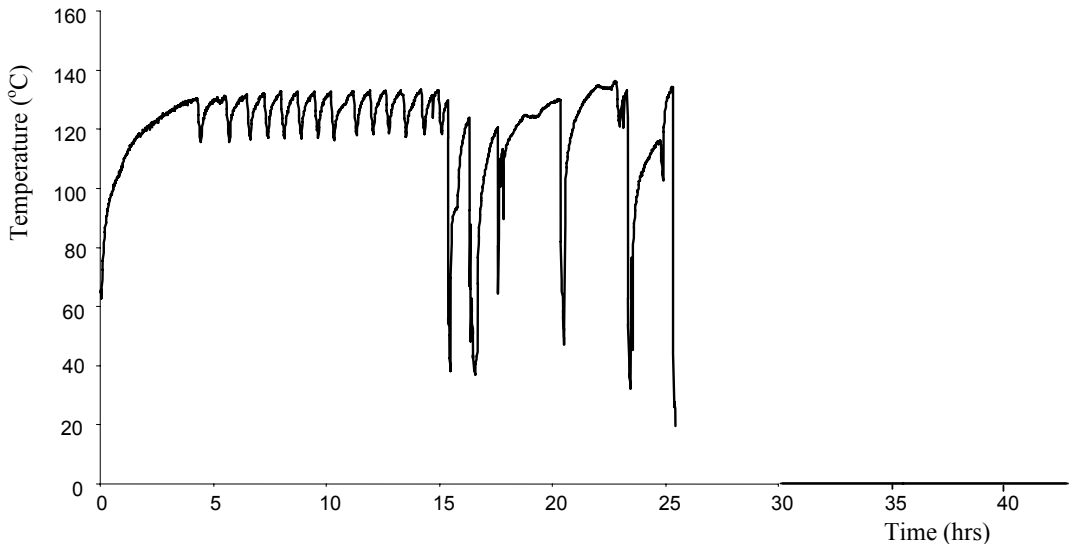

Figure 3b: Temperature variation Inside the Oven for transformers in Figure 3a

1.2 Transformer selection

Distribution Transformers were selected for the study, considering their high voltage ratings (11 kV and 33 kV) and their capacities (100 kVA, 250 kVA,400 kVA,630 kVA,800 kVA).

1.3 Performance

The oven temperature was set at 120°C as it is required to maintain a safe bond between the conductor and the layer insulation. Temperature variation inside the oven was observed through out the experiment. This was done using temperature sensors placed inside the oven. The data obtained was stored in a Data Logger. The Insulation Resistances throughout the drying process were measured using the Meggar Test Set. Drying was continued for 36 hours.

First the test was conducted for 2 types of transformers while the normal production process was going on. The test results were given in the figure3a, and from that it can be observed that insulation resistance has increased with time and after that tends to drop.

During the test period oven was switched off after about 16 hours to take out another set of transformers for tanking. Therefore temperature inside the oven was dropped rapidly as shown in the figure 3b. It was evident that the sudden increases in resistance of both transformers have occurred almost at the same time as the switching off the oven.

When the oven is opened the moisture trapped inside the oven can be released to the outside quickly and this can be a reason for the above observation. In order to clarify whether there is any relation between the above observations, the test was repeated with another set of transformers. Through out the test the oven was not switched off or opened. Results obtained for the tested transformers are shown in Figure 4.

Although there is a peak in all of the above graphs the insulation resistance value at the peak is not high as the first set of transformers. So it was obvious that the sudden increase in insulation resistance is due to the opening of the oven.

Theoretically the insulation resistance should increase up to a maximum value and thereafter it should remain at that value with further drying. But according to the above graphs it is observed that the insulation resistances of all the tested transformers were reached to a maximum value and with further drying the theoretically expected variation couldn't be obtained.

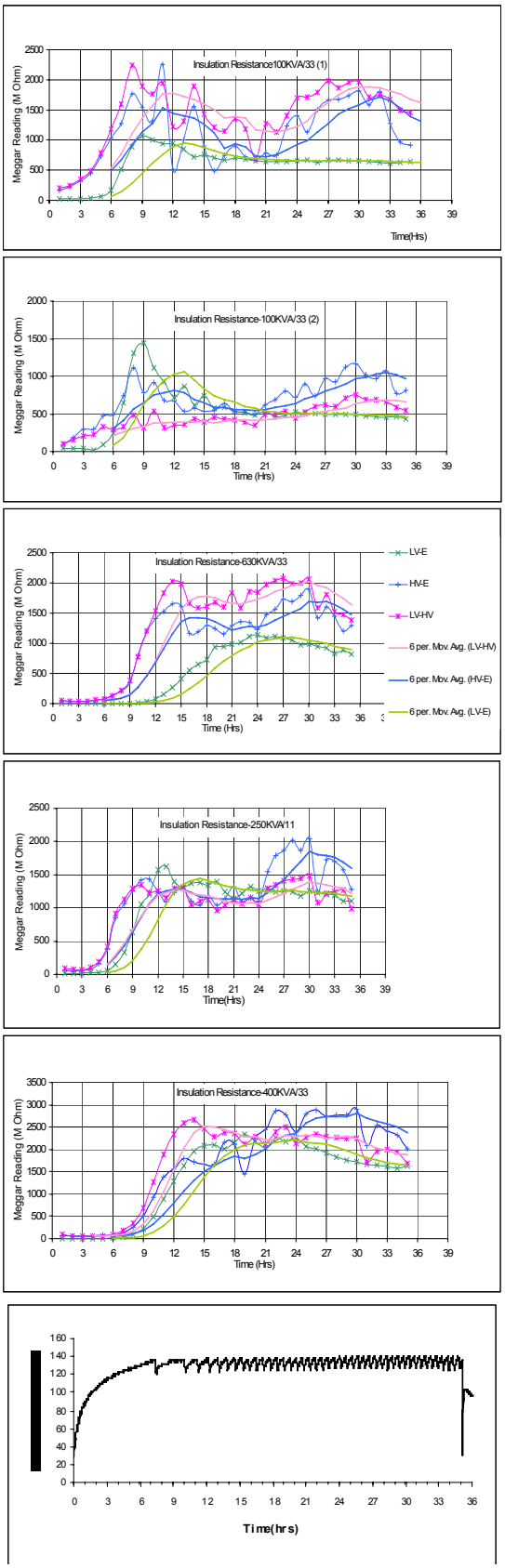

Figure 4: Insulation Resistance Variation &Temperature variation inside the Oven

As transformer core and winding assembly is highly packed, the removed moisture can be trapped inside the assembly it self and this may be a reason for the above deviation of the results from the theory. From the test results it is reasonable to decide the required drying time to be the time when the insulation resistance rises to the peak value. It can be concluded that the drying time for the tested transformers to be in the range of 15 hours to 20 hours.

In order to confirm this, another set of transformers of the same ratings were dried for the pre-determined period, and they were subjected to the required Routine Tests according to the IEC 60076 Standard.

The results were up to the standard and thereby it can be concluded that the drying time can be reduced by a significant time period.

2.0. Temperature Control System

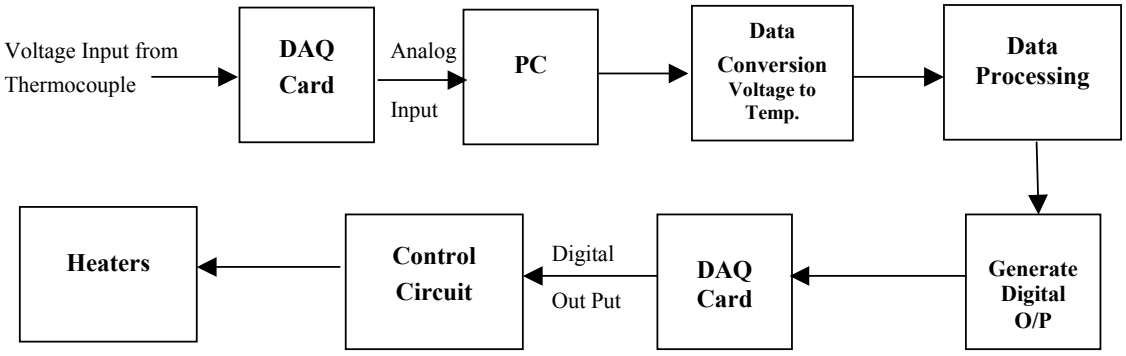

Figure 5 : Control Circuit

2.1. Selection of Temperature Sensors

Among various types of temperature sensors such as thermocouples, RTDs, thermisters, IC sensors, thermocouples were selected as the sensor considering the cost, accuracy, sensitivity and precision. From the different types of thermocouples (J,K, S,T,R) , J type was selected, because of its compatibility with the requirement and cost effectiveness.

2.2. Calibration of thermocouples

Thermocouples were calibrated at the ice point and boiling point and the error was negligible.

2.3. Performance

As the cold point is taken as the 0^{o}C, compensation should be done to the room temperature, which is sensed using a RTD.

A digital signal is generated to control the heaters inside the oven according to the temperature, which can be set as required.

2.3.3. Out put and Control Circuit

Generated digital signal is used to switch the three-phase contactors, which connect the power supply to the set of heaters. The Personal Computer and the DAQ card are electrically isolated using opto–isolator. The complete diagram of control system is shown in figure 5 and the control circuit is given in figure 6.

The Control System is basically consists of three parts, namely Data acquisition, Data processing and Out put and control circuit. Mainly it was focused on getting uniform temperature distribution inside the oven at the same time achieving user-friendly system.

2.3.1. Data Acquisition

Data acquisition is done through DAQ card. It reads the voltage relevant to the temperature in side the oven with reference to the 0^{o}C cold point. Room temperature is sensed as a resistance for cold junction compensation.

2.3.2. Data Processing

To convert the voltage sensed by thermocouples to corresponding temperature, database was prepared using Visual Basic.

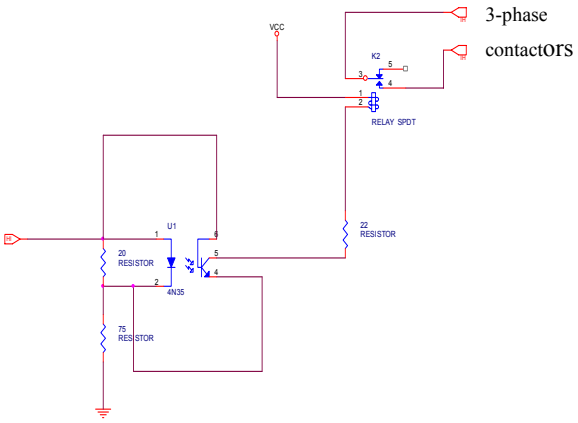

Figure 6-Control circuit

3.0 Conclusion

The main objectives of our project were to save energy and increase the efficiency of the transformer manufacturing process.

According to our test results it was possible to reduce the drying time for transformer core-winding assembly significantly (approximately half of the current drying time) at the same time achieving effective drying of transformer core-winding assembly.

The main weaknesses of the current temperature control system are that it senses temperature only at one point in the oven and according to the out put signal of the sensor, the set of heaters (32 heaters of 1825W) are controlled as a one batch and also it is not user friendly. The implemented control system provides solutions for the above problems in the following ways.

- Input signals to the control system can be given using 8 sensors; thereby temperature can be sensed at different points of the oven.
- Heaters can be controlled individually depending on the temperature of those points.
- Internal temperature of the oven can be set to a desired value using PC.

Further studies should be carried out on the transformer drying process in order to supplement the conclusion about the required drying time of transformer core-winding assembly. We will be able to decide the drying time more accurately by using following ways.

- By monitoring the moisture level inside the oven through out the drying process.
- If there are facilities to continuously measure the tan δ(loss factor) of the transformer during the drying process.
- By monitoring the volume of extracted water during the process.

We would also like to suggest the followings, for further improvements of the drying process of transformer core-winding assembly.

- A reduction of the initial moisture content in the insulation materials prior to the drying. This can be achieved by stock keeping of the insulation material at controlled ambient conditions. (Air-conditioned warehouse).
- Changes in oven structure such as proper sealing of the oven doors, making arrangements to remove moisture at a particular place, proper dehumidification of intake air etc.

4.0 Acknowledgements

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5.0 References

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- J&P Transformer by Martin J Heatchote (CEng, FIEE), 12th Edition.