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Vapor Phase Drying for Moisture Removal from Transformer Coil Insulation

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Abstract-Cellulose based material like paper & pressboards form a very important feature of the transformer construction process. The life end of a transformer depends on the state of cellulose insulation materials like paper & pressboards. Paper with 1.5% moisture content ages 10 times faster than with only 0.3% moisture. It is very critical that the moisture is removed from transformer insulation. Technology has evolved for the moisture removal process from transformer insulation but has not remained efficient over the period of time due to the need of transformers of higher rating. All the methods have an extensive cycle time which may last up to days together incurring heavy energy expenses. Today's best method available for moisture removal from insulation is vapor phase drying and as compared with other conventional methods, has relatively less cycle time.

KEYWORDS: Vapor phase drying, moisture, transformer

1 Introduction

Healthy power transformers are one of the key components in a reliable electrical grid. Unplanned interruptions can disturb a large supply area or the production in industry, which can lead to enormous financial losses. On the other hand, the pressure to keep older units into operation for economical reasons is growing steadily. This leads to a situation, where the population of the transformers is getting older and at the same time running at a higher load, due to the steadily growing demand. Transformer is required to withstand high voltages during the process of power transfer from primary to secondary. For this purpose it is required to have adequate insulation. In construction of transformer, the insulation system is the most important feature and hence requires maximum attention. Normally the insulating materials used are the oil, paper, and pressboard insulation. Cellulose based insulation used in transformers contains 8-10% moisture by weight at ambient temperature. But this moisture is injurious The transformers do not live forever. The life end of a transformer depends very much on the state of the solid insulation & ultimately it is the condition of the cellulose of the paper insulation that determines the life of the transformer. It is well documented that the rate of to the health of the transformers since it reduces the electric strength, resistivity and accelerates deterioration of solid insulation.

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deterioration of the paper and the breakdown strength of the insulating oil is significantly influenced by moisture contamination. If transformers are to have service life extended it is imperative that moisture is removed from the oil & the paper insulation. Thermal heating has been conventionally deployed for the moisture removal from transformers. Over the years the process has not remained efficient in terms of energy and effectiveness. Introduction of vacuum has improved the process largely but a lot needs to be done on the thermal engineering aspects of the moisture removal process [1]

2 Drying Technologies

The technology for moisture removal has been the main area of concern over the years. The well established processes for transformer drying which have eventually lead to vapor phase drying technology are hot air, hot air with rough vacuum, vacuum drying oven, oil circulation, oil spray & vacuum pressure impregnation.

2.1 Hot air

Hot air with a maximum temperature of 120oC is used for heating up the active parts of the transformer. A maximum insulation temperature of 150oC is recommended. Provided that the transformer tank is vacuum tight, the drying process can be optimized by evacuating the transformer. This process has a drawback back that the active parts are non-uniformly heated.[2]

2.2 Hot Air with Rough Vacuum

The transformer is heated with hot air so to vaporize the moisture content in it. Then this hot air is extracted by the means of rough vacuum to remove water so vaporized. This ensures that the water which has vaporized does get reabsorbed in the insulation materials. But this process also is time consuming as well not efficient. [2]

2.3 Vacuum Drying Oven

In this process the transformer is kept in a vacuum oven where it is heated by means of electrical heaters. This results in water being evaporated which is present in the layers of insulation. Once the required temperature has been attained, vacuum is created in the oven with the help of vacuum pump so that the water vapor present in air around the transformer is extracted & maximum drying can be ensured.[2]

2.4 Oil Circulation

Transformer oil is circulating through oil purification equipment. After filtering the oil to remove the particles, the oil is heated to 80oC. In a so called vacuum degassing unit, all residual gasses are removed and the moisture contents of less than 5ppm can be reached. This is a necessary maintenance process for oil filled transformers but not very efficient for removing moisture as there is indirect heating of the insulation which takes a very long time.[2]

2.5 Oil Spray

After removing the transformer oil from the tank, spray nozzles are assembled at the man holes & flanges of the transformer tank. The tank is evacuated by a vacuum pump to a pressure of 5mbar. Oil is pimped through filter devices & a heating unit to the top of the autoclave. Via nozzles, the oil is sprayed onto the surface of the active parts. The active parts are heated up & the moisture evaporates. The vacuum pump unit continuously sucks the water vapor out of the transformer tank. The absence of oxygen allows the increase of the oil temperature to 120 oC. in this process also the drying times are very long.[2]

2.6 Vacuum Pressure Impregnation

In VPI the transformer coils are heated initially to remove the moisture from the layers of insulation. After the desired temperature has been attained, vacuum is created in the tank so as remove the air along with the water vapor. On reaching the desired level of vacuum, resin, which is atmospheric pressure, is allowed to impregnate the coils at a low pressure. As a result of the pressure difference, resin impregnates the innermost parts of the coils thereby providing effective insulation.[2]

3 Vapor Phase Drying

As of now, the most advanced drying technology for power transformer is the vapor phase drying method. Vapor phase drying is the method which applies vacuum but the method of heating is not through air. In this method the carrier of heat is vapor of low viscosity solvent like kerosene with a sufficiently high flash point instead of air. In vapor phase drying, as shown in figure 01, the vapor is heated in a chamber by the use of electric heaters and is passed over the core coil assembly kept inside for drying. The solvent vapors thus condense on the drying mass and are collected back in form of liquid solvent which is recirculated in the system. For this purpose the vapor phase drying systems have an evaporator and condenser system in addition to the vacuum chamber and vacuum pulling equipments such as vacuum pump, roots pump etc which are part of conventional vacuum system. Thus the system in total consists of solvent heat conveyer system consisting of storage, evaporation, condensation, filtration, solvent feedback and control arrangement.

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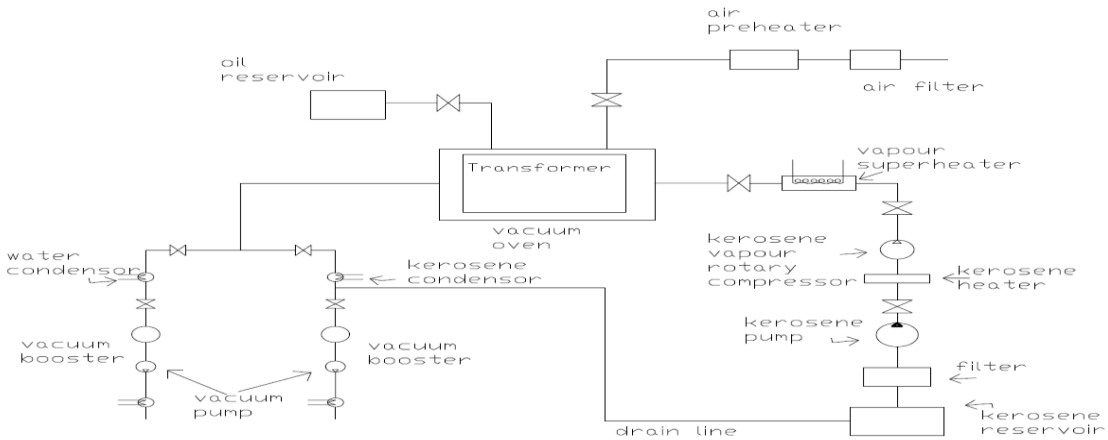

Fig 01

3.2 Methodology of VPD

The drying process typically consists of following steps [3]

(a) Preparation
(b) Heating and drying
(c) Pressure reduction
(d) Fine vacuum

Figure 2 shows the sequence of operation of Vacuum Phase Drying in a vacuum vessel and the four typical stages of vapor phase of drying process.

a)Preparation

The complete evaporator and the condenser system is applied with full vacuum to the level of 5 torr before drawing the solvent in the evaporator and heating it to the level of 130°C. The vacuum chamber of the VPD is also applied with vacuum of 5 torr. The core coil assembly is kept with slope to assist draining of the solvent

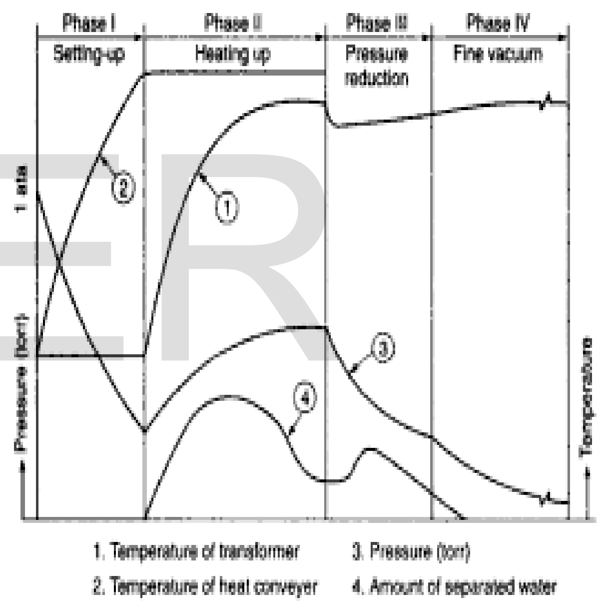

Figure 02

b) Heating and Drying

Heating is started after all the air has been taken out. The valves are kept open for the solvent vapors to enter the vacuum chamber and condense over the surface of the drying mass loaded. The condensation releases the heat and the loaded mass temperature increases thus causing evaporation of water. The mixture of water and solvent drains out for recirculation.

c) Pressure Reduction

During this stage the supply of solvent vapor is stopped and most of the solvent vapors which were absorbed by the insulation re-evaporate, condense out in the condenser

and finally get returned to the evaporator. This phase continues till the pressure in the vessel reaches 15-20 Torr.
d) Fine Vacuum
This is the final stage of the cycle which immediately follows the pressure reduction stage. The vessel or the vacuum chamber is again reduced to pressure not exceeding 0.1 Torr. The water extraction is monitored and recorded at regular intervals. When the water extraction rate becomes constant to the desired level the cycle is stopped.

3.3 Time Saved in VPD

As compared to the conventional method of vacuum drying, the time required for moisture removal from transformers of the same rating, VPD has a relatively less cycle time. This is evident from the following

TABLE. 1

Cycle time in hrs (avg.)		
Rating	Vacuum drying	VPD
11 KV, 500 KVA	16	12
11 KV, 1000 KVA	18	12
11 KV, 2000 KVA	18	14
33 KV, 3000 KVA	30	24
33 KV, 5000 KVA	36	24
33KV, 10000 KVA	42	30

3.4 Properties of The Solvent Vapor

VPD uses solvent vapor as a heat carrier instead of air. This solvent vapor should posses certain properties which can be enumerated as follows [3]

a) Vapor pressure must be distinctly lower than that of water, so that a large pressure difference assists efficient water diffusion from the beginning of the heating phase.
(b) Evaporation heat should be very high.
(c) The solvent must not have any effect on the insulation properties and their expected life.
(d) The solvent must be reusable for unlimited no of times however this not true practically as it is required to be topped up at regular intervals and to be changed after 3-5 years.
(e) Flash point should be above 55°C

3.5 Advantages of VPD

Advantages associated with VPD can be enumerated as follows. [4]

Prevents oxidation during drying,
Uniformity of Temperature (Heating),
Excellent Quality of Dryness,
Associated Components Drying.

A further advantage of the vapor-phase process is that dirt and dust deposits formed on live components during factory assembly are carried away by condensate during the heating stage.

4 Conclusion

It is well documented that the rate of deterioration of the paper and the breakdown strength of the insulating oil is significantly influenced by moisture contamination. Conventional drying processes have not remained efficient in terms of cycle time and effectiveness. Introduction of vacuum has improved the process largely but a lot needs to be done on the thermal engineering aspects of the moisture removal process.

In this age, when energy crisis is rampant in every sector, vapor phase drying may serve to bring down the energy consumption in moisture removal from transformer insulation by effectively reducing the cycle time. Yet, to have a greater impact on energy saving, further research is required in vapor phase drying.

References

[1] Anand Bhanpurkar, Ajay Bangar , Rajan Sharma, H.P.Tripathi. "Comparative analysis of moisture removing processes from transformer which are used to increase its efficiency." *Global Journal of Researches in Engineering* (Global Journals Inc. (USA)) 12, no. 5 (2012): 6-10.

[2] Stefan Zabeschek, Helmut Strzala. *Drying of high voltage power transformer in the feild with a mobile vapor phase drying equipment.* Ehringshausen, Germany: HEDRICH Vacuum Systems, 2007.

[3] "Transformers" by Bharat Heavy Electricals Limited.

[4] AlFanar Technical Seervices. *VAPOR PHASE DRYING PLANT.* Jubail, KSA: AlFanar Technical Seervices.

[5] Vishvas Power Engineering Services (P) Ltd., K5 MIDC, Butibori, Nagpur, Maharashtra, India