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Advance Cooling Technique of Large Power Transformer and Impacts of Cooling On the Age of Transformer

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Abstract: **The paper presents the most recent results of an advance experimental research in the area of cooling and ageing processes taking place in large power transformers in oil-paper insulation. 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 temperature increment or a mechanical failure. 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. The "Rule of 6" (based upon the Arrhenius Equation of chemical reaction time v/s temperature) can be adapted to approximate the relationship between insulation life and total operating temperature. This rule states that if a transformer's maximum operating temperature is reduced by 6°C, the thermal life of the insulation system is approximately doubled. Conversely, if the total operating temperature is raised by 6°C, the thermal life expectancy of the insulation system is reduced by one half. The goal of this discussion is to use all necessary measures to prevent the inevitable shortening of the traditionally expected life-time of 40 years in newer transformer and discussion to increase some year of transformer life.**

Keywords: **Transformer lifetime, OFAFWF cooling, insulation ageing, temperature, water coolant.**

I. INTRODUCTION

Most of the reason of frailer of a transformer or degrade electric power transformer age is failing of transformer insulation. In general, we use oil-paper insulation in a transformer, insulation mostly affected by temperature increment of winding. Transformer life expectancy at any operating temperature is not accurately known, but the information given regarding loss of insulation life at elevated temperatures is considered to be conservative and the best that can be produced from present knowledge of the subject. The effects of temperature on insulation life are being investigated continuously, and new data may affect future revisions of this guide.

1. ***Aging acceleration factor:*** For a given hottest-spot temperature, the rate at which transformer insulation aging is accelerated compared with the aging rate at a reference hottest-spot temperature. The reference hottest-spot temperature is 110 °C for 65 °C average winding rise and 95 °C for 55 °C average winding rise transformers (without thermally upgraded insulation). For hottest-spot temperatures in excess of the reference hottest-spot temperature the aging acceleration factor is greater than 1. For hottest-spot temperatures lower than the reference hottest-spot temperature, the aging acceleration factor is less than 1.

2. Supplemental cooling of existing self-cooled transformers

The load that can be carried on existing self-cooled transformers can usually be increased by adding auxiliary cooling equipment such as fans, external forced-oil coolers, or water spray equipment. The amount of additional loading varies widely, depending upon the following:

a) Design characteristics of the transformer

b) Type of cooling equipment

c) Limitations in associated equipment

No general rules can be given for such supplemental cooling, and each transformer should be considered individually.

The use of water equipment for supplemental cooling is not recommended for use in normal loading beyond nameplate rating. Appropriate precautions should be made for application of water equipment for supplemental cooling during emergency overloads. The major problem is the build up of scale on the cooling equipment due to minerals in the water. Over the long term this build-up will hinder the cooling efficiency.

The traditional transformer cooling technologies mainly involve natural air cooling, air forced cooling and water cooling. And the last two cooling methods are being used more widely due to the larger and larger capacity of transformers need in urban grid nowadays. However each cooling method above has its own shortcomings when used in urban power substations.

The only advantage of natural air cooling is that its cooler is cheap and no need any maintenance. Due to poor heat transfer coefficient of air, natural air cooling system results big volume and occupies massive pricy urban land. It is known that the higher cooler is assembled above the heat centre of the transformer, the better the cooling effect is. So when the natural air cooling system is applied in substation, it implies great oil height and heavy oil pressure to the oil tank, which leads to high cost of manufacturing and risk of oil leakage .

In order to get better cooling effect, forced air cooling with fans blowing the air is adopted. However, the fans have brought noise and high failure probability besides high heat transfer coefficient. Sometimes the cooler is installed underground in urban substation to depress the noise of the fans, but the limited space and isolated air in basement deteriorate the cooling effect of wind. The result leads to the need for more fans, which means higher failure probability is brought into the whole cooling system. Sometimes pumps are adopted to draw oil circulation to get better cooling effect, but pump has even poorer maintainability than fan.

3. ***Water coolant with water****:* The water cooling method, with the heat transfer coefficient of water achieving more than $1000 W/m^2K$, has much better cooling effect than air cooling. This system is used when water coolant with water is as a coolant medium. The high specific heat and heat conductivity of water make it a superior cooling medium and water-cooled transformer can get by with the smallest coolers.

Fig1. Image of water coolant

Coolant can be plain water; water is a very effective coolant but would not protect against sub freezing temperatures or protect against corrosion inside the engine. The use of antifreeze protects against both problems. Antifreeze not only suppresses the freezing point of your engine coolant, but provides good corrosion protection and increases the boiling point during use.

II. TEMPERATURE AFFECT ON THE LIFE OF A TRANSFORMER

Temperature is one of the prime factors that affect a transformer's life. In fact, increased temperature is the major cause of reduced transformer life. Further, the cause of most transformer failures is a breakdown of the insulation system, so anything that adversely affects the insulating properties inside the transformer reduces transformer life. Such things as overloading the transformer, moisture in the transformer, poor quality oil or insulating paper, and extreme temperatures affect the insulating properties of the transformer. Most transformers are designed to operate for a minimum of 20-30 years at the nameplate load, if properly sized, installed and maintained. Transformers loaded above the nameplate rating over an extended period of time may have reduced life expectancy.

According to IEC 60076-12, average insulation working hours for the different insulation system are calculated based on the Arrhenius equation. Every 6°C degree that the hot spot temperature of a transformer is reduce, the expected insulation life is doubled. Consider the effect of elevated temperatures on insulation. The life of insulation follows a physical relationship based on temperature, expressed by the Arrhenius's equation:

$k = Ae -Ea/RT$

(1)

In this form, the equation is not terribly useful. However, if we take the natural logarithm and rearrange the terms, it becomes a generalized expression for a straight line:

$\ln k = \ln A – (Ea/R) * (1/T)$

(2)

Since A, Ea and R are constants, this becomes a straight line with a negative slope of (Ea/R) plotted against the inverse of temperature (1/T). The practical use of this expression is from estimating the life of electrical insulation, which would be the value "k" in the Arrhenius expression. There are a wide variety of insulating materials used in switchgear equipment, but a general rule of-thumb is the age of electrical insulation is reduced by half for each rise of 6°C in insulation average temperature. The most commonly used indicator of electrical insulation age is dielectric capability, so the Arrhenius expression becomes an indicator of dielectric life.

In 1948, Dakin also made a significant advancement in defining insulation aging rate following a modification of Arrhenius' Chemical Reaction Rate Theory. According to this theory, the rate of change of a measured property can be expressed in the form of a reaction-rate constant *R* and can be expressed by:

$R = A'e^{B/T}$

(3)

Where, *A'* and *B* are empirical constants

T is the temperature in ^{0}Kelvin.

Dakin showed that all aging rate data (including Montsinger's) could fit into the Arrhenius Reaction Rate equation. This was later accepted widely by the technical community and become the foundation for determining the loss-of-insulation-life. From the reaction rate equation, the insulation life is now defined by:

$L = A\, e^{B/T}$

(4)

Where, *L* is insulation life in either per-unit (or hours)

A is a constant, derived from the insulation life at 110□C hottest-spot temp.

B is the same aging rate slope defined in equation

Some other researchers found that the doubling of velocity occurs when temperature increases from between 5°C to 10°C. Consequently today the generally adopted estimate states that an increase in temperature of 6°C doubles the velocity of ageing. Based on experience and findings, the family of standards IEC 60076-x and the standard IEC 60354, which was recently renamed to IEC 60076-7, give Guidance to maximum allowed temperatures of oil and windings so that, in the given climatic conditions and with the full load of a transformer, a transformer ought to reach a normal life-time of at least 30 years. But are such expectations firmly grounded? If we analyze the results of the latest research, the question is more than justified.

III. PRACTICALLY WORKING MODEL OF AN ONWFAF (WATER COOLANT) TRANSFORMERS

The basic purpose of a cooling system is to control the temperature of transformer winding and insulating oil. The cooling system of a natural convection cooling system rises automatically with the rising of the temperature of a transformer. The temperature of a transformer depends on the load, atmospheric condition, cooling efficiency and ambient temperature. Power losses raise the temperature of a transformer to the point whereby an equalization of cooling power with the power losses is reached. In systems with forced convection, adjustment of the cooling power of the cooling system is carried out with the thermal device which switches oil pumps and fans on in the cooling blocks. These systems usually make use of fin type coolers whose cooling power depends on the power of fans and pumps. Since it is not always necessary to have full cooling power with partial loads and low ambient temperatures, the thermal adjusts the activity of required cooling blocks.

To verify the feasibility of applying the new cooling technology in power transformer, an experimental model is designed, implemented and tested in this paper. The heater power and the air cooling area of the model are in proportional to an oil-immersed power transformer. The model contains oil tank, electric heaters and cooling system, which is internal connected and sealed, consisting of fined tubes, condenser and linking pipes, as shown in Fig2.

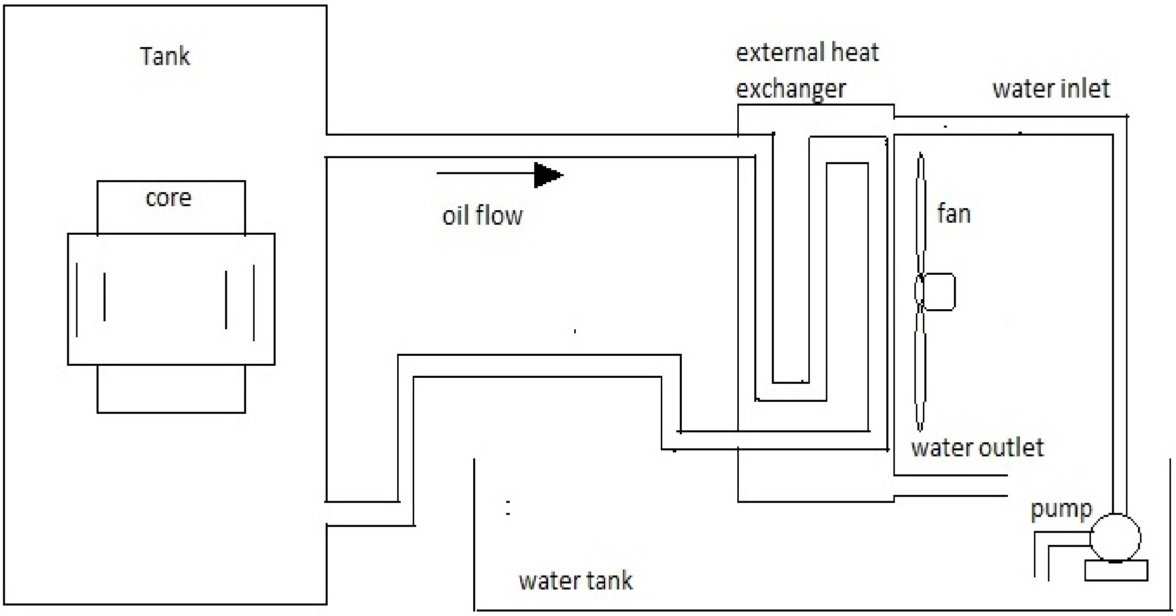

Fig2. The sketch of cooling system applied in transformer with ONWFAF (with water coolant)

1. *Cooling system parts and working:*

The cooling of a transformer depends on several factors. Transformer oil must have low viscosity as possible throughout the entire working temperature interval; here we are using fresh transformer oil. A tank as shown in fig2 filled with transformer oil up to a limited volume. An electrical coil connected to the tank that increases temperature of oil continually. Inside the tank three sensing devices are connected at different-different height to measure the temperature of oil. These devices measure the temperature of bottom oil and top oil and these sensing devices directly connected to electronics circuit, the circuit show the temperature of top oil and bottom oil of transformer tank, and temperature also measured by software. The electronic circuit connected with computer to USB port, the software show the temperature of every minute of transformer tank, and reading recoded by software of every minute.

Tank has oil pipes in which oil circulate by natural phenomena of hot oil and cold oil through these pipes oil naturally cooled.

Surround the oil pipes water with water coolant circulate with the help of water pump as shown in fig2, water cools hot oil of tank that is flowing inside the pipes. Water coolant with water filled in a water tank with a certain limit and put a pump for circulate water surround oil pipes, cold water use as a coolant for hot oil after complete the cycle hot water goes inside air forced cooling system. in air forced cooling system a fan is connected with a carburettor , now hot water comes inside the carburettor and hot water cooled by air cooling that cooled water go back to the water tank, again this process go on for maintain the temperature of hot oil.

Fig3. Practical working model of cooling system in lab

2. *Temperature range and about software:*

There are three temperature sensing units which are sense the temperature of every one second and all cooling system operate automatically at predefined temperature. Software has programmed for these temperature, it gives command to electronic circuit, in this circuit relays are connected, whenever temperature reach at predefined temperature of operation it automatically trip and next cooling device start to cooling process.

Naturally oil cooled up to 58°C ,after 58°C water pump start it continuously cool transformer oil until temperature not reach 63 °C ,after 63°C air cooling stars. After 63°C both water pump and air cooler work until temperature not decrease predefine temperature. If temperature decrease below 63°C air cooling system automatic off, if temperature decrease below 58°C water cooling system automatically off, below 58°C oil naturally cooled only.

IV. EXPERIMENT RESULT AND DISCUSSION

From table no.1 we can see that temperature of oil at every three minute, and show results of oil cooling with simultaneously three cooling techniques oil natural, water forced and air forced (ONWFAF) experiment model start at 11am at that time temperature of bottom, meddle and top 33.5°C, 33.5°C, 33.5°C respectively, after three minute at 11.03am we are seeing meddle oil temperature T2 increasing fast as compare to T1, it is because of heating coil connected at meddle, hence coil heat up meddle oil fast as compare to top oil, hence these all reading are given in red color until T1 not lead T2, in a power transformer heating of oil is not this way like with the help of heating coil, hence heating coil increase T2 continually and T1 increase but in slow manner and make a big difference between them but after some minute T1 leads T2, can see from table, at 11.24am T1=52.5C, T2=51.5.5°C it is because of natural cooling of oil. It is a property of transformer oil it cools itself by natural convection method, here natural convectional flow of hot oil is utilized for cooling. In convectional circulation of oil, the hot oil flows to the upper portion of the transformer tank and the vacant place is occupied by cold oil. This hot oil which comes to upper side will dissipate heat in the atmosphere by natural conduction, convection and radiation in air and will become cold. In this way the insulation oil in the transformer tank continually circulate when the transformer put into load. As the rate of dissipation of heat in air depends upon dissipating surface of the oil tank, it is essential to increase the effective surface area of the oil tank. Here for cooling technique we are providing electronics circuit board that trip the cooling system at predefine temperature through relay as sensing devices. In a table no.1 all results are at 11.00am T1=33.5°C, T2=33.5°C and T3=33.5 °C as heating coil plug in oil temperature increase and T1, T2, T3 increase as shown in table no.2 and oil try to cool itself by natural convection method.

TABLE-1Water level of tank before experiment = 9.6 cm, after experiment = 6.5 cm Atmosphere temperature = 39°C

Time (minute)	Temperature °C			Oil natural cooling	Water forced cooling	Air forced cooling
	T1	T2	T3			
11.00am	33.5°C	33.5°C	33.5°C	√	×	×
11.03am	35.5°C	44.5°C	33.5°C	√	×	×
11.06am	39.0°C	46.0°C	33.5°C	√	×	×
11.09am	41.5°C	48.0°C	33.5°C	√	×	×
11.12am	44.0°C	48.0°C	33.5°C	√	×	×
11.15am	47.0°C	49.5°C	33.5°C	√	×	×
11.18am	48.5°C	50.0°C	33.5°C	√	×	×
11.21am	51.0°C	51.5°C	33.5°C	√	×	×
11.24am	52.5°C	51.5°C	33.5°C	√	×	×
11.27am	56.0°C	53.0°C	34.0°C	√	×	×
11.30am	57.5°C	54.0°C	33.5°C	√	×	×
11.33am	60.0°C	54.0°C	34.0°C	√	√	×
11.36am	60.5°C	54.0°C	33.5°C	√	√	×
11.39am	62.0°C	51.5°C	33.5°C	√	√	×
11.42am	62.0°C	51.5°C	33.5°C	√	√	×
11.45am	63.5°C	53.5°C	34.5°C	√	√	√
11.48am	65.5°C	53.5°C	33.5°C	√	√	√
11.51am	67.0°C	54.0°C	33.5°C	√	√	√
11.54am	68.5°C	54.0°C	34.0°C	√	√	√
11.57am	70.0°C	54.0°C	33.5°C	√	√	√
12.00	71.5°C	53.5°C	33.5°C	√	√	√
12.03pm	73.0°C	53.5°C	33.5°C	√	√	√
12.06pm	74.0°C	54.0°C	33.5°C	√	√	√
12.09pm	76.0°C	54.0°C	34.0°C	√	√	√
12.12pm	76.0°C	54.0°C	34.0°C	√	√	√

T1= temperature of top oil

T2= temperature of meddle level oil

T3= temperature of bottom oil

In transformer cooling model we connect personal computer, in PC software install which give command to circuit board to start a new cooling. Natural cooling process continually works until temperature not reach 58°C, we can see that from table no.2 at 11.33am temperature T1=60°C, T2=54°C here temperature T1 is greater than 58°C hence now water pump start to cooling of transformer oil, it continually cool transformer oil until temperature not reach 63°C, after 63°C air fan on, and start to cool warm water which comes after cooling the hot transformer oil.

Fig4. Show table no.1 results in graphical form; in graph all readings are same as in table no.1, graph show variation of temperature T1, T2, T3 with respect to time, which varies 11am to 12.09pm. In graph variations of T1 is shown by blue line, which is top level oil temperature, at starting its values are less than T2 after some time it leads T2 and increase linearly. T2 temperature of meddle level oil its graph shown by red line and last one T3 is base oil temperature which is shown by green line.

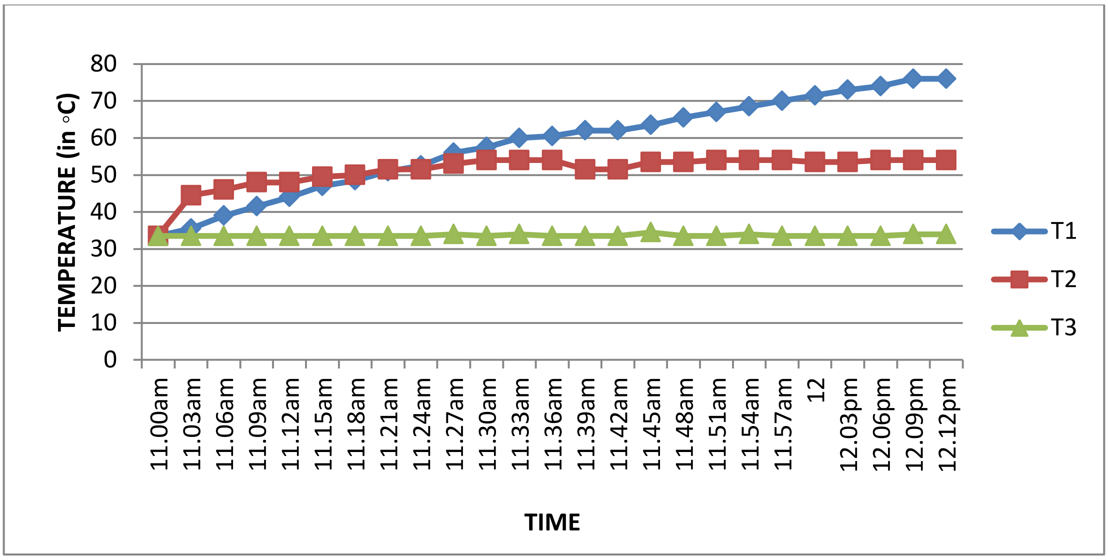

Fig4. Graph between time and temperature at ONWFAF cooling system

When experiment start we meager water level of tank that is 9.6cm and we do not mix water coolant with water and after complete experiment again we meager level of water tank and now it’s level is 6.5cm, hence large part of water vaporized in experiment, 3.1cm water has been vaporized.

TABLE-2Water level before experiment of tank = 9.6 cm, after experiment = 7.9 cm Atmosphere temperature = 39.5°C

Time (minute)	Temperature °C			Oil natural cooling	Water forced cooling (with water coolant)	Air forced cooling
	T1	T2	T3			
11.00am	31.5°C	35.0°C	32.0°C	√	×	×
11.03am	35.0°C	39.0°C	32.0°C	√	×	×
11.06am	38.0°C	39.5°C	32.0°C	√	×	×
11.09am	40.0°C	41.5°C	32.0°C	√	×	×
11.12am	44.0°C	42.0°C	32.0°C	√	×	×
11.15am	46.0°C	44.0°C	32.0°C	√	×	×
11.18am	48.0°C	44.5°C	31.5°C	√	×	×
11.21am	50.0°C	44.0°C	31.5°C	√	×	×
11.24am	51.5°C	45.5°C	31.5°C	√	×	×
11.27am	55.0°C	45.5°C	32.0°C	√	×	×
11.30am	56.5°C	45.0°C	32.0°C	√	×	×
11.33am	59.0°C	45.0°C	31.5°C	√	√	×
11.36am	60.0°C	45.5°C	31.5°C	√	√	×
11.39am	61.0°C	46.0°C	32.0°C	√	√	×
11.42am	62.0°C	46.0°C	32.0°C	√	√	×
11.45am	63.0°C	44.0°C	32.0°C	√	√	×
11.48am	64.5°C	44.5°C	32.0°C	√	√	√
11.51am	66.5°C	44.5°C	32.0°C	√	√	√
11.54am	68.0°C	46.0°C	32.0°C	√	√	√
11.57am	70.0°C	46.0°C	32.5°C	√	√	√
12.00	71.5°C	46.0°C	32.0°C	√	√	√
12.03pm	72.5°C	46.0°C	32.0°C	√	√	√
12.06pm	74.0°C	47.0°C	32.0°C	√	√	√
12.08pm	75.0°C	47.0°C	32.0°C	√	√	√
12.09pm	75.0°C	47.0°C	32.5°C	√	√	√
12.10pm	75.0°C	47.0°C	32.0°C	√	√	√
12.11pm	76.0°C	47.0°C	32.0°C	√	√	√
12.12pm	76.0°C	47.0°C	32.0°C	√	√	√
12.13pm	76.0°C	47.0°C	32.0°C	√	√	√

From table no.1 and fig4, we can see that when we are providing water cooling and air cooling, it takes 69 minute to reach at temperature at 76°C. We can also see that at 76°C temperature, continually four reading of 76°C are given by software, hence it is also a stabilized temperature of system.

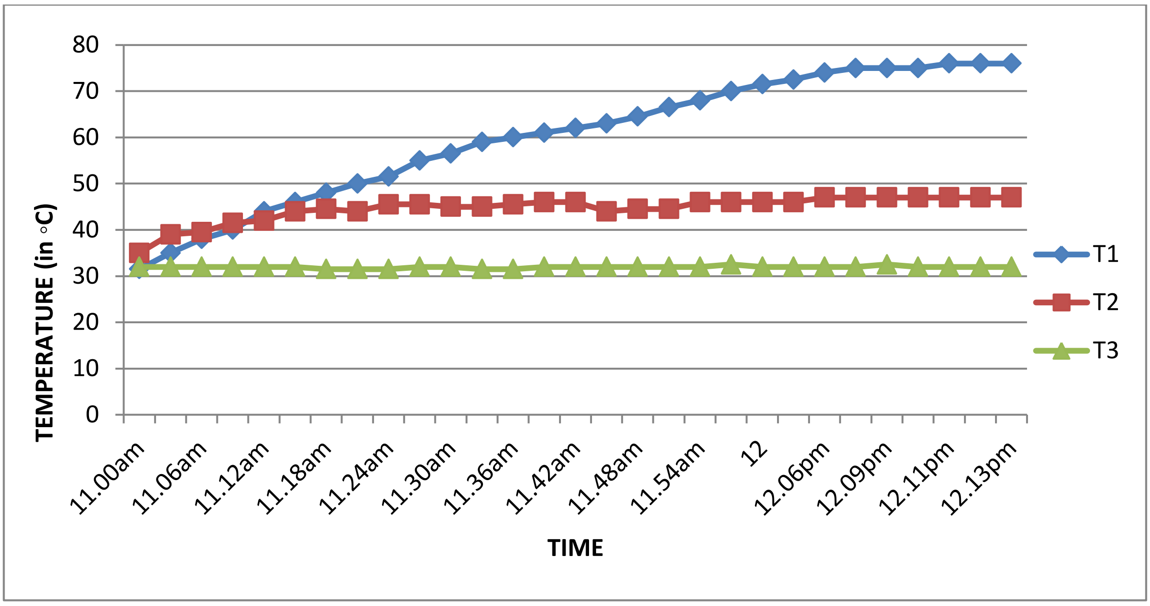

Fig. 5 Graph between time and temperature at ONWFAF (water with water coolant) cooling system

Here in table no.2 all results are shown when water coolant mixed with water, in table no.2 all results are different because all results are of deferent day and at deferent atmosphere, hare room temperature is 39.5°C. In table 2 experiment start at 11:00am, at that time temperature T1, T2, T3 are 31.5°C, 35.0°C, 32.0°C respectively, these temperatures increase as time increase as show in table 2 till 58.0°C natural oil work to cool transformer insulation, after 58.0°C water pump start to cool transformer oil, now water is not only cooling substance to cool transformer oil here we are using water coolant with water. Till 63.0°C water pump work and then after air force cooling start as shown in table 2, after 63.0°C both water pump and air fan work together to cool transformer oil. Fig 5 is representation of experimental data in form of graph, in this graph T1, T2, T3 varies with respect to time, where T1 is represented by blue line, T2 represented by red line and T3 by green line.

Fig 4 show variation of temperature with respect to time, we can observe that from graph, T1 take 69 minute to reach at 76.0°C temperature, which is establish temperature of model and from table 1 we can also see that continue four readings shown of 76.0°C temperature. Fig 5 show results of variation of temperature with respect to time, when water cooling done with water coolant in this graph we see that to reach 76.0°C temperature experiment model take 71 minutes, before reach at 76.0°C temperature it gives three reading of 75.0°C temperature and then after it show three reading of 76.0°C temperature, hence 75.0°C temperature is also a establish temperature of model, when cooling done with water coolant. It is clear from results water coolant give better result as compare to only water cooling technique. To reach at 76.0°C temperature it take 2 minute extra as compare to table 1 data, these two minute are big difference between two result to justified the result.

1. *Effect of water coolant on evaporation of water:*

From table 1 and table 2 we can compare the results of both cooling techniques, without water coolant and with water coolant, in both experiment water level is same that is 9.6cm, in table 1 , water tank contain only water and that is only water level and after completed experiment now water level is 6.5cm. In table 2 starting water level same as table 1 but here water tank contain water coolant with water, hence it is level of both water coolant and water and after completed experiment water level is 7.9cm. From comparison of both table results, we can see that water coolant try to low vaporize as compare to water. From both result we can see that water difference from both results is 1.4cm, it show the effect of coolant on vaporization process of water.

Area of land where little precipitation occurs and consequently living conditions are hostile for plant and animal life, there may be lack of water sources or underground sources of water, here cost of water is very high and not available easily, deserts as a area where more water is lost by evapotranspiration. As an example, Tucson, Arizona receives about 300mm

(12 in) of rain per year, however about 2500 mm (98 in) of water could evaporate over the course of a year. In other words, about eight times more water could evaporate from the region than actually fall as rain. In India most of areas of Uttar Pradesh, Rajsthan and Bihar get very high temperature in summer region, about 45^{0}C temperature reach in summer region in India. In India water availability is better than desert areas and also at low price, in India water average price about 3-4 rupees per liter or less than 3 rupees or free of cost in most of areas of India. Arab countries Saudi Arabia, Iraq, Oman and all host space countries transport water or treat water through water treatment plant, usually the average price of water in these countries is $1–$2 per cubic meter or in India currency 8 to 9 rupees per liter, it is also a big difference between price of water. In gulf area the price of water coolant is similar to water, $2–$5 per ton of water coolant. It is clear from results of both tables coolant mix water evaporation is less as compare to only water, so it is best use of coolant for cooling technique of transformer evaporation wise.

In India most of the transformer are in last stage, there is need of replacement of transformer, if we go for replacement of transformer it would be very costly, because of the price of a single transformer is very high, mostly transformer cooling technique in India is natural and air forced cooling, and we know that through efficient cooling the life of transformer can increase. It is better option than replace of transformer is to cooling technique improve and increase working year of old transformer.

TABLE-3

1st DAY READING(NO COOLING)		2nd DAY READING(ONWFAF COOLING)		3rd DAY READING(ONWFAF WITH WATER COOLANT COOING)	
STABILISE TIME (minute)	TEMPERATURE RANGE OF T1	STABILISE TIME (minute)	TEMPERATURE RANGE OF T1	STABILISE TIME (minute)	TEMPERATURE RANGE OF T1
6 M	40.0°C-45.0°C	6 M	40.0°C-45.0°C	6 M	40.0°C-45.0°C
6 M	45.0°C-50.0°C	6 M	45.0°C-50.0°C	6 M	45.0°C-50.0°C
5 M	50.0°C-55.0°C	5 M	50.0°C-55.0°C	5 M	50.0°C-55.0°C
6 M	55.0°C-60.0°C	6 M	55.0°C-60.0°C	6 M	55.0°C-60.0°C
10 M	60.0°C-65.0°C	10 M	60.0°C-65.0°C	10 M	60.0°C-65.0°C
5 M	65.0°C-70.0°C	5 M	65.0°C-70.0°C	5 M	65.0°C-70.0°C
9 M	70.0°C-75.0°C	11 M	70.0°C-75.0°C	12 M	70.0°C-75.0°C
2 M	75.0°C-77.0°C	4 M	75.0°C-77.0°C	5 M	75.0°C-77.0°C

Table no. 3 show stabilize time at various temperature range at various cooling technique process, at starting all three day cooling temperature stabilize time is approximately same but changes in results near to 65^{0}C can see in table 3, here we can see that the stabilize times of 2nd day and 3rd day are nearly same but the 1st day reading is different as compare to 2nd day and 3rd.

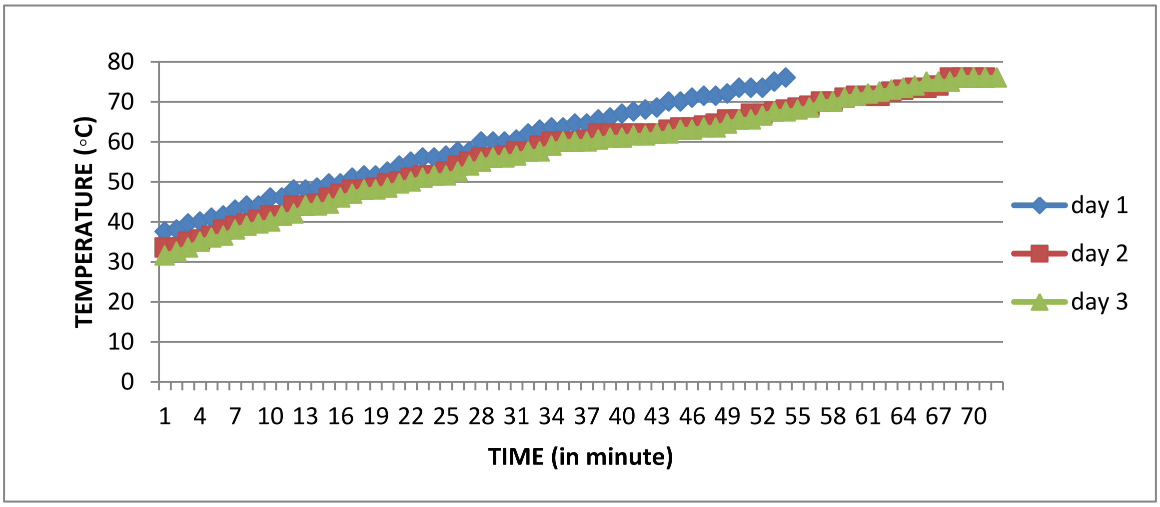

Fig6. Temperature variation T1 at different day per minute

The result of temperature T1 of top level oil of 1st day, 2nd day and 3rd day variation with respect to each minute is shown n fig 6 through a graph blue line show that when oil cool through naturally only, this line is always above the other two line which show that without cooling temperature of top oil T1 is always greater than when we provide cooling in the system. Temperature T1 vary in day 2 and day 3 compatibly same because of day 2 water cooling provide and day 3 water cooling with water coolant is provide. But change in 3rd day reading is 2 minute leading compare to 2nd day reading because of water coolant.

2. *Increment of-Life Calculation, IEEE Method:*

In the IEEE loading guide (C57.91-1995), aging equations have been changed to accommodate the recent results. There is no longer the absolute life value. Instead, “the relative aging rate” and “per-unit life” have been introduced. The per-unit life (*L*) for 65^{O}C average winding temperature rise transformer is defined by (5). For, *THS* = 110^{o}C , the perunit life = 1.00.

$$L = 9.80 \text{ x } 10^{-18} e^{[\frac{15000}{THS+273}]} \tag{5}$$

The equation for the Relative Aging Factor (*FAA*) can be derived from:

$$FAA = e^{[39.164 - \frac{15000}{THS+273}]} \tag{6}$$

The value of *FAA* is greater than 1, when the hottest-spot temperature is greater than 110^{O}C, suggesting loss-of-life (from normal aging) and less than 1 when hottest-spot temperature is less than 110^{o}C, meaning life extension. If we put the value of THS is 116^{o}C in the place of 110^{o}C , means increasing 6^{o}C temperature, than the value of life or L will be .5. It means if we increase 6^{o}C temperature life becomes half.

From the result of this paper we are able reduce THS temperature about 2^{o}C then put the THS value 108^{O}C in place of 110^{o}C

In equation (5).

$$L = 9.80 \text{ x } 10^{-18} e^{[\frac{15000}{108+273}]} \tag{7}$$

$$= 1.229$$

Now increase life can seen in per unit

$$1.229-1.000 = .229 \tag{8}$$

Let the average life of transformer is 40 year than according to result is the life of transformer in years is .229×40 = 9.16, hence the increased life of transformer is about 9 or 10 years.

Based on result it is clear that if water coolant mix with water and use as a cooling medium in a power transformer, it increase the stabilize temperature of oil insulation. All result are shown on the basis of lab experiment model, in this model surface is low to cool oil with water, hence if we use this cooling technique in large power transformer, this cooling technique show more better result as compare to lab experiment model. A power transformer size is big and its cost is also very high hence we try to maintain transformer for a long duration, mainly the average life of transformer is 40 year, a transformer in service has losses which are transformed as heat to be dissipated and thus leading to a temperature rise in the transformer. In order not to allow the temperature to rise above the permissible level, a suitable cooling method should be considered and adopted. The main region behind to reduce life of transformer is deduction of insulation of transformer, a general rule of-thumb is the age of electrical insulation is reduced by half for each rise of 6°C in insulation average temperature.

The results shown in table 1 is that the establish temperature of transformer is 76.0°C, and table no.2 show the establish temperature of model transformer is 75.0°C, it is clear that there is 1.0°C difference between two reading, and if we go to near the 110^{o}C temperature range with a another better model it defiantly show 2^{o}C temperature difference. If electrical insulation life is reduced by half for each rise of 6°C in insulation average temperature, from result we can reduce allow temperature 2.0°C with the help of cooling technique, hence now if new advance cooling technique use than life of transformer can be increase about 9 to 10 year more from average life.

IV. CONCLUSION

In this paper two cooling techniques results compared from table no.1 and table no.2, table no.1 show results when three cooling (ONWFAF) system work together and table no.2 show results when water coolant mix-up with water, from two tables we observe that water coolant try to cool water and try to reduce evaporation of water and try to maintain low temperature of water and transformer oil. From table no.2 we see that when we mix coolant with water the stabilize temperature also reduce. Water coolant affect on the evaporation of water, we have been seen from result of evaporation from table 1 and table 2, hence in hotter area this cooling technique show more better result. In India these cooling techniques use to increase the life of last stages transformer. In summary, the new cooling system of transformer could solve the cooling and noise nuisance problem well simultaneously, fulfils the demands of modern power transformer. Thus this novel new cooling technology is quite valuable and would be used widely in future. Next, a transformer prototype with the new coolant cooling system will be fabricated, tested and tentative operated. These three cooling work together to control the transformer winding temperature and to increase the life of oil-paper insulation and power transformer. With optimizing cooling it is possible to lower the life cycle costs (LCC) of a transformer with normal reliability of operation.

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