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Design Changes to Improve Transformers Performance

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Abstract - Transformers are vital components of electrical system equipment for efficient and reliable operation of electric power network. In any Industry, electrical Transformers plays an important role. In AC power transmission and distribution system, Transformer is the heart for either step up or step down the voltage to the desired level. Transformers are some of the most efficient electrical 'machines', with some large units able to transfer 99.75% of their input power to their output. Transformers come in a range of sizes from a thumbnail-sized coupling transformer hidden inside a stage microphone to huge units weighing hundreds of tons used to interconnect portions of national power grids. This paper describes some design changes to improve its performance.

Key Words: Transformer, Design, Core, Winding, Insulation, Oil, SF6 Gas, GIS, transposition.

1. INTRODUCTION

Electric Transformers have become an essential part of human kind's everyday life. It supplies electricity to both domestic and industrial units. Even though it is the top rated efficient equipment in electrical system, some design aspects are proposed in manufacturing stage to improve its performance further. The main parts in transformer are belonging mechanical, electrical and dielectrics. To check the process stages, a nearby transformer manufacturing unit is visited and studied the process in depth and some process time visuals are taken. After a detailed study some changes are proposed in subsequent paragraphs.

2. TYPES OF TRANSFORMERS

There are wide variety of transformers being manufactured to cater the needs of various users. They are like power & distribution transformers, current and voltage transformer, rectifier transformer, locomotive transformer, welding transformer, tiny converter transformers like mobile chargers, audio transformer and so on. Any kind of transformer is mainly used to increase or lower the alternating current. It also helps in regulation of current and hence, improves the overall system efficiency. The main components in any transformer are the core, the winding and the coolant and off course the final fitment with a tank and other accessories like conservator, radiator, explosion vent etc. A sample assembly is shown in fig. 1.

Fig -1: Assembly unit

2. STAGES OF MANUFACTURING

The various stages in producing a transformer are Design, Winding, Core Building, Assembly, Tanking and Testing which is shown in the flow chart-1.

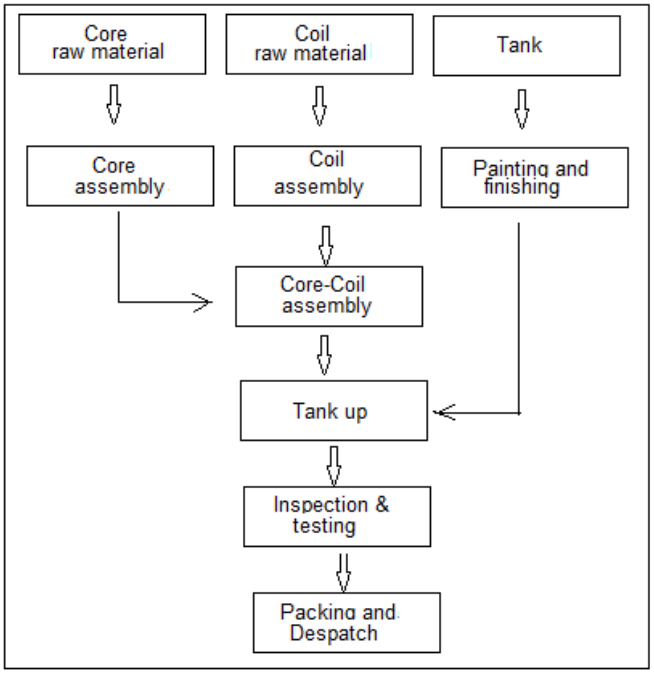

Chart -1: Process flow chart

2.1 CORE

Core is generally made with with CRGO silicon Steel (Cold Rolled Grain Oriented) sheets in the range of 0.27 to 0.35 thickness as shown in fig. 2 and 3. To reduce the Iron loss, the thinnest (0.27 mm) plate to be used. This will ensure lower core loss with conventional CRGO silicon steel.

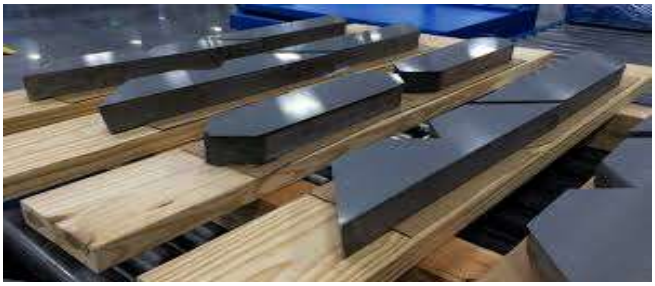

Fig -2: CRGO lamination

Fig -3: CRGO Steel core limb formation

The final core formation is shown in fig. 4.

Fig -4: CRGO steel core

Now the latest is Amorphous metal, shown in fig. 5, which is an alloy with a non crystalline structure and non-anisotropic properties, originated from a crystalline structure. Since there are no crystalline grain boundaries to prevent motion of magnetic domain walls, it gives out excellent magnetic properties like high permeability and low iron loss while having a high-saturation magnetic flux density of order of 1.8 tesla. The losses in this core are very small and in the order of 20% silicon steel. Hence Amorphous core metal can be used as an improvement. Also Glass- fiber bands are to be used to bind the core into asingle unit which helps in stabilising its performance. For larger transformers. it is preferred to use five legged core instead of three legged core. This will reduce the overall height of unit and best fit for thickly populated city urban areas.

Fig -5: Amorphous core

2.2 WINDING

The main Type of Windings are Cross Over(used for HV with a rating of 11 KV or higher voltages), Spiral (for LV with a rating of 433 Volts), Disc(used when the input supply is high with same rating as Cross over and Helical (used for LV with higher input supply) types. Transposed conductors, as shown in fig. 6, are to be used which make the continuous winding work reasonably easy in fastest time and also reduces eddy current losses in the winding.

Fig -6: Continuously transposed conductors

The insulation of the oil-immersed transformer is basically a composite insulation structure consisting of insulation oil and oil-impregnated paper. For covering with insulation, there are of four types viz; Double paper covering (DPC), Triple paper covering (TPC), Quadruple paper covering (QPC) and Multiple paper covering (MPC) and of course enamel Covering is used for less than 1.2mm as shown in fig. 7.

Fig -7: Coil Insulation

2.3 COOLANT

The insulation oil used as on date is a grade-B mineral oil having good insulating and cooling properties. But the problems faced are flammability and reactions with atmospheric oxygen and water or moisture. Some improvements are being suggested to use other liquids like Vegetable oils (like coconut and soybean oils) which have excellent cooling and insulation properties as listed in table-1.

Table -1: Various oils

Property	Unit	Existing mineral (crude) oil	Vegetable oil (soybean & coconut)
Viscosity at 40°C	mm^2/s	7.6	39.20
Density, 20°C	kg/dm^3	0.877	0.91
Breakdown voltage (2.5 mm)	kV	40–60	81
Acidity	Mg KOH/g	0:01	0.05
Tan delta (90°C and 50 Hz)	—	0.001	0.013
Flash point	°C	144	332
Pour point	°C	-30 to -60	-19 to -33
Moisture content	mg/kg	< 20	100

It has been found from the world oil market, that most of the physical properties such as moisture content, flash point, dielectric strength, etc. of vegetable insulating oils are within the recommended level. Research studies are on to bring the viscosity to recommended level by doing some chemical modifications. At present some companies like Lankan transformers are using coconut oil as insulating liquid in their transformers by reducing the pour point of coconut oil to a considerable level by adding styrenated phenol. To improve the cooling , the oil flow shall be made zigzag diverted flow with barriers instead of vertical directed duct flow as shown in fig. 8.. This will reduce the temperature rise with proper heat dissipation.

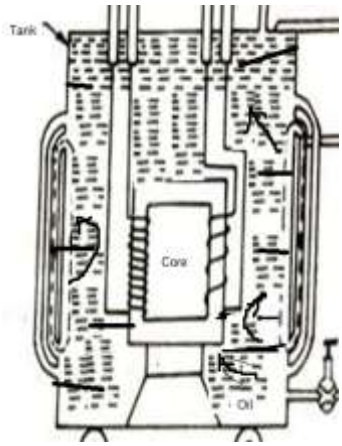

Fig -8: Oil flow ducting

Also in place of mineral, Gases like Sulphur-hexa fluoride (SF6), the best electro-negative gas can be used having best cooling and insulating properties. There are several advantages of using gas in transformers like non- flammable, which gives significant space savings and allows the transformers to be installed in underground installations, which is practically not possible with oil-filled transformers, especially after the bad incident took place at Uphaar cinema theatre in Delhi in 1997. The SF6 causes no pressure increase in the case of faults, which reduces the possibility of rupture of the container and damage to the plant and can be directly coupled to Gas Insulated Sub-stations(GIS).

2.4 OTHER ACCESSORIES

There are certain accessories like conservator, radiators and protective equipment which can also have improved versions to enhance the performance of transformer. Built in Surge arresters, as shown in fig. 9, are suggested instead of going for separate Surge arrestor to protect against high voltage surges due to lightnings and transient switching's.

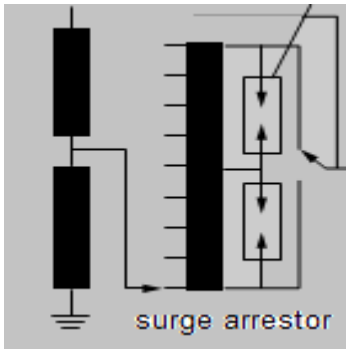

Fig -9: Surge arrestor

To reduce the noise due to magneto-striction, core corner sheet jointing can be done as step-lap from the conventional bat-lap which also reduces the no-load loss. Vacuum switch type on-load tap-changers, as shown in fig. 10, can be used in place of conventional oil immersed tap changers which greatly reduces the wear and tear.

Fig -10 Vacuum type tap changer(ABB)

3.0 CORE-COIL ASSEMBLY

The completed core-coil assembly is shown in fig. 11.

Fig -11 Core assembly

For better Insulation resistance and polarization index values, it is preferred to keep it Oven for 24 hours, as shown in fig. 12, instead of other conventional heating methods

Fig -12 Core assembly in Oven

After successful drying it goes for tanking and other accessories fixing as shown in fig. 13.

Fig -13 Tanking and accessories fixing

4.0 TESTING

Tests conducted as Indian standard, IS-2016 includes Insulation Resistance (IR) Values, ratio te4st, Vector Group Test, Winding Resistance Test, Open Circuit Test, Short Circuit Test, Separate Source Voltage Test (SSVT), Induced Over Voltage Test (IOVT) and Magnetic Balance Test as in fig. 14.

Fig -14 Testing

5.0. DISPATCH

After acceptance of tests, it will be ready for in shop floor as shown in fig. 15.

Fig -15 Testing

6.0 COCLUSION

Transformer industry is continuously changing with new design techniques and manufacturing methods to improve its performance with a mention of environmental protection by reducing noise and pollution levels and meets the expectations of customers. In this paper an attempt has been to highlight the existing practices with an industry process example.

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