Conference on

Modern Technology trends in Power Transformers including OLTC, Bushings etc .

27-28 February 2019

CBIP Conference Hall, New Delhi

(Under the aegis of CIGRE NSC A2 on Transformers & A3 on HV Equipments)

Modern Trends in Upper End of Windings and Lead Exit Insulation Technology of HV Power Transformers , a Case study

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ENPAY Transformer Components

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Abstract

Large HV power transformers at critical units in the transmission grid are strategically important components and their failure is a very costly event. The effects of short circuit currents in network are tremendous for windings in a transformer. The reliability of them is vital for the safe and stable operation of whole power infrastructure. The insulation of the winding technology and material quality have an important role for it.

The upper end and lead exits with bushings of the HV windings of large power transformers are very sensitive parts. Especially, the connecting and sealing parts need high attention and experience. Leads can be in top or in the middle of HV winding. Both of parts require advanced insulation materials and design tools. Finite Element Method (FEM) 2D and 3D model can find the best design solution. The geometries of the structures should be arranged to optimize the field stress distribution. For subdividing large oil gaps into smaller oil gaps; molded pressboard insulation barriers are used. The barriers can obtain the ‘field conform’ structure. In state of barrier system to use thick wrapped thin crepe paper has big disadvantages.

And there is a case study for the renewing of the HV Winding upper end insulation and with drip-proof seals, bellows and lead exit parts from a defect large power transformer, 400 kV, 125 MVA.

Keywords: Upper end insulation, lead exit, barrier system, partial discharge

Introduction

New worldwide target for the life time of power transformers is more than 50 years under proper conditions. The short circuit in the network and leakage humidity entrance in the transformer are the important cause of trouble for transformer. According to various studies, the life of transformers is limited to the life of its solid insulation. A lot of diagnostic techniques are used to determine the condition of that. Main problem is breakdown of insulation materials and components which are caused by the aging earlier, the more paper in active part, the sooner aging occurs (1). The upper end and lead exits of the HV-UHV windings are very risky parts. In the past in a basic experiment, the differences between molded pressboard barrier and full wrapped crepe paper insulations were reported. Dielectric strength of the oil gaps can be considerably increased with pressboard barriers compared with paper wrapping (1), (2). Generally barrier systems consist of pressboard cylinders, clamping rings, spacers, handmade wet molded parts, like snouts, angle rings, caps etc. (3).The winding ends are covered by metalized and rounded grading rings or shielding electrodes.

Application of Pressboard in Power Transformer

In insulation design, as a fundamental criteria is taken field stress distribution between oil impregnated solid insulations. In AC transformers this stress is distributed in accordance with the permittivity of insulating materials and the geometry. Degree of polymerization should be in high value for long life transformer. Metal particles in pressboard directly contaminate oil and winding insulation. To checking the impurity of pressboard with chemical test is very easy. Furthermore the insulation arrangement is constituted according to the design curves (4). The crucial usage of pressboard in transformers is subdivision of the wide oil gaps into smaller oil gaps. It has pure cellulose fibers that increase the oil strength and provide a higher safety margin.

In the solid insulation system of the ends of windings; angle rings/caps, snouts, clamping rings, spacers, strips, shield rings, lead exit connection are used, see in Figure 1. The design of that portion and dimension of parts can be determined with finite element method (FEM) program. The stress analysis of the oil gaps in modified design with safety margins is receivable from this program.

High field strength is created at the exposed edges of the winding ends below yokes. Therefore the winding ends must be covered with special shielded rings which are made better from polyester laminated pressboard.

During the short circuit forces tend to compress the windings. The design of this portion must be so that the forces distribute on the clamping rings equally. The thickness, the mechanical and insulation quality of the clamping rings must be sufficiently (5). In UHV transformer and in the areas of higher field strengths HV transformers should use polyester laminated pressboards generally. At the end we can say that, the mechanical role of pressboard is to support windings during short circuits, high voltage leads, auxiliary equipment, to maintain dielectric clearances, (6).

Figure1.Insulation parts of HV transformer

The End Insulations and Barrier Systems

The end insulations are that of the winding ends from each other and winding to yoke. The electric field at the winding edges and in lead area zone is quite non homogenous. The end insulation of the windings is designed to meet this requirement (7). For the optimal of the oil circulation in the windings and to have a high electric strength in the both end of the windings the barriers must have effective design. The barriers increase especially the dielectric strength of the oil gaps by subdividing the gaps into narrower sub-gaps. In this way the same voltage can be insulated over a shorter distance (8).The upper end of the windings is more complicated than under end. The clamping rings and the shielding rings are in upper side. In some type of transformers the lead exits are also in the upper side like our case. In order to optimize the thickness of clamping rings and to have the Permissible limits of design and safety margins calculated for oil gaps FEM 2D-3D methods can be used,(9).

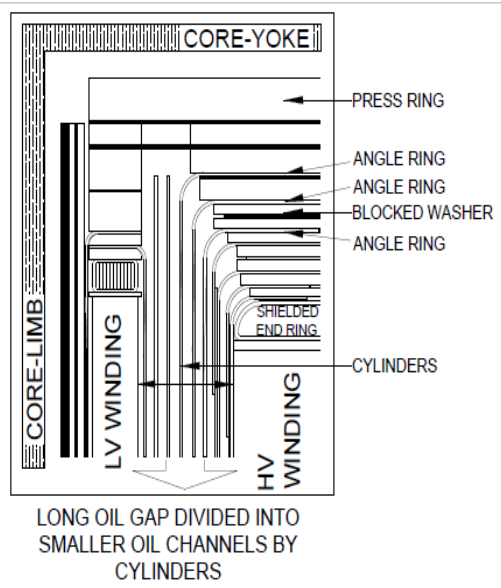

Figure2. Schematical barrier system at upper end of transformer winding

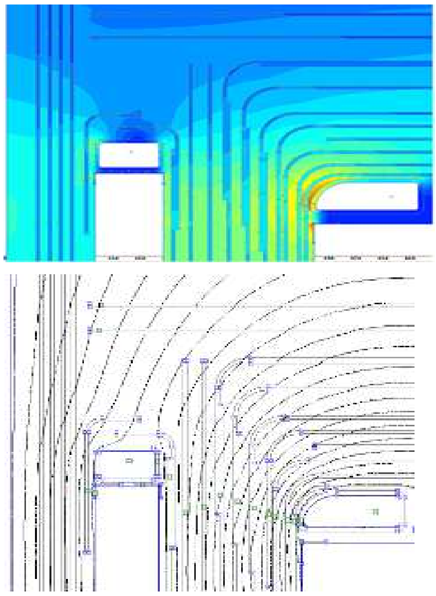

Figure3. Simulation and Voltage stress in TAP zone

Lead Exits

The lead exits are one of the most important part of transformer, consisting of metal pipe covered with wet molded cellulose and multiple pressboard barrier pipes, with vertical and horizontal supports, optimized design (10). Lead exits connect HV winding end in middle or upper end with the bottom of the bushing in an electrode (shield). Instate of molded cellulose and multiple pressboard barrier pipes to use fully wrapped paper have disadvantages. Simulation studies have presented in (1). Different type of lead exits are seen in Figure 4.The corner of the lead exit should be investigated separately due to their structural difference, see Figure 6. The type of middle exit constitutes a safe volume surrounding high voltage winding with less field stress to connect regulating winding to top changer (11) Figure 5.

Figure4. Different type of lead exit designs for different voltages, from mid or upper of HV windings

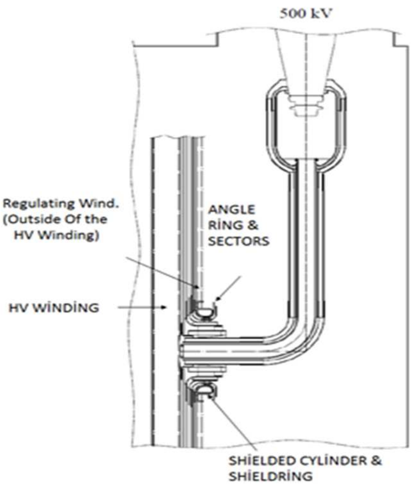

Figure5. Middle exit solution for aut side regulatin winding

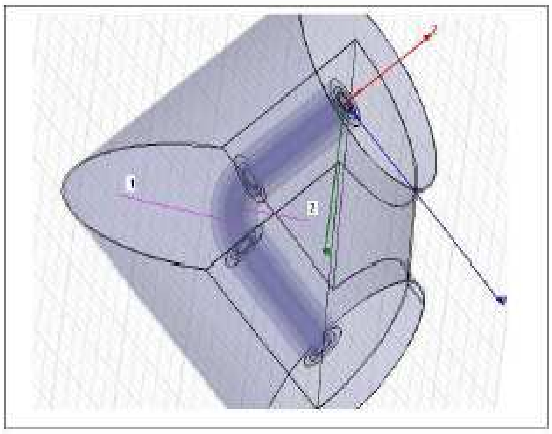

Figure6. FEM-3D model, for corner of lead exit

Electrodes (Bushing Shields)

As a part of lead exit, the screening electrodes cover the connection of winding end and the bushing. The metal surfaces of electrodes must be very smooth and brightly. The rough surfaces (with burr) can deform the field and insulation. Best production technology for that is screening.

The surface of electrodes must be complete insulated. Insulation can be up to 110 kV with epoxy powder and in higher voltages must be with molded press board, Figure 7- 8. The insulation with thin crepe or craft paper wrapping can have problems, it is not recommended (1).

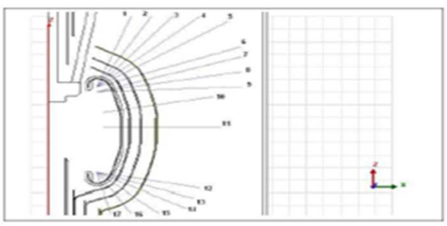

Figure7. Field plot of electrodes

Figure8. Different type of electrodes acc.to differed voltages

Case Study

General Information

Successful operations and life management of power transformers are dependent on consequent surveillance and periodical condition assessment, followed by required maintenance. Any defect or failure investigations must start with a **design**, **production quality review** and **operating conditions.**

3 Ph. / 10, 5 kV/400 kV/125 MVA, Generator Transformer was in operation for 30 years. The upper insulation of HV windings, Lead exit part and the bushing faulted completely, which is shown in the pictures, figure 9-10. Major reason of insulation components breakdown was partial discharge (PD). In HV power transformers PD may occur due to over voltage, overheating, particles in the oil, deterioration of materials, loose connection, etc. (12), (15). Very often high moisture content in insulation can cause PD, significant reduction in dielectric strength, accelerated aging of cellulose. Monitoring and detection of PD is important task to keep the transformer in healthy condition. To prevent the ageing and moisture effect on the breakdown strength of insulation parts it is necessary to aim to steps. With the several diagnostics techniques can be estimate, moisture of oil, dissolved gas analysis (DGA), furans, degree of de polymerization (DP), polarization index and power factor.

The main ageing factors are: moisture, air and oxygen, temperature, electrical and mechanical stress, insulation contamination. The rate of aging depends greatly on the temperature and the water content in the insulation. With damp insulation and high operating temperatures can age transformer in very short time. To mitigate the ageing process of the cellulose insulation in the transformer; the following steps can be used: Due to processing the oil removing the particles, moisture, gasses, acids, reset the furan levels, drying the transformer and removing moisture from solid insulation.

The detailed inspection findings, designing and refurbishment activity

The transformer developed one time some fault and windings were replaced, HV windings and insulation parts were renewed, and put in operation some years ago. Some after years from this repairing is second time was again a trouble (13).

We concentrate here to study and inspect the insulating parts and specially lead exit. Because the design of Lead exit must be changed and new lead exit must be produced, after dismantling of the pieces it was seen all of them was burn, Figure 9-10. The faulted old version was bellows type and with drip proof seal (14). Probable the sealing and connecting part was loose. End assembly of Transformer must check very carefully. The bellows was burned totally. Due to some leakage from drip proof seal and bellows comes humidity to inside. High water content in paper may result in bubbling, the formation of free water and an increased risk dielectric breakdown. Particularly the connecting and sealing part need high attention and experience. According to the report of engineers in grid, bellows type was not preferable for new version. It is seen that the complete upper end insulations of HV windings with Lead exits were faulted, (15). We illustrate here in Figure 9-10 the damaged upper insulation parts and the lead exits in detail, (16-17).

Figure9. Burned bellows and upper leads of HV winding

Figure10. Burned snouts, electrodes, bellows

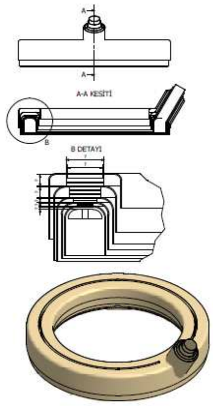

Figure11. New design of upper side and lead parts

The Bushings were also faulted and changed with new units (18). In some places subjected to a low electrical stress may have inherently high dielectric losses. These losses can mask problems in the main oil barrier insulation space. It is seen on all faulted insulation parts are occurred by the creeping discharge on the surface and carbonized traces (19).

The new design of lead exit started to analyze the electrical fields. The product design is made according field evaluation, Figure 12-13.

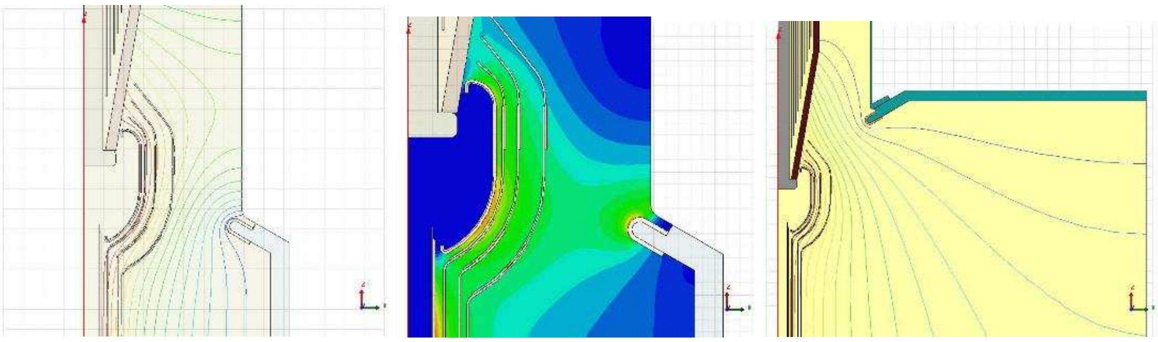

Figure12. Electrical field analyzing of electrode to tank

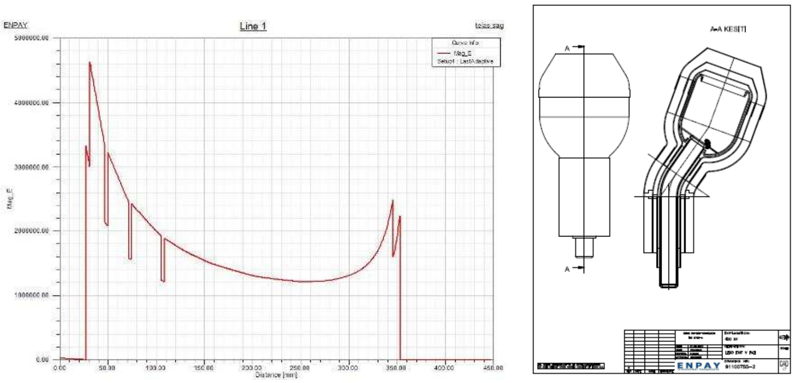

Figure13. Field curves and design of the lead exit

Figure14. X- ray lab.

Purity of insulations is the most important point. With high modern and precise X-RAY inspection system critical parts are kept under control against any unexpected impurities and inhomogeneous permittivity values. This kind of controlling is used at especially for development new design UHV transformer insulation components. During using of wet mold some air pocked or metal particle can stay in product. This is a state- of- the art method for inspection of purity, Figure 14.

Figure15.Assambling of new upper end insulation parts

Figure 16. renewed connecting cables and upper insulation part, finished active part of transformer

The Figure 15-16 shows the end montage of the new parts. After finishing the repairing and measurement of transformer, it was putted in operation without any problem.

Knowledge of transformer condition is essential for lowering the total cost of ownership (20), (21).

Conclusions

Cigre statistic shows that 50 % of major failures occur in the windings. The life of transformers is limited to the life of its solid insulation. The upper end and lead exit of HV windings are very risky parts. FEM 2D and 3D models can find best design solution. The barriers can obtain the ‘field conform’ structure.

The more paper in active part, the sooner aging occurs. Due to its hygroscopic nature paper can carry a lot of moisture.

Barrier system is consisting of pressboard cylinders, clamping rings, shield rings, spacers, strips, angle rings, wet molded snouts and pipes.

The lead exit is consisting of metal tube covered with wet molded cellulose and pressboard barriers, which connect HV windings with the bushing in an electrode. It must be done a field analyzing with FEM program before design of lead exit.

The case study gives information how to repair a 420 kV. 125 MVA power Transformer. Their upper part of insulation, lead exit and bushing was completely destroyed. All the HV winding upper part of insulations were renewed. The lead exit type was changed, because the old type was bellows type with drip proof, which was burned completely, due to leakage from sealing and from loose connecting part.

Acknowledgement

The author is thankful to provide the information and pictures of defected transformer by colleagues at ENPAY.

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