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VII INTERNATIONAL SCIENTIFIC AND TECHNICAL CONFERENCE
«LARGE POWER TRANSFORMERS and DIAGNOSTICS SYSTEMS»

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Technical Assesment of Lead Exit and Design Process

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Technical Assesment of Lead Exit and Design Process

In today's world, with the increasing demand for power it has become more essential to transmit higher and higher MW power from the generating station to the load centers. The transmission losses reduce with higher voltages. With availability of appropriate materials and optimized manufacturing practices, it is now possible to have transformers of voltage ratings up to 1200 KV. This voltage range requires very advanced insulation materials and insulation design tools. One of the most important components that are produced from insulation materials are the lead exits up to 1200 kV.

INTRODUCTION

The general knowledge about transformer Insulation System Design is based on the use of cellulose in insulations which is basicly used in mineral oil. For more than one hundred years, transformer design and manufacturing methods are based on this knowledge. In insulation design, field stress distribution between oil impregnated solid insulations is taken as the fundamental criteria. This stress is distributed in accordance with the permittivity of insulating materials and the geometry. Furthermore the insulation arrangement is constituted according to the design curves. They are based on decades of experience and depend upon manufacturing, process, workmanship, quality of materials and so on.

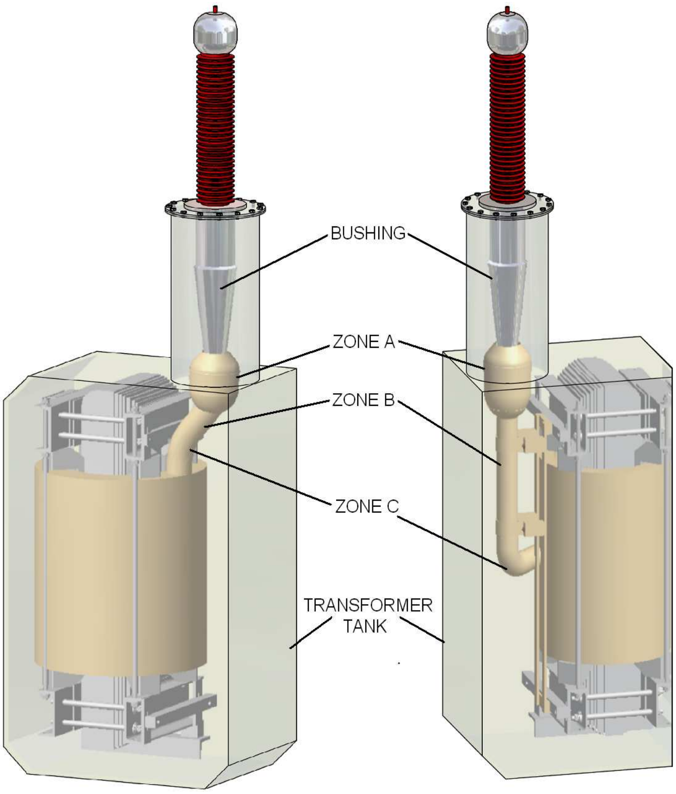
Deficiency of materials that are essential for producing oil-cooled transformers, such as Grain Oriented Silicone Steel, Copper, Mineral oil, and their increasing and fluctuating prices necessitate to find alternative solutions to reduce the cost, weight and dimensions of the transformers.

This paper aims to demonstrate optimizing process by means of 'lead exits'. The lead exit is an insulation component and connecting element between high voltage winding end and the bottom of the bushing end. High voltage winding end can be positioned at the top or in the middle of the axial height of the coil. Common practise for each lead system is the phase current through a turret to the bushing bottom end. The turret diameter depends on system voltage and design of the lead exit. Determining of the turret diameter will certainly effect the quantity of steel, mineral oil..etc. and this is important for both material cost and the weight and dimensions of the transformers. Lead exit allows reducing the clearances and the diameter of turret therefore provide saving from materials for power transformer manufacturers.

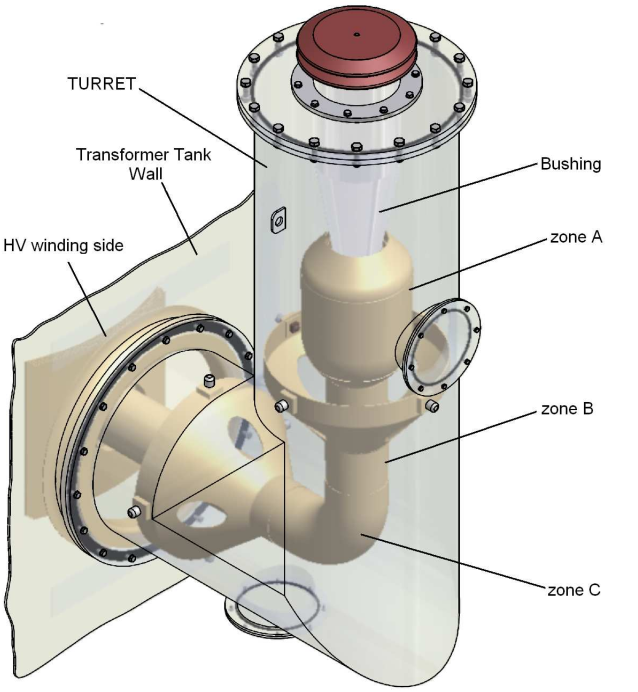
DESIGN PROCESS

Position of lead exit can be in a turret or in a tank. Connection to winding can be at the top or in the middle of winding for each position. Power transformers up to 500 kV level are either single phase or generally three phase, but 765 kV and 1200 kV transformers are mostly single phase due to transport and handling constraints.

Lead exit design should be investigated in 3 part; first around the electrode (zone A), second through the tube (zone B) and third bending part of the tube (zone C). The analyses of these insulation designs can be done by FINITE ELEMENT METHOD (FEM) (In this process analyses, the software package Maxwell by ANSOFT is used). A and B parts can be analyzed with a 2D rotational model, but zone C is more complex and it should be modeled in 3D.



Above illustations demonstrate TOP and MIDDLE entrance Lead Exit that are in the tank and critical zones.



Above illustation demonstrate MIDDLE entrance Lead Exit that is in the turret and critical zones.

As will be seen at below curves, the field stress distribution of such a lead exit are highly non-uniform. The geometries of the structures should be arranged to optimize the field stress distribution. For this optimization, it is necessary to comprehend and compare the geometries.

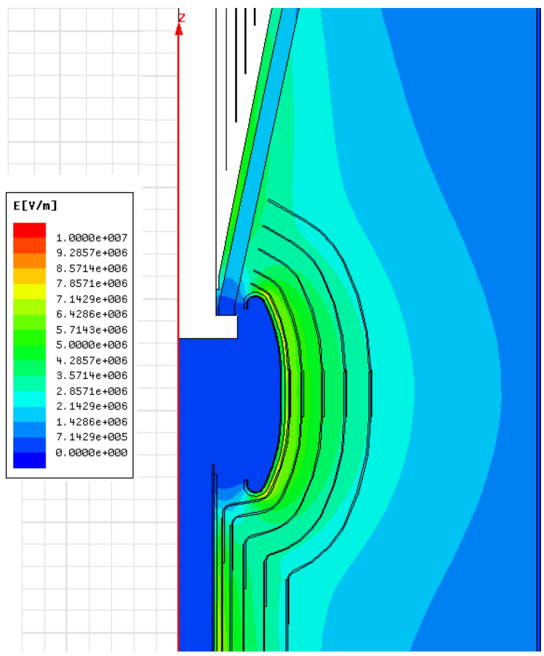
Whilst decide the oil-ducts and insulation requirements, highest stress part of the lead exit should be deeply analyzed. The highest stress value should be restricted under a definite value for preventing PD (partial discharge) and oil-breakdown from this part. The safe maximum permissible stress depends upon the thickness of oil ducts. The studies are made with the curves of partial discharge inception voltage versus width of oil duct for degassed oil. Also we assume that the transformer oil has a breakdown voltage of more than 60kV/2.5 mm.

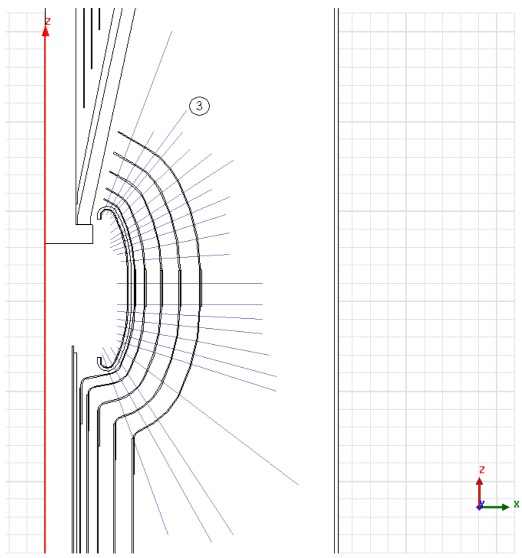
Insulation barriers, made from Transformerboard, are used for subdividing large oil gaps into smaller oil gaps. Transformerboard has pure cellulose fibres that increase the oil strength and provide a higher safety margin. While designing lead exit barriers the important point is to obtain the 'field conform' structure, i.e. electrical field patterns are perpendicular to barriers and equal potential field patterns are parallel with barriers as will be seen from the below FEM analyze illustrations.

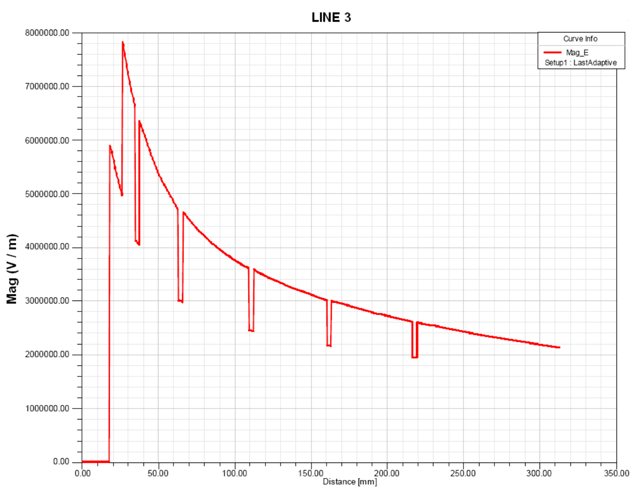
The below examples show design process for 1200 kV and 765/400 kV lead exit applications:

1200 kV Lead Exit

BIL : 2300 kV
SIL : 1675 kV



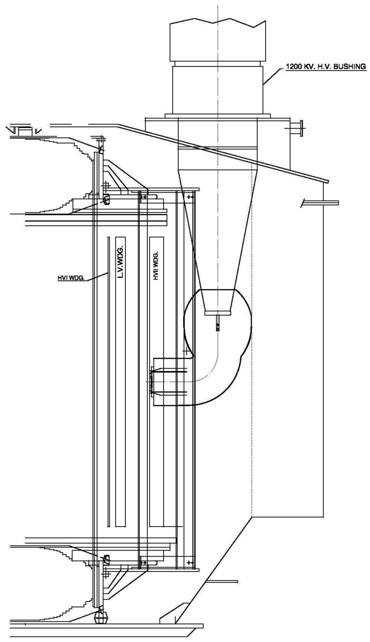




Above three illustrations shows field distribution and an example of field distribution curve, belong to line 3.

The design was developed by performing advanced FEM field plot studies. In order to determine size and exact location of barriers lots of critical paths are investigated during analyzes.

1200 kV Lead exit for test transformer

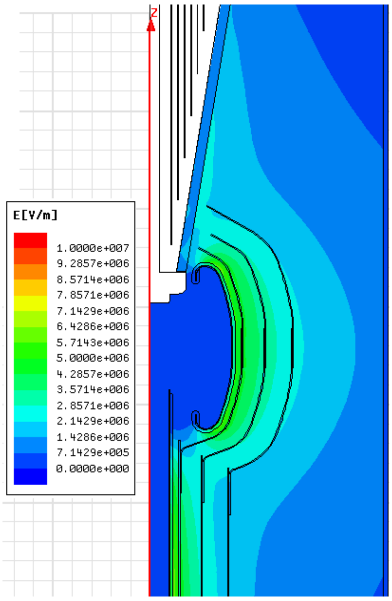


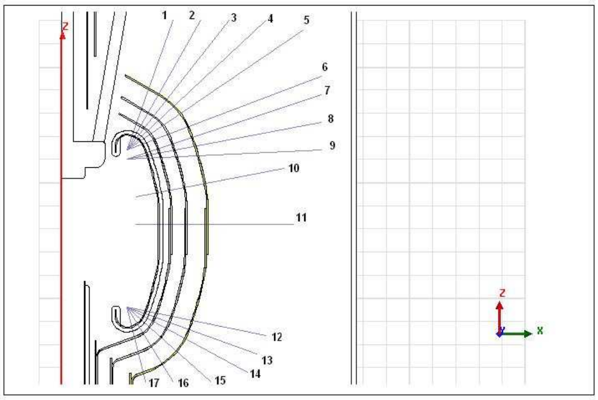
1200 kV Lead Exit Location in Transformer tank

765/400 kV transformer

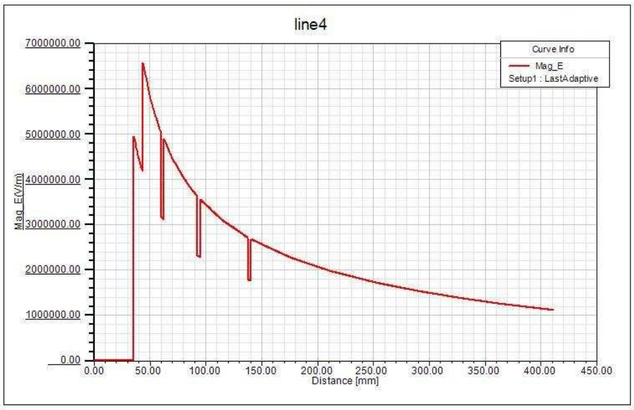
765kV Side Lead Exit

BIL : 1950 kV
SIL : 1550 kV





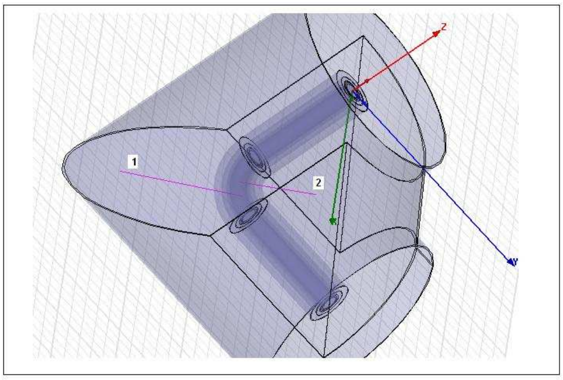
Select Lines Determination of Field Stress



The Field Distribution on Line 4

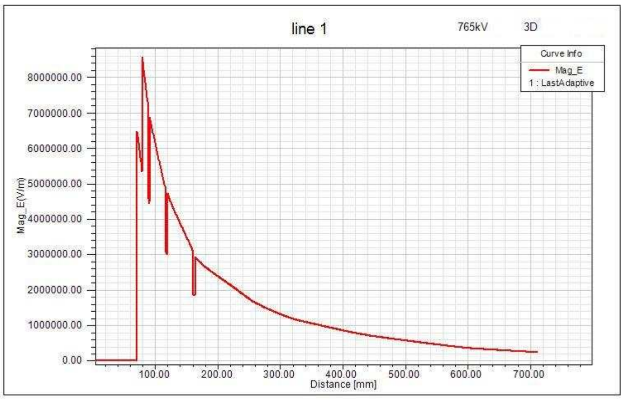
Above illustrations show field distribution and an example of field distribution curve, belong to line 4.

The design was developed by performing advanced FEM field plot studies. In order to determine size and exact location of barriers lots of critical path investigate during analyzes.



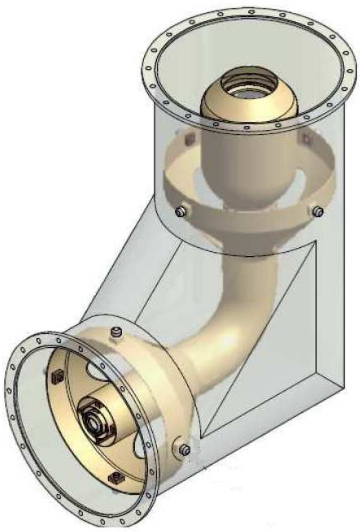
3D Calculations of Critical stress

The corner of the lead exit should be investigated separately due to their structural difference. Above illustration shows simulation of the corner of lead exit. Below curve show field distribution graphic of line 1.



Field Distribution on Corner Side Line 1

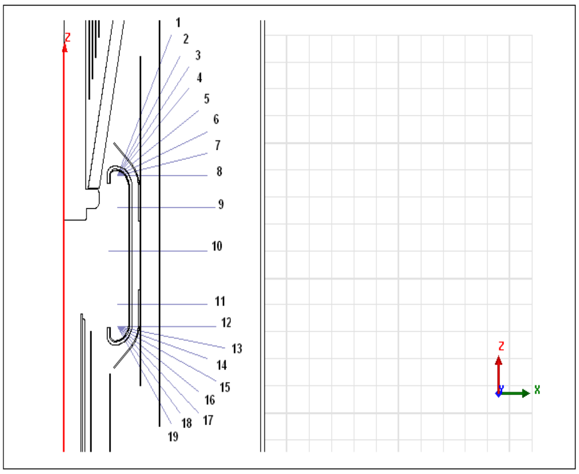
765kV Lead Exit



765kV lead exit location in turret

400 kV Side Lead Exit

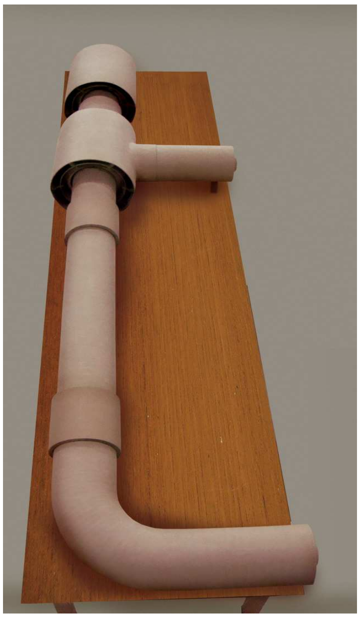
BIL : 1300 kV
SIL : 900 kV



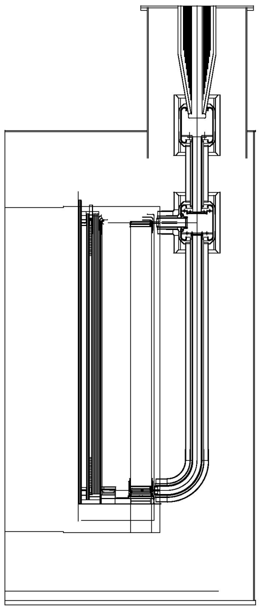
Select Lines Determination of Field Stress

Field Distribution on Line 7

Above two illustrations show field distribution and an example of field distribution curve, belong to line 7.



400 kV Lead Exit



400kV Lead Exit Location in transformer

As a consequence, lead exits bring power transformer producer cost, weight and dimensions optimization with perfect dielectric strength. This can be successfully achieved by using FEM analyzer software and Transformerboard technology.