Exit Insulation Systems (EIS) & Middle Exit Systems

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Abstract

This paper presents design process of middle exit and Exit insulation system by calculating field on existing Project.

Keywords: Insulation design, Middle Exit, Exit Insulation System , Regulating winding .

1. Introduction

In developing World, with the sprawling demand for electricity it is required to transmit more power from generating stations to end-users. This sprawling cause's longer transmission lines with increasing loss. With accessibility of suitable advanced materials, prescient design process and optimized manufacturing practices, it is now feasible to produce transformers with various voltage ratings as 420kV, 800 kV, 1200 kV. With the special optimized design process and advanced insulation materials 1200 kV levels now can be realized. These increasing voltage ratings make Exit Insulation System and Middle Exit System most important components in Transformers.

Exit Insulation Systems and middle exit systems are critical insulation components that are used to provide not only a safe connection between the High Voltage Transformer Winding end and the bottom of the bushing, but it also allows a cost optimization of steel and mineral oil by minimizing volume. Predictive design and advanced convenient materials of Exit Insulation System allows reducing of diameter of turret due to amount of barriers which results in savings of materials for transformer manufacturers.[4] When analyzed the total cost of steel and mineral oil, which are used in turret, %35-40 reduction can be achieved with safer design process and less material use in weight and volume by application of Exit Insulation System.

2. Design Procedures

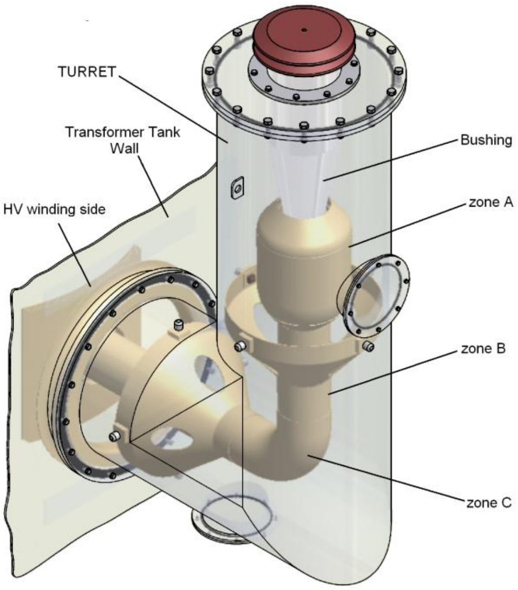
The general knowledge about transformer Insulation System Design is based on the use of cellulose in insulations which is basically used in mineral oil. For more than fifty years, transformer design and manufacturing methods are based on this knowledge. In insulation design, field stress distribution between oil impregnated solid insulations is taken as the fundamental criteria. This stress is distributed in accordance with the permittivity of insulating materials (mineral oil and Solid insulation) 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 others. 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 finding alternative solutions to reduce the cost, weight and dimensions of the transformers. İn İnsulations we made safer and more economical design by making big oil gap into the smaller oil gap with barrier system. And we will have excellent drying performance and longer and longer aging time.

3. Exit Insulation System

The Exit Insulation System 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 practice for each Exit Ins. system is the phase current through a turret to the bushing bottom end. The turret diameter depends on system voltage and design of the EIS. Determining of the turret diameter will certainly affects the quantity of steel, mineral oil, etc. and this is important for both material cost and the weight and dimensions of the transformers by making big oil gap into the smaller oil gap. Exit insulation system allows reducing the clearances and the diameter of turret therefore provide saving from materials for power transformer manufacturers.

Position of EIS 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.[2]

EIS 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 ANSYS 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.[1]



Şekil 1. Middle Entrance Exit Insulation System that is in the turret and critical zones.

As will be seen at below curves, the field stress distribution of such a EIS 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 exit insulation system 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. [2]

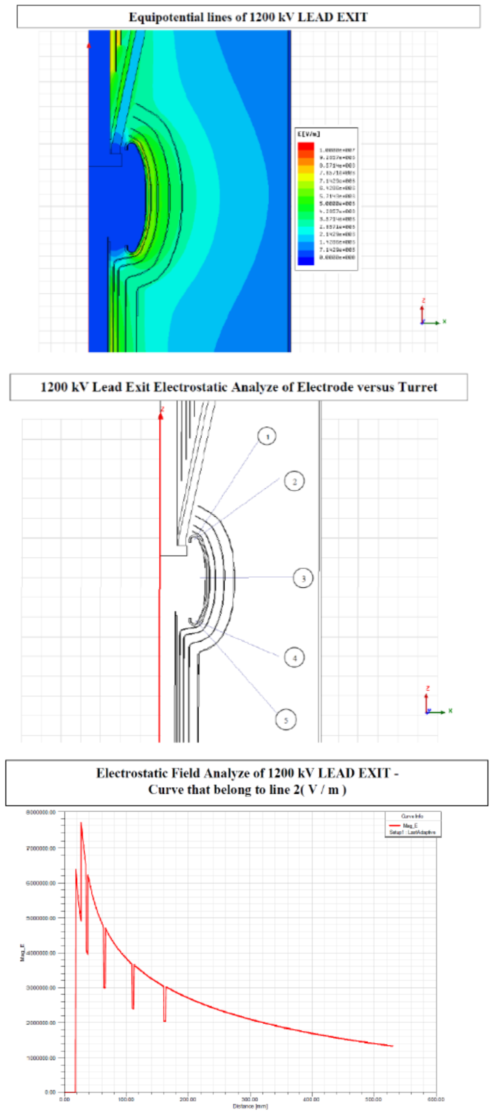
Insulation barriers, made from Transformer board, are used for subdividing large oil gaps into smaller oil gaps.[3] Transformer board has pure cellulose fibres that increase the oil strength and provide a higher safety margin. While designing insulation barriers the important point is to obtain the 'field 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 behavior of oil immersed transformer board and oil make possible to design smart solution as Exit Insulation Systems and middle exits.

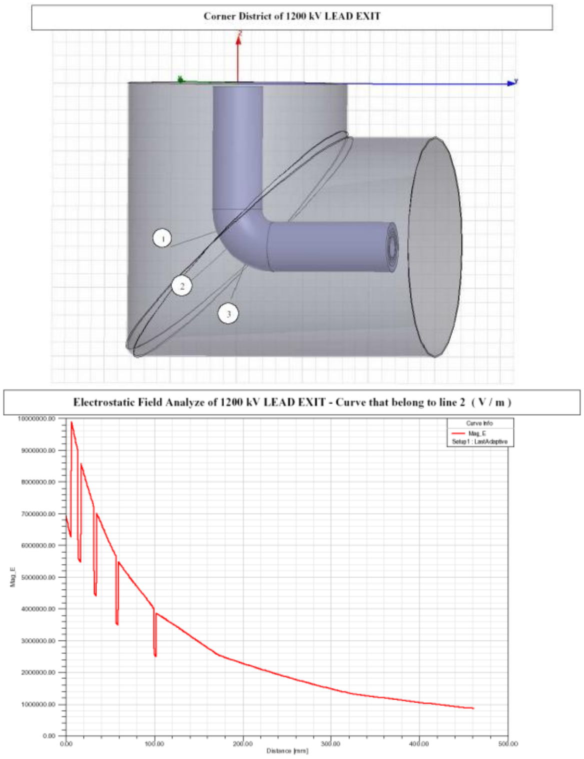
The examples below show design process for 1200 kV Exit Insulation System and 420 kV Middle Exit.

1200 kV Exit Insulation System

BIL : 2300 kV
SIL : 1800 kV



Şekil 2. Field distribution and an example of field distribution curve belonging to line 3.



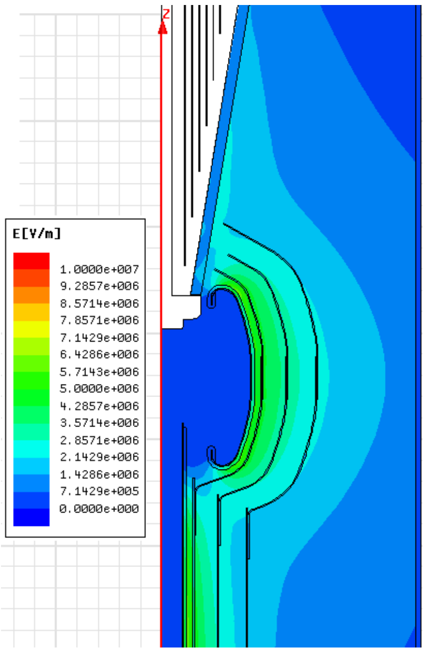
Şekil 3. Field distribution and an example of field distribution curve belonging to line 2.

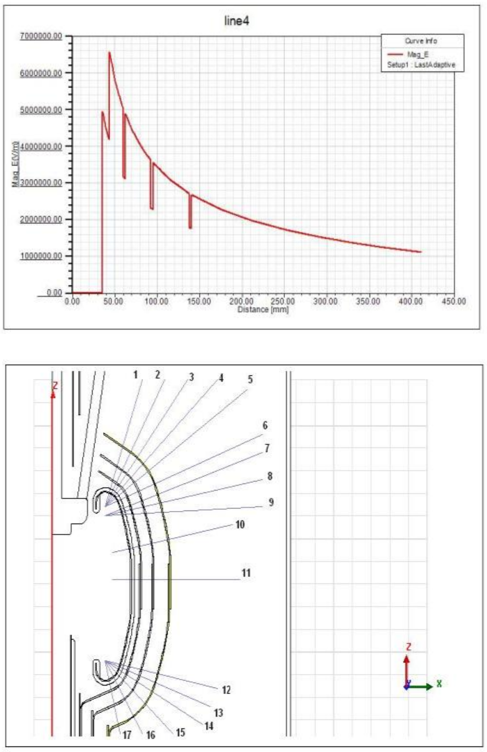
The design was developed by performing advanced FEM field plot studies. In order to determine size and exact location of barriers lots of critical paths are investigated during analyzes.

Şekil 4. 1200 kV Exit Insulation System located in Power Transformer Turret.

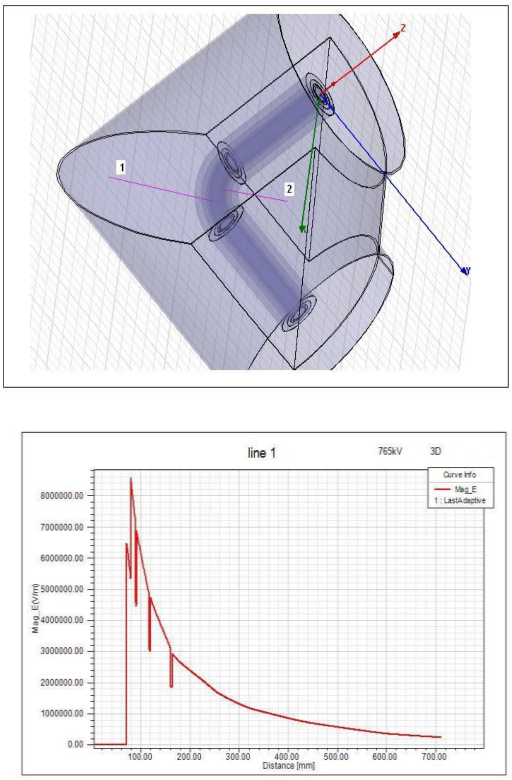
<u>800 kV Exit Insulation System</u>

BIL : 1950 kV
SIL : 1550 kV

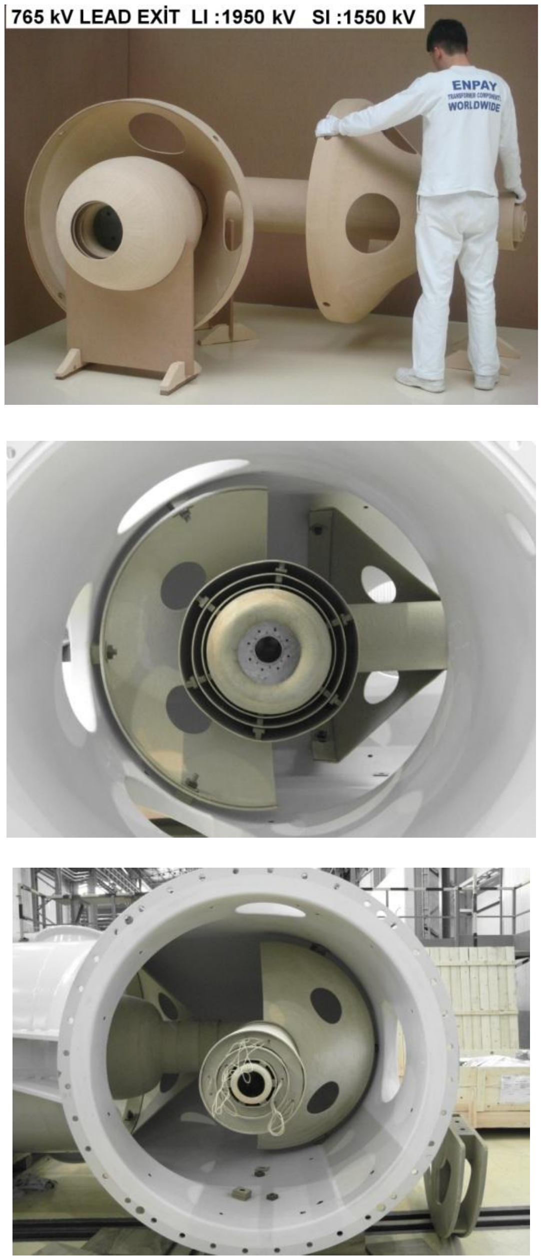




Şekil 5. Field distribution and an example of field distribution curve belonging to line 4.



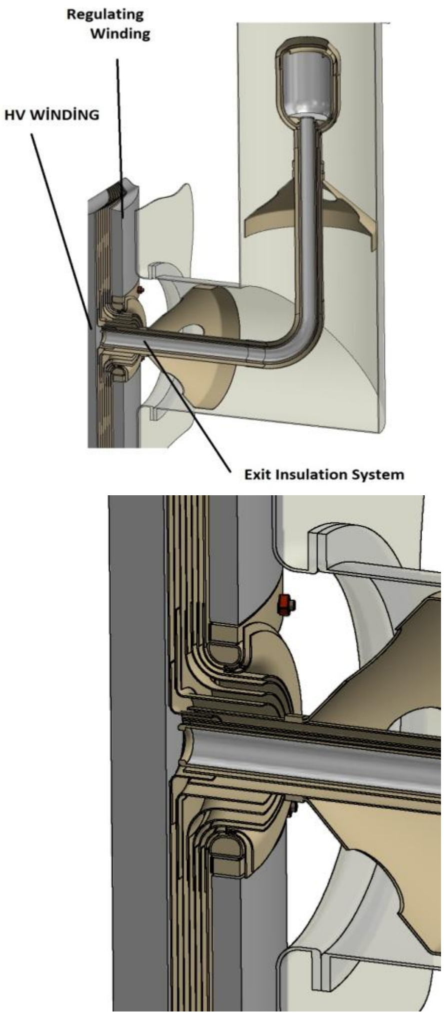
Şekil 6. Field distribution on corner and an example of field distribution curve belonging to line 1.



Şekil 7. 765 kV Exit Insulation System located in Power Transformer Turret

1200 kV and 800 kV designs were 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.

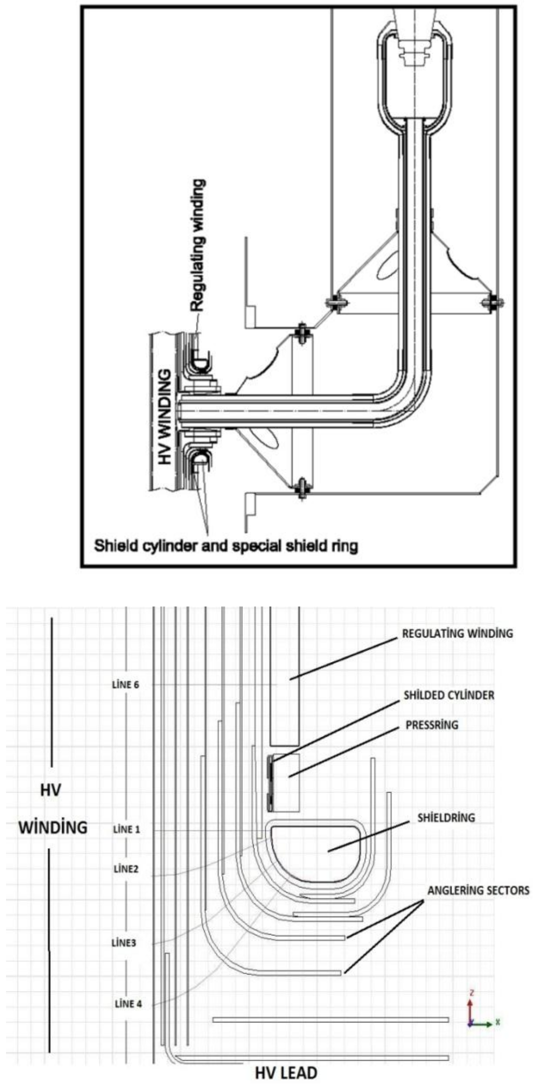
4. Middle Exit System



Şekil 8. Middle Exit System

When Regulating winding located outside of HV winding; we should use middle exit app. to make system safety and optimized. Middle Exit connected to regulation winding and protects exit insulation system by making mounting process easier and shorter with convenient regulating winding support.

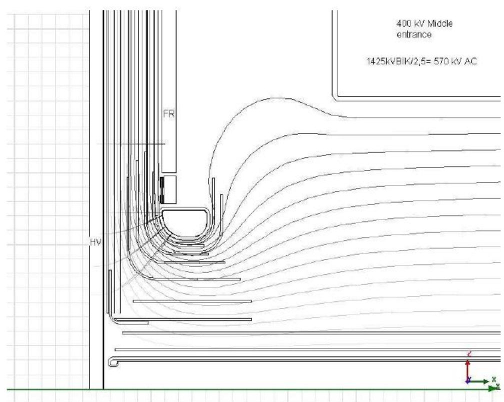
Middle Exit system is an advantageous insulation component that is used to provide not only a safe connection between the High Voltage Winding end and the bottom of exit insulation systems, but it also allows a cost optimization of less workmanship by making mounting process easily. In additional to this we can eliminate the fault related to workmanship.



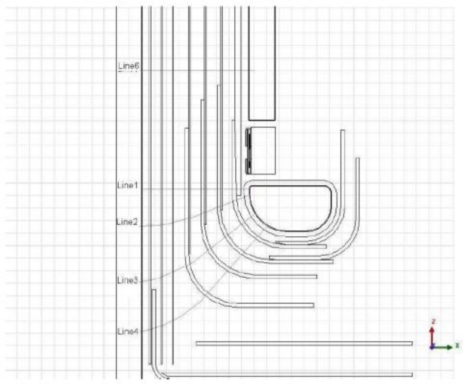
Şekil 9. Middle Exit's Parts Locations for field simulations (section view)

Defined lines to calculate field distiribution and compare stress with permisible values.

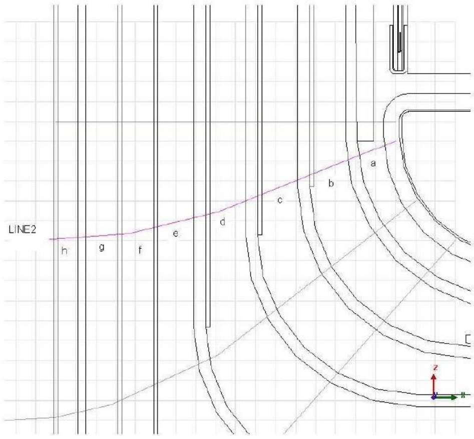
Voltage Distribution



Defined Lines



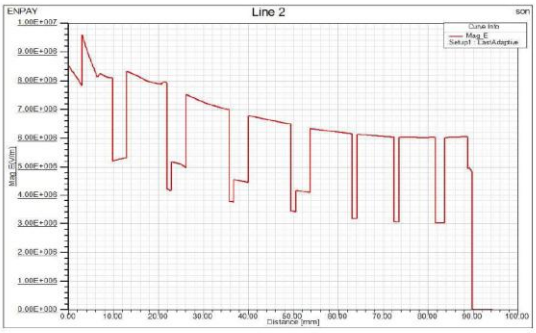
Line 2 Oilducts



Şekil 10. Geometries

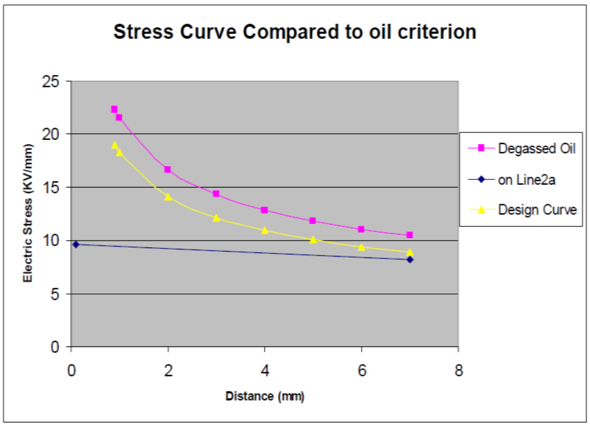
The design was developed by performing advanced FEM field plot studies. In order to determine size and exact location of barriers lots of critical paths are investigated during analyzes. And the system is designed according to most critical zone. Every oil duct stress distribution is compared with stress curve to control system safe.

Stress Distribution



Şekil 11. Field distribution curve belonging to line 2

Compared electric stress on each oil duct
Line2 Duct a



Şekil 12. Comparison calculated field on oil duct with permissible stress

Şekil 13. Location of middle exit on transformer

You will have safe volume surrounding HV winding with less field stress to connect regulation winding to tap changer.

You can decrease the distance between top and bottom regulating winding so you can get smaller height.

It's convenient for vertical and horizontal winding machine process.

We can provide better mechanical strength than traditional method by using press-ring between top and bottom regulating winding.

5. Conclusion

Exit Insulation System and Middle Exit System with barrier system are the best solution. Because conventional types with paper wrapped main conductor and single wide oil gap for Exit insulation system; Conventional insulation made of blocks and washers are risky and not economical solution.

Insulation components as middle exit system allows for less production costs and decreased manufacturing cycle time of power transformer production. There are a lot of technical and economic advantages to use middle exit's kits (packages).

There is indeed a need for theoretical knowledge and R&D in production, however the products must be reliable, thus a sustainable high quality level in production must be achieved.

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