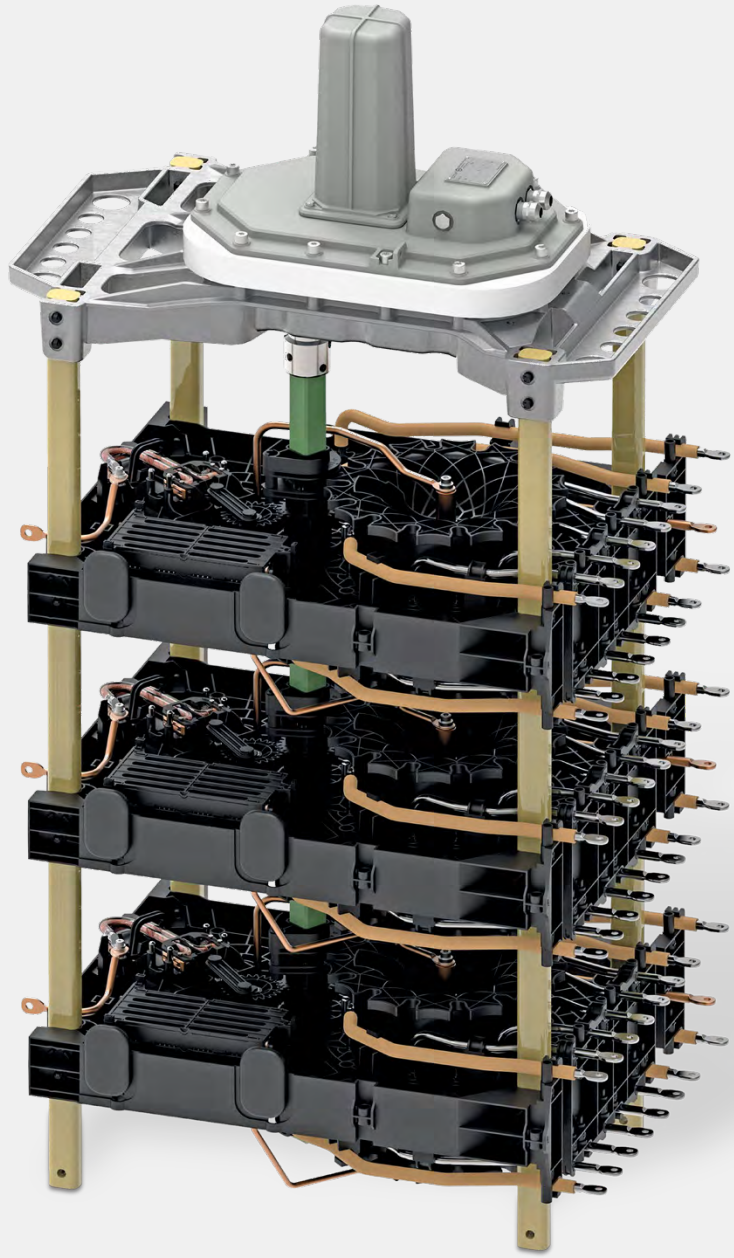
THE POWER BEHIND POWER.

Guideline for dielectric integration of VACUTAP® VI in transformer

Whitepaper | Dr. Beate Glaser



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1 Introduction

The VACUTAP® VI is an innovative, integrated on-load tap-changer (OLTC) in vacuum technology that is used in small and medium-sized power transformers. It impresses with material savings – also on the transformer – as well as with simplified customer interfaces during installation and commissioning (Figure 1).

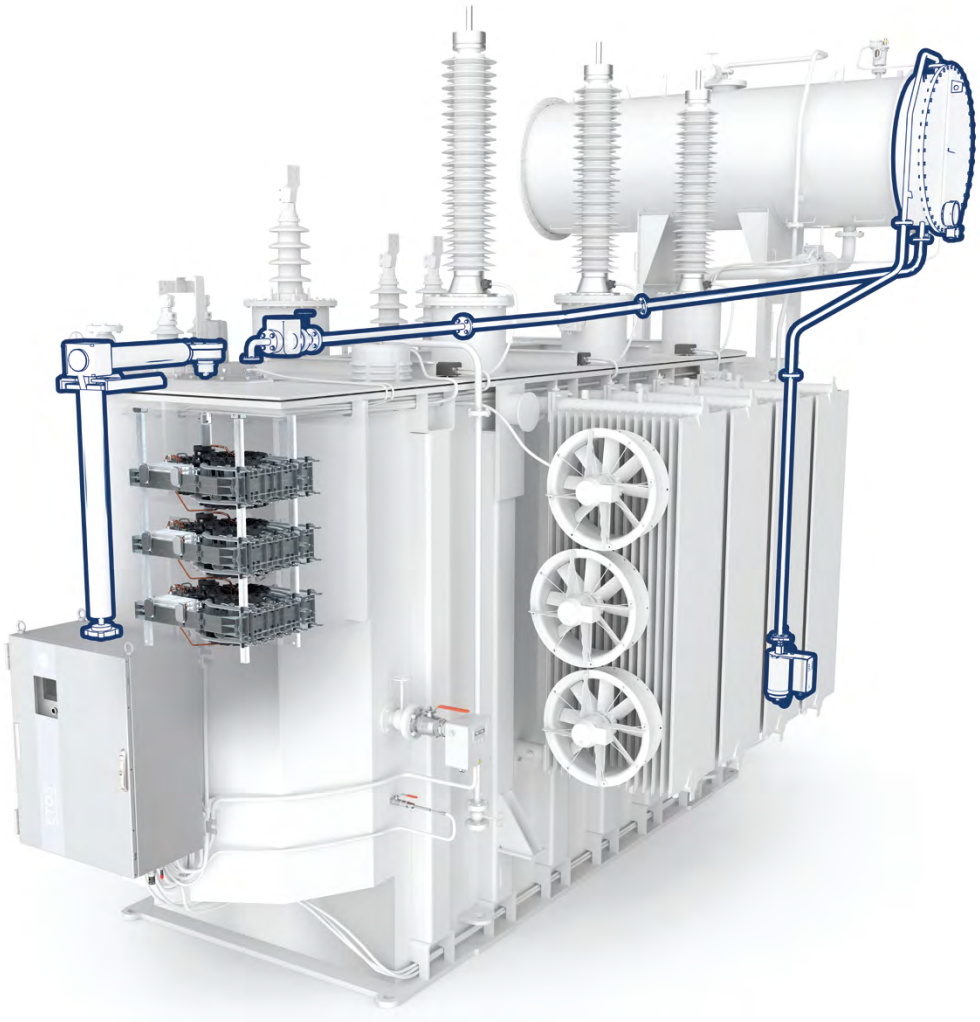

Figure 1:
VACUTAP® VI
in transformer.

To make it easy to integrate the OLTC into the tank and to minimize the influence of the transformer on its dielectric strength, conductive shields are attached next to all key components on the outside of the VACUTAP® VI. In addition, the outer tap leads are paper-isolated (see Figure 2).

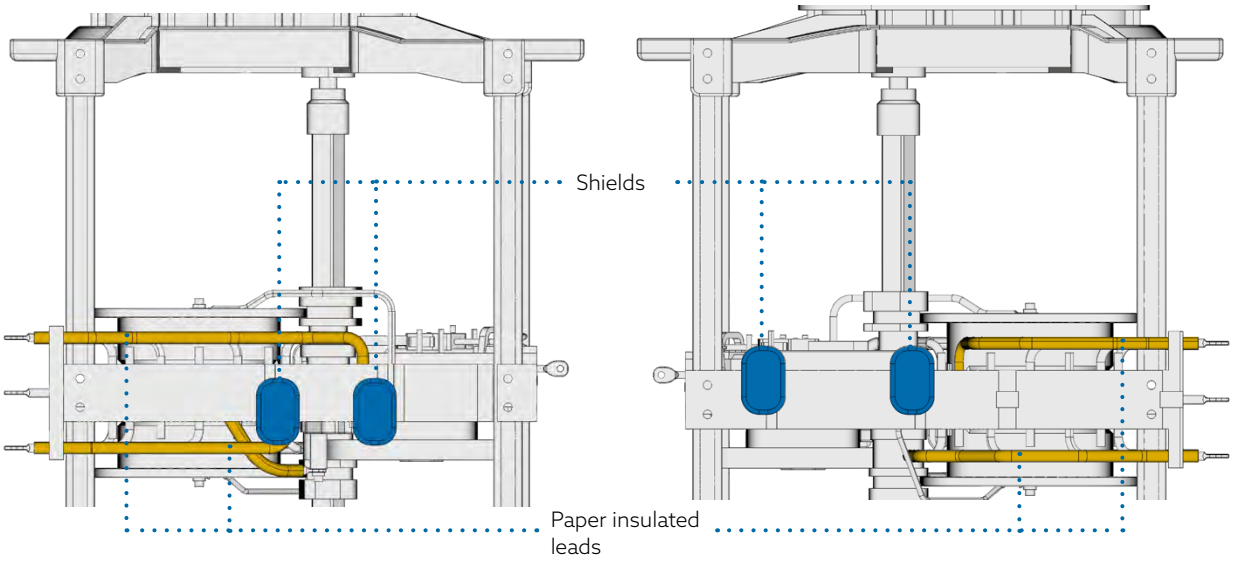

Figure 2:
Integrated OLTC design.

This allows the VACUTAP® VI to be integrated with the smallest possible clearance based on well-known geometries and thus enabling the most compact but safe transformer dimensions.

The geometry of the shields is a flat shielding plate with rounded corners as seen in Figure 3. It is connected to the potential of its neighbouring parts, which is the take-off potential or, for the preselector, the contact potential.

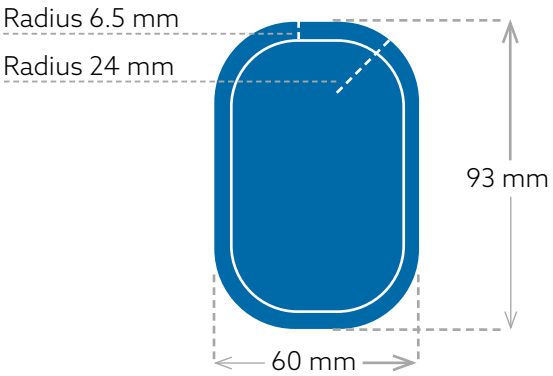

Figure 3:
Shield dimensions.

The following sections show that the dielectric integration of the VACUTAP® VI can be realised in two different ways:

1. Procedure analogue to conventional OLTCs: due to the shields and the paper-isolated leads insulation coordination for the VACUTAP® VI can be carried out in the same way as for OLTCs with oil compartment.

2. FEM simulation-based procedure: dielectric integration using a simplified 3D-model of the VACUTAP® VI

2 Procedure analogue to conventional OLTCs: Insulation coordination is not affected by the new design

Simulations of the dielectric strength inside the transformer tank prove that insulation coordination based on the shields is sufficient. The electric fields were calculated and the dielectric strength evaluated using the streamer criterion. Further details regarding this analysis can be found in [1], [2], [3].

In the simulation setup, the transformer tank is modelled with simple, plane walls (see Figure 4). In the first step, only the insulation to ground is considered. The blue components are grounded while the parts of the OLTC, which are on a higher potential, are illustrated in red.

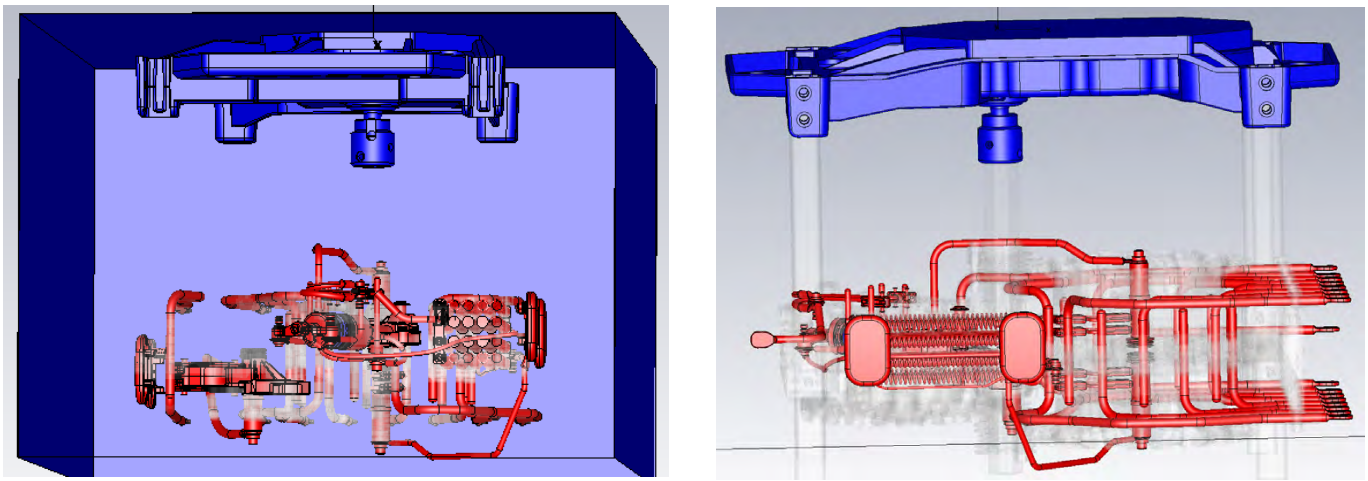

Figure 4:
Insulation to ground analysis – left with transformer tank – right without.

For the VACUTAP® VI with U_m = 40 kV, the simulation result of the electric field calculation is shown in Figure 5. The image on the left represents the electric field distribution without transformer tank, while the one on the right includes the tank. As seen in comparison, the presence of the transformer tank significantly increases the strength of the electric field.

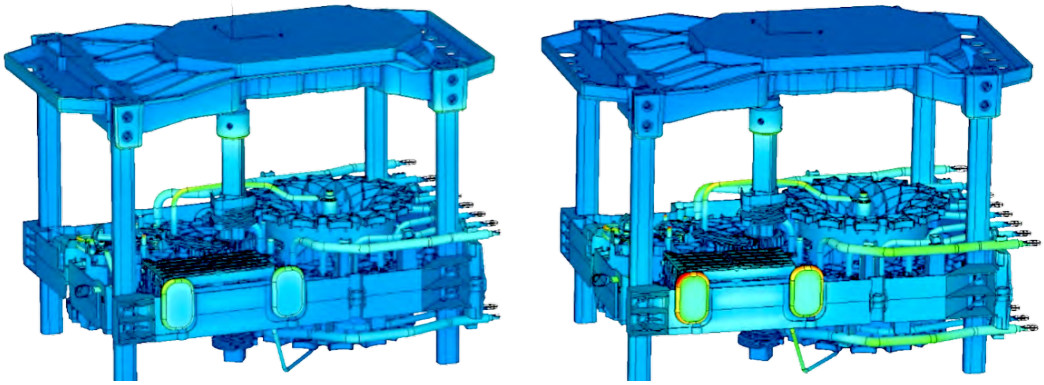

Figure 5:
Electric field simulation without transformer tank (left) and with the tank (right).

To evaluate the influence of the transformer tank, the dielectric strength is analysed at six areas with high field stress. Three of them are located on the outer shields and the other three are inside the OLTC. Figure 6 shows the simulation result of the dielectric strength for these areas. The light blue symbols represent the dielectric strength without a transformer tank, while the dark blue symbols correspond to a larger tank size (resulting in a larger distance between OLTC and tank), and the grey symbols indicate a small tank (resulting in a smaller distance between OLTC and tank). It is clearly shown that dielectric strength at the shields is highly affected by the distance to the tank, while it changes only slightly for the inner points.

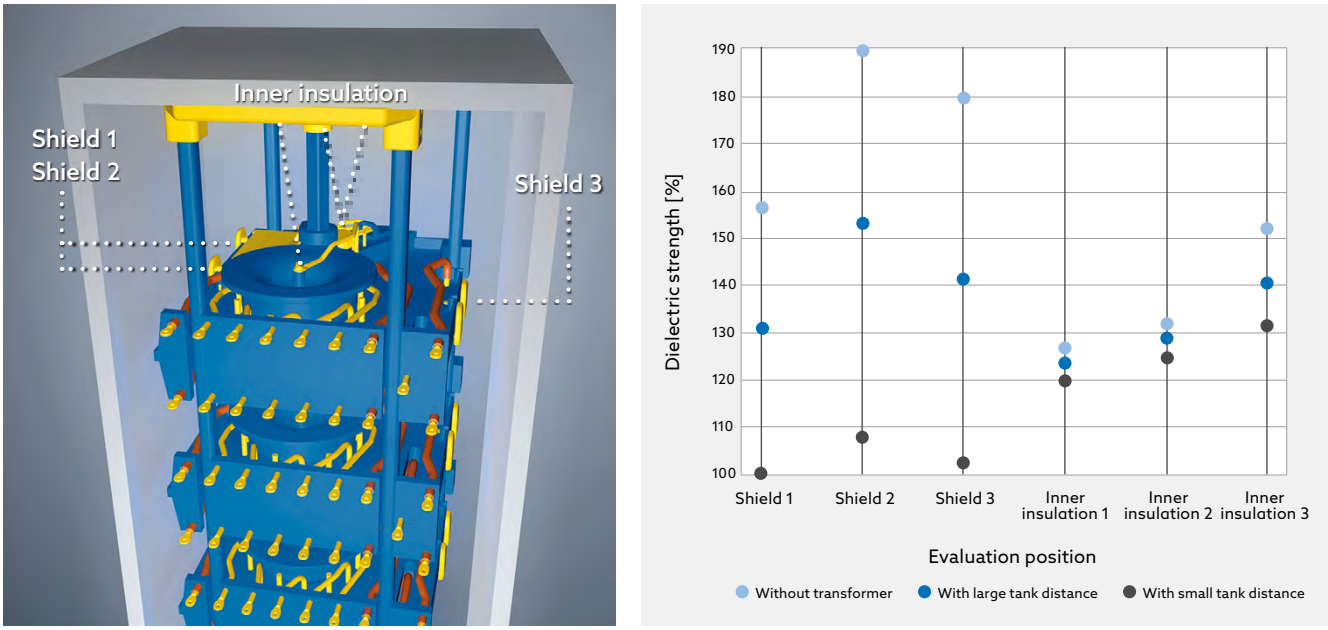

Figure 6:
Influence of the transformer tank distance on the dielectric strength for different areas.

Equivalent simulations were carried out for the insulation between phases, where two phases are grounded and one is not (see Figure 7). Like in the previous simulation, the dielectric strength at the shields is strongly influenced by the tank, while it changes only slightly on the inside.

Furthermore, for all variants of VACUTAP® VI it was ensured by simulation that a dielectric integration into the transformer based on the shields is sufficient.

Therefore, the insulation coordination is the same as for conventional OLTCs, where only the outer parts must be considered.

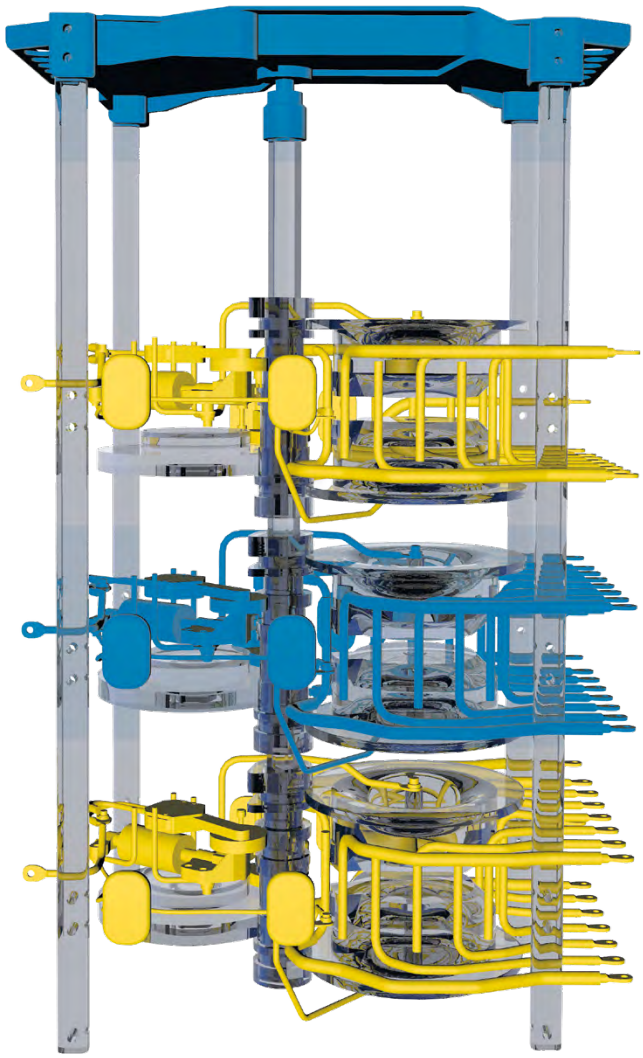

Figure 7:
Simulation of insulation between phases.

3 FEM simulation-based procedure: Simplified model for your own simulations

Another possibility to do the insulation coordination is to simulate the VACUTAP® VI in your transformer environment. The simplified 3D model of VACUTAP® VI (see Figure 8) is designed in a way that allows for simulations with this model. While the shields keep their original geometry, other parts have been greatly simplified. For instance, the model includes sharp edges on inner metallic components, which are not present in the actual OLTC design. However, this simplification has been tested to be sufficient for dimensioning the distance between transformer tank and OLTC.

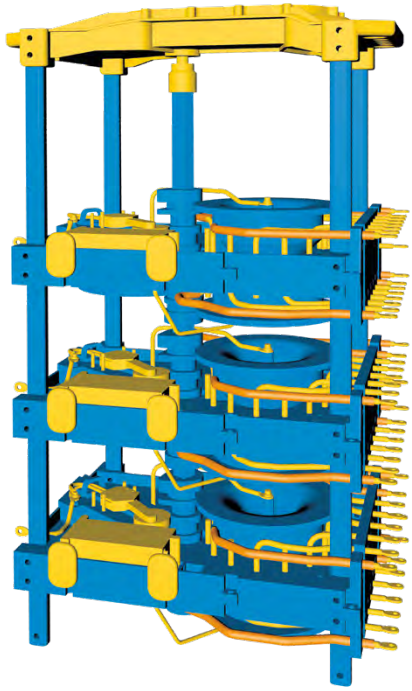

Figure 8:
Simplified 3D model of the VACUTAP® VI.

There are only three materials in the model:

- Blue: Thermoplastic with relative permittivity 4,3
- Orange: Oil-impregnated paper with relative permittivity 3,5
- Yellow: Metals and conductive plastics

The model is available for every variant of VACUTAP® VI:

- VI III 400 Y 40
- VI III 400 D 40
- VI III 400 Y 76
- VI III 400 D 76
- VI III 400 Y 123

References

[1] Wiesmüller, M., Glaser, B., Fuchs, F., Sterz, O.: Dielectric breakdown simulations of an OLTC in a transformer, COMPEL, Vol. 33 No. 4, 2014, S. 1145 –1160

[2] Glaser, B., Fuchs, F., Sterz, O., Krämer, A.: Computational dielectric stress analysis for OLTCs throughout the product lifecycle, ISH 19th International Symposium on High Voltage Engineering, Pilsen, Aug. 23 –28, 2015

[3] Glaser, B., Fuchs, F., Sterz, O., Krämer, A.: Approval of Contact Geometry by Computer Based Dielectric Stress Analysis (in German), VDE-Hochspannungstechnik 2016, Berlin, Nov. 14 –16, 2016

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