DESIGN AND SIMULATION OF AN ANODE STALK SUPPORT INSULATOR*

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Abstract

An anode stalk support insulator in a magnetically insulated transmission line was designed and modeled. One of the important design criteria is that within space constraints, the electric field along the insulator surface has to be minimized in order to prevent a surface flashover. In order to further reduce the field on the insulator surface, metal rings between insulator layers were also specially shaped. To facilitate the design process, electric field simulations were performed to determine the maximum field stress on the insulator surfaces and the transmission line chamber.

INTRODUCTION

A pulsed X-ray source for radiography was developed at Lawrence Livermore National Laboratory [1]. The goal of this project is a flashed, isotropic, point X-ray source. A commercial power supply was used to produce a 1.5-MV, 20-KA, 20ns pulse. Power is channeled through a magnetically insulated transmission line (MITL) to a diode. Solenoid is contained in the outer wall of the MITL. A new configuration (Figure 1) was proposed for blast protection. In the figure, the original configuration which includes the Blumlein insulator stalk and MITL is shown on the left. In the new configuration, an anode stalk and its support insulator (on the right) have been added and are perpendicular to the original configuration. The anode stalk support insulator needs to hold up to 1.5 MV.

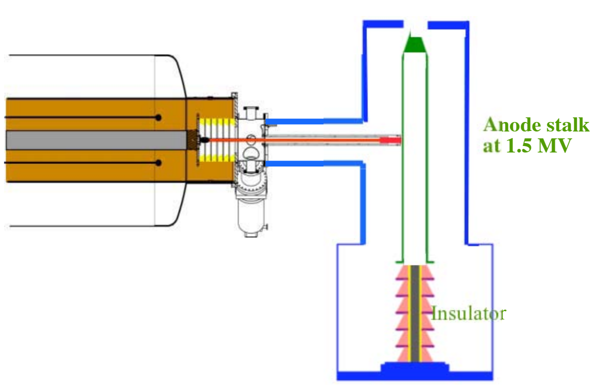

Figure 1: Overall Configuration.

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INSULATOR DESIGN

Figure 2 shows the design of the anode stalk and its support insulator. One important design consideration is to minimize the electric field along the insulator surface within the space allowed in order to prevent the surface flashover. Two chambers of different sizes are used. A chamber with a larger diameter is used on the bottom to reduce the field on the insulator surface. The anode stalk is at 1.5 MV and the insulator base is at ground. There are six insulator layers. The insulator layer is made of Rexolite with dielectric constant equal to 2.53, and is separated by metal grading rings.

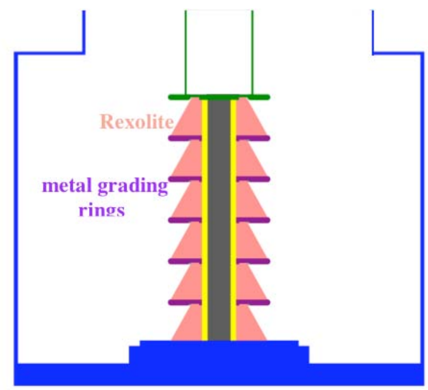

Figure 2: Anode stalk support insulator.

A more detailed view of an insulator layer is shown in Figure 3. In the middle of the insulator is an insulating tie rod with dielectric constant equal to 2.8. The rod is surrounded by resistive fluid with dielectric constant equal to 80 and conductivity equal to 0.105 siemans/m. The fluid is a component of a resistive voltage divider incorporated into the base of the stalk support. A section is removed from the metal grading ring where top of Rexcolite meets the ring. The metal rings are specially shaped in order to reduce the field on the insulator surface and triple point.

ELECTRIC FIELD SIMULATION

The electric field simulations were performed to facilitate the design process and to determine the maximum field stress on the insulator surfaces and the transmission line chamber. Figure 4 shows the voltage plot. The plot shows that the voltage at the anode is at 1.5 MV and reduces to zero at the chamber wall. The voltage drops about 0.3 MV for each layer. The magnitude of the electric field in the insulator region is displayed in Figure 5. The plot

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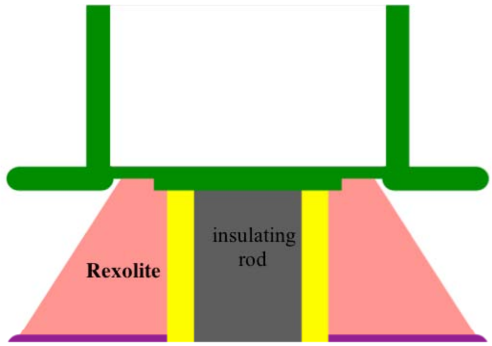

Figure 3: Top layer of the insulator.

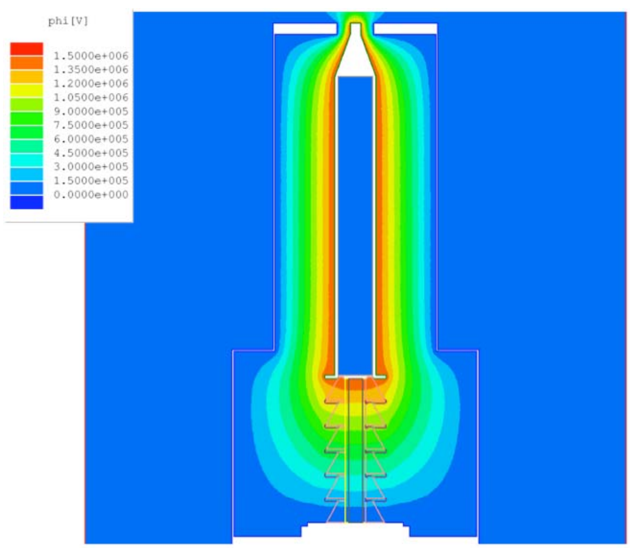

Figure 4: Voltage plot.

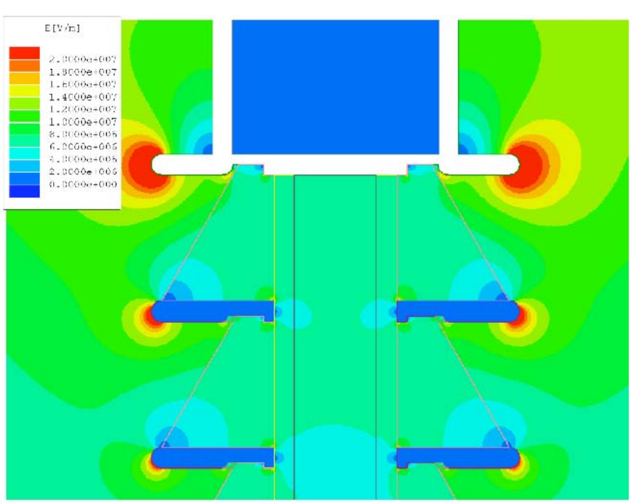

Figure 5: Magnitude of electric field.

shows that high field (> 200 KV/cm) occurs around the edges of the top metal grading ring. Since this is an anode surface, we are not overly concerned about the field stress on this surface. As the major concern is the surface flashover, electric fields along the insulator surfaces are plotted in Figures 6 and 7. The results show that the electric fields along the insulator surface are below 90 KV/cm which we consider sufficiently low for the 20 ns pulse length.

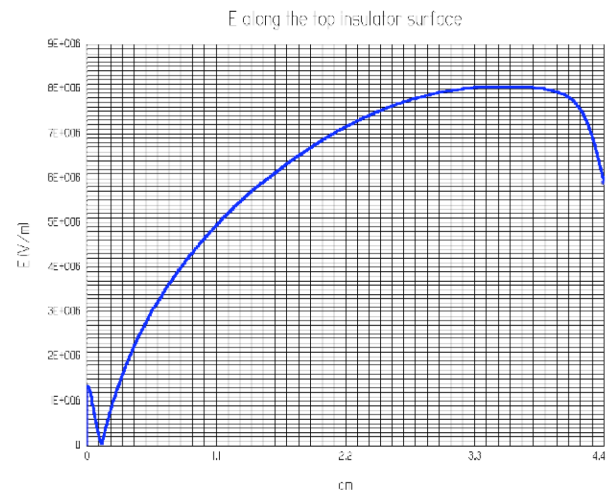

Figure 6: E along the top insulator surface. Electric field varies from 0 to 90 KV/cm on the vertical axis.

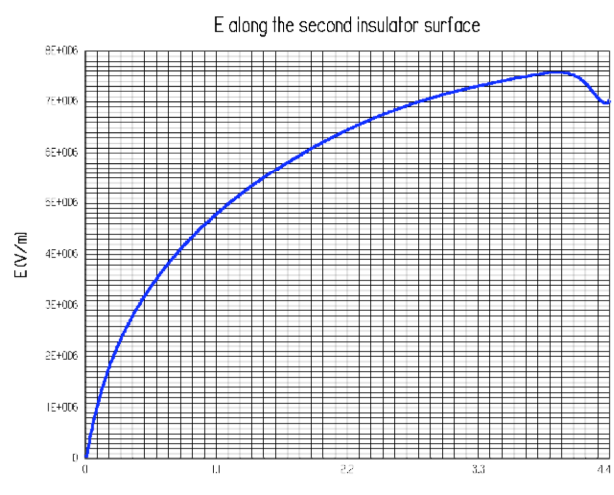

Figure 7: E along the second insulator surface. Electric field varies from 0 to 80 KV/cm on the vertical axis.

In addition to the insulator, the junction of two vacuum chambers needed to be shaped. The sharp corners of the

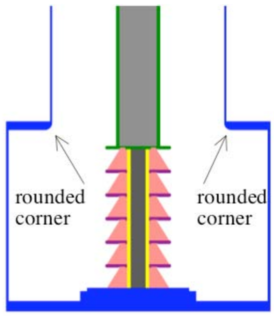

Figure 8: Configuration with the rounded corner in the junction of two MITL chambers.

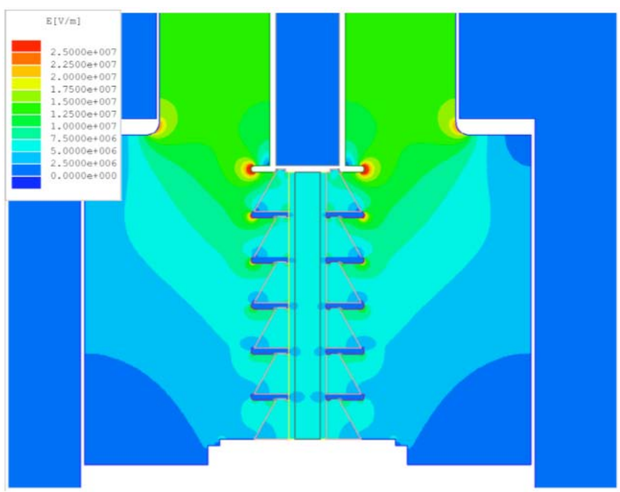

Figure 9: Configuration with the rounded corner in the junction of two MITL chambers.

junction were rounded as shown in Figure 8. Figure 9 displays the plot of magnitude of electric field in the region. The simulation results show that the maximum electric field around the junction of two chambers is reduced by almost a third to 200 KV/cm by rounding the corners.

An insulator was fabricated based on this design. During full voltage testing, voltage and radiation monitors indicated no arcing or measurable emission from the stalk support or surrounding surfaces. Post testing inspection showed no damage or tracking to the insulator and metallic surface. Mechanically, the stalk support is sufficiently rigid to maintain the alignment of the two meter long, cantilevered anode stalk without additional support. The fabricated insulator is shown in Figure 10. Figure 11 displays the anode stalk and the insulator inside the chamber.

SUMMARY

The anode stalk and its support insulator was designed and analyzed using an electrostatic model. Electric field along the insulator surface is less than 100 KV/cm with the current design, By rounding the corners of the junction between the two vacuum chambers, the electric field was reduced by almost a third in the junction area. The experimental results show there is no surface flashover along the insulator surface when the full voltage is applied. The configuration as designed and built has been used in full voltage operations for over six months without any failure or degradation.

Figure 10: An insulator based on this design was fabricated.

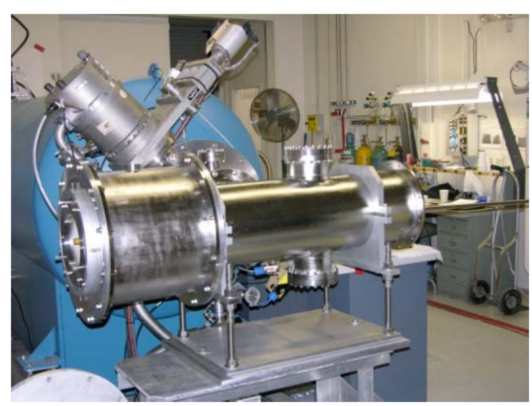

Figure 11: Insulator (inside the chamber) and the anode stalk protruding from the vacuum chamber to the right (MITL removed).

REFERENCES

[1] S. Humphries, T. Orzechowski, and J. McCarrick, "Simulation Tools for High-Intensity Radiographic Diodes," PAC'03, Portland, Oregon, May 2003, pp. 3557-3559,

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