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Simulation based design of GIS sensors for partial discharge measurements

Master Thesis

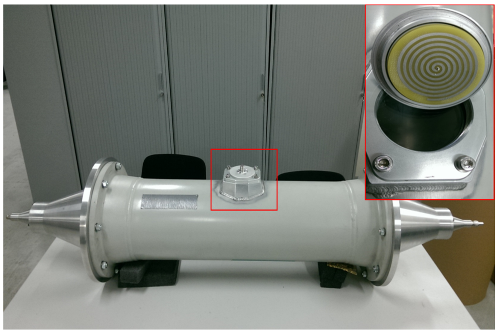
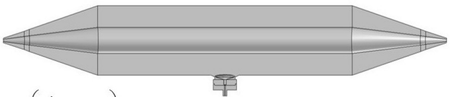


Figure 1, GIS dummy for sensor measurements



$$\nabla \times \left(\frac{1}{\mu_r} \nabla \times \vec{A} \right) + j\omega\mu_0\sigma\vec{A} - \omega^2\mu_0\varepsilon_0\varepsilon_r\vec{A} = 0 \text{ in } \Omega \subseteq \mathrm{R}^3 \quad (1)$$

$$\vec{n} \times \vec{A} = 0 \text{ over } \partial_{PEC}\Omega \subseteq \mathrm{R}^2 \quad (2)$$

$$-\vec{n} \times \left(\frac{1}{\mu_r} \nabla \times \vec{A} \right) - j\omega \frac{\mu_0}{Z_{PORT}} \vec{n} \times \left(\vec{n} \times \vec{A} \right) = \frac{2\mu_0}{Z_{PORT}} \vec{n} \times \left(\vec{n} \times \vec{E}_0 \right) \text{ over } \partial_{PORT}\Omega \subseteq \mathrm{R}^2 \quad (3)$$

Figure 2, Full-Maxwell simulation model

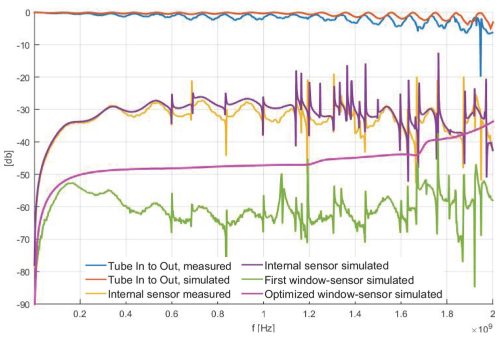


Figure 3, Results

Introduction: Gas insulated switchgear (GIS) comprise key components installed at the nodes of high voltage transmission and distribution networks. Their main purpose is to perform switching operations between e.g. HV cables, overhead power lines, and transformers during regular system operation and also maintenance outages. Partial discharges (PD) can cause degradation of insulation systems over time. The reliability of GIS installations can be enhanced by effective detection of PD,which is in turn dependent on PD sensors installed throughout the entire GIS. Typically, PD sensors are designed and installed internally in the GIS,thus the measuring points are pre-defined. However, the RF signals excited by PD are very weak and composed of different modes; this may make it difficult to detect signals at the installed sensors. To address this problem, a sensitive, wide-band external sensor has to be designed for use at observation windows which are distributed throughout the GIS. Virtual prototyping offers an efficient way to save manufacturing costs and production time by realizing an optimized sensor design in advance of production. To evaluate prototype PD sensors and verify the accuracy of the models used, a suitable test rig has been built as shown in Fig. 1. A cylindrical tube whose internal dimensions correspond to those of the actual GIS includes tapered-line impedance transformers at its ends, equipped with standard 50 ohm RF connectors

Proceeding: The problem posed requires a 3D full wave simulation. Since the test structure depicted is relatively large and complicated, such a simulation can be very time consuming. Therefore, a first step is to simplify the real device as much as possible. This was done by modeling only the electric conducting faces seen by the incoming wave on the left-handside. Additionally, the rotational symmetry of the tube was used for a further simplification. Whenever simulation based design is used,the model has to be confirmed by actual measurements.

Result: Different results of these measurements are shown in figure 3. First, the blue and orange traces show the measured and simulated input-to-output behavior of the test device. Second, a normal internal PD sensorwas produced by the HSR factory,and the corresponding measurement and simulation is shown by the yellow and purple traces respectively. After a good match was achieved, the model was used for virtual prototyping of the window-sensor. Finally, following several more iterations, a sensor was found with a very constant gain, fulfilling the criteria mentioned in the introduction. This improvement can be seen by comparing the green and magenta traces.