Virtual Prototyping of HV Switchgear

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In the last ten years there has been rapid development in Computer Aided Engineering (CAE) software such that it is now possible to create virtual prototypes of High Voltage (HV) Switchgear rapidly and accurately. These virtual prototypes helped to significantly reduce development and testing costs considerably at Reyrolle, London, England.

Reyrolle modelled a number of HV switchgear designs using a 3-D electrostatic CAE tool called COULOMB. One design is an epoxy rod between two coaxial electrodes in which the electrical field distribution is required at various locations.

High voltage CAE tool

The 3-D electrostatic tool COULOMB, from Integrated Engineering Software, Winnipeg, Canada, is based upon the Boundary Element Method (BEM). For electrostatic designs, the BEM has some distinct advantages over traditional methods, such as the Finite Element Method (FEM) and Finite Difference Method (FDM), which use differential operators to compute the field. These advantages include:

- BEM requires only the discretisation of dielectric and conductor surface. FEM and FDM require the problem space to be truncated at some arbitrary distance from the device model. The entire problem space up to the truncation then requires meshing. This comparison is illustrated in the two-dimensional case of a parallel plate capacitor (figure 1).
- BEM allows the fields and potentials to be computed at any point including the interior of devices and the exterior space to infinity. FEM and FDM require an artificial boundary condition to be placed at the truncation of the problem space introducing further approximations.
- There is an inherent smoothing effect when calculating the fields using BEM as opposed to FEM. BEM is much less sensitive to numerical errors in the potential calculation.

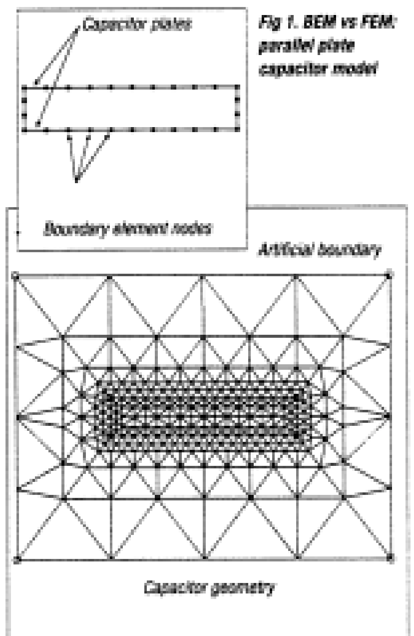

Fig 1. BEM vs FEM: parallel plate capacitor model

Practical applications

The most common problem in HV Switchgear design is to find and optimise the electrical field distribution in a complex geometry consisting of insulating materials and metal parts at earth or HV potential. In a gas insulated substation an epoxy rod penetrates the grounded metal chamber and into the conductor assembly (figure 2).

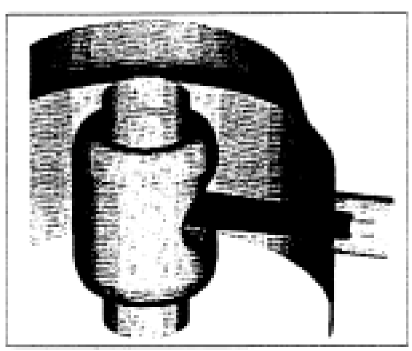

Fig 2. Insulated rod connecting the HV conductor and the grounded metal chamber in a gas insulated substation

The insulated rod contains two metal inserts, one each at the earth and HV ends. The maximum electric field value and distribution must be determined. We need to define the internal breakdown voltage value inside the resin to determine material suitability. Also, we need to define the flashover voltage along the surface between the HV conductor and the grounded chamber.

The maximum electrical stress in the epoxy resin is on the curvature radius of the HV electrode (figure 3). The junction of the rod and the HV conductor is well shielded and shows low field values. Consequently the maximum field on the rod surface is situated more central to the length.

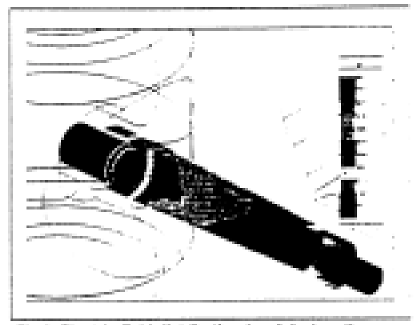

Fig 3. Electric field distribution (modulus) on the surface of contact between the epoxy resin and the embedded electrodes and on the external surface of the insulated rod

Optimisation occurs by modifying the curvature radius of the HV insert or its position with respect to the HV conductor. The COULOMB analysis is repeated until the stresses and distributions are reduced to an acceptable level.

There are also occasions when it is necessary to predict the behaviour of the fields in a device under conditions that change the original electrostatic configuration (ie. the accumulation of static charge on insulators, pollution or transients provoked by discharge).

A BEM based analysis tool is found to be ideally suitable for electrostatic prototyping in HV Switchgear design. One example of common problems in HV Switchgear shows how it is possible to get fast and accurate results of electric field distributions using 'virtual' prototypes. While the engineer must still analyse the information from the 'virtual' prototype and finalise optimising changes, CAE design tools enable real-time prototyping in a cost effective manner. **EDI**

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