INTEGRATED ENGINEERING SOFTWARE

Electric field calculations are essential for high voltage insulators

By Prathap Basappa of Norfolk State University, Virginia, USA.

Occurrence of water droplets due to environmental conditions on outdoor high voltage (HV) insulators can lead to localised field enhancement, causing partial discharges and dry arcs which can ultimately result in complete flashover. The reason for this study was to explore the effect of contact angle of water droplets on electrical stress intensification and its implications. Delivering power from a generating station and delivering it to the end customer – whether a consumer or a business- is a complicated process. Ultimately a power grid is as good as its weakest link. A major part of the grid is designing and creating insulators that reduce the likelihood of failure due to flashovers.

These insulators provide isolation between HV power lines and the grounded structures and need to be able to survive the extremities of electrical and mechanical stresses in order to achieve a better longevity. There are two types of insulators present in the market today, Ceramic and Non-Ceramic or Polymer Insulators. Polymer insulators, which were introduced in the 1970's, are increasingly being used due to their characteristics such as better hydrophobicity, light, weight and ease in handling. However, ageing through deterioration is unavoidable since the polymer insulators are made up of organic materials.

When exposed to certain environments, such as pollution, wet conditions, acid rain and ultraviolet radiation, the ageing of the polymer insulator speeds up. Whilst pollution is of little significance under dry conditions, the presence of water droplets enhances the electric field intensity, which causes the droplets to become deformed and elongate in the direction of the electric field. This results in a shortening of the insulating distance, causing a leakage path on the insulator surface. Development of arcs takes place, and ultimately results in complete flashover. Hydrophobicity is affected by this phenomenon, decreasing the lifetime of the insulator. Even under relatively moderate applied voltages, the enhanced stresses occur at triple points of solid, gas and conductor interfaces and initiates partial discharges. Photons and ions produced by the discharges may lead to secondary electron emission and other discharge processes along the solid and trigger flashover, if the stress is sufficiently large.

To increase the longevity of the insulator a study has been undertaken of the behaviour of water droplets on the insulator in presence of electric field. This was done using a 3D Boundary Element package from INTEGRATED Engineering Software. The COULOMB modelling software is a 3D electric field solver used for applications such as power transmission lines, transformers, insulators, bushings and grounding electrodes. Its calculations include electric field strength, force, torque and capacitance and designers can automatically vary and experiment with geometry, materials and sources.

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The sheath part of the insulator has a narrower dimension when compared to the shed region, which means it experiences a higher amount of stress. On the sheath region, the water droplets will deform into an ellipsoidal shape that leads to greater enhancement of the electric field. Simulation showed that along the sheath, the direction of stress concentration is tangential to insulator surface, explaining why the stress concentration occurs at the triple point between insulator, water and air. In the case of water droplet on the shed the electric field is perpendicular to the shed. Because of this the electric field is enhanced at the top of the drop away from the insulating material comprising the shed. This means that the corona initiation, and subsequent flashover, occurs at the sheath region and the field distribution in the shed region may not significantly affect the conditions. In reality there are often many water droplets on the insulator and each drop would have an effect on the electric field and on each other.

The first set of results show that water droplets in the sheath region greatly contribute towards enhancing the probability of initiation and progression of wet flashover on the insulator surface. The second set of simulations revealed that the electric field intensification is more when there is abatement of hydrophobic property on the SIR insulators when compared to the discrete droplets case. The team concluded that on application of higher voltages the percentage of the length of the insulator, where the field exceeds the streamer threshold, voltage also increases as well as in locations where the voltage spikes (implying locations where the flashover can probably start) occur. Reduction or absence of hydrophobicity leads to formation of water films but when hydrophobicity is increased by RTV coating the possibility of water films forming is drastically reduced. The water films are broken up into discrete particles and, although the voltage spikes are increased in number, the stresses at the initial water droplets end, close to the HV, only exceed the streamer threshold voltages.

Using software for modelling and simulation made all the difference to the work required for this study as it would involve writing several thousands of lines of code, debugging and implementing complex surfaces and interfaces Much of the modelling work was undertaken by students, under the guidance of a junior and senior professor, and they all found the simulation programmes easy to use with good back-up and assistance from INTEGRATED Engineering Software. Apart from its ease of use, one benefit the team found using COULOMB was that they were able to create complicated geometries and obtain usable results in a relatively short amount of time. In the past solutions were pure guesswork and the results could never be exact. Now the calculations are done within the software reducing the need to play around with coding. One can concentrate more on analysing the results and producing useful practical conclusions instead of incessantly debugging and creating meaning out of numbers which may not be accurate.