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Electromagnetic Field due to a Single Electron Avalanche on Transmission Line Conductors

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Electric power is indispensible in the modern world. For various reasons, the generating plants and the load centers are geographically separated by large distances. Bulk power transmission over large distances is possible only through the use of high voltage transmission line systems. At present, overhead transmission lines (both AC and HVDC) dominate the scenario with EHV and UHV transmission systems extensively in operation. With further and rapid growth of power demand, transmission at even higher voltages is being sought.

The use of high voltage results in high surface gradients at the surface of the line conductors and transmission system equipment and hardware. Although the transmission line conductors and equipment are suitably designed to control the surface gradient, close to surface irregularities, locally the gradient may reach extremely values. These surface irregularities can arise during installation and operation, in the form of surface abrasion, accumulation of dust particles, water drops, bird droppings, particles of vegetation, snow etc. The local intensification of the electric field, along with the fact that the intrinsic geometry of the transmission system, results in non-uniform distribution of electric field in the vicinity of the electrodes, leads to corona.

Corona is a local, partial breakdown of air (or other gas), which takes place when the electric field exceeds a certain critical or threshold value. It produces a violet glow, hissing sound, acoustic noise, some amount of power loss in the system, chemical degradation of the conductor and more importantly, electromagnetic noise. Corona occurring close to the line conductor induces current (pulse current) in the conductor which has a steep rise (few tens of ns) followed by a relatively long tail time (few hundreds of ns). These current pulses propagate along the line over long distances, undergoing attenuation and distortion producing electromagnetic noise which leads to electromagnetic interference (EMI).

In the earlier days, when the interference problem was first encountered, interference was observed chiefly in the AM radio frequency range (535-1605 kHz) and the low television range (54 to 88 MHz). Studies were carried to quantify the interference, restricting primarily to the AM radio frequency range. However, in the modern world where communication is carried out over much wider frequency spectrum, investigation must be carried out over the appropriate range and if possible, the entire range of frequencies which can be potentially influenced.

In literature, apart from the restriction on the frequency range as discussed above, efforts have been made to quantify, only the noise produced by corona current in the conductor. However, it is well known that the phenomenon of corona should produce its own electromagnetic noise. This is due to the fact that, the basic underlying mechanism behind corona is the electron avalanche. The electron avalanche involves sudden separation of charges (free electrons and positive ions) due to ionization in the space where it develops. These suddenly separated charges which thereafter undergo rapid acceleration in the intensified electric field region (especially the free electrons) can produce their own electromagnetic noise. The frequency spectrum of this noise can be very different from that produced by the corona current and needs to be investigated. However, such a study has not been carried out in literature and therefore is taken up in the present work.

The present work, being the first of its kind will deal with the study of the electromagnetic field produced by a single electron avalanche developing in the vicinity of a transmission line conductor. The field due to corona can be taken up for study in a later work. A number of different background electric fields will be considered and the growth of an avalanche will be traced in each case. The frequency spectrum of the electromagnetic noise will be characterized. Both negative and positive avalanches will be studied and the effect of space charge will also be suitably taken into account in tracing the avalanches.