LOW FREQUENCY INDUCTION IN PIPELINES, POWER LINES AND CABLES

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Abstract:

Large-scale technological systems using long conductors are exposed to electromagnetic disturbances from a variety of sources. Variations in the Earth’s magnetic field, due to electrical currents in the plasma environment above the Earth’s atmosphere, have frequencies from 10-5 to 1 Hz (periods from days to seconds). Interference with power systems occurs at the fundamental frequency of 50 or 60 Hz and its harmonics, and fault currents have a broad spectrum up to kHz frequencies. The induced currents produced by these sources can disrupt the operation of any technological system, such as power transmission systems, can interfere with corrosion prevention on pipelines or interrupt cable communications.

Although the sources of geomagnetic and ac induction are significantly different, the same analysis techniques can be used to study the effects of the disturbance fields on conducting structures. Here we model pipelines, power lines, and cables as multi-layered cylinders with different conductivities and permeabilities. A modeling program, originally developed for investigation of geomagnetic induction in pipelines, is expanded for frequencies from dc to MHz and used to illustrate the attenuation of the fields both outside and inside the layered conductors and to compare the frequency response of the different systems.The response was characterized by calculating the electric field and current in the conducting layers.

The model shows, that the induced electric field in any conductor placed in the same media has three general regimes, depending on the factor kr, where k is the propagation constant of the conductor and r is the radial coordinate. These are: 1) no attenuation by the conductor (kr< 0.2), 2) significant change inside the conductor (intermediate values) and 3) “skin effect” (kr>3), when electric field concentrated only close to the surface of the conductor with total reflection as the limit. The three different regimes of the kr response are seen at different frequencies depending on the size and electromagnetic properties of the conducting structures.

For this study we used cylinders with the properties and dimensions to represent typical copper cables, aluminum/steel power lines, and steel pipelines. At the lower frequencies, the induced electric field is constant. With the increase of frequency, the electric field decreases as 1/f for frequencies above: 50 Hz in the cable, 0.2 Hz in the power line, 0.01 Hz in the pipelines. Then electric field frequency dependence changes from a 1/f to a 1/f

½ at frequency 10 kHz for cable, while for power lines it starts at 50 Hz. For pipelines the change occurs at 200 Hz for pipeline steel with relative magnetic permeability of free space and at 1 Hz for steel with relative magnetic permeability of 250. The impedance of the cable is constant for the frequencies below 10 kHz, for the power line below 50 Hz and for the pipelines below 1 Hz.

The model can be used to show the electric and magnetic fields both inside and outside the cylinder and for frequencies from dc to MHz Results can also be applied for setting boundaries of applicability for different approximations of impedances.