A Low-Frequency FDFD Scheme Based on the Quasi-TEM Approximation Applied to Non-Segregated Phase Bus Structures

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The simulation of 60 Hz current distributions on non-segregated phase bus structures requires that both the skin effect and the proximity effect be modeled accurately, given the large currents flowing on the three-phase bus bars in close proximity, which are normally configured in a side-by-side configuration. The phase bus conductors are assumed to be air insulated and a conducting enclosure is assumed for the non-segregated phase bus system. The simultaneous impacts of skin effect and proximity effect on the bus bar current distributions preclude the use of simple skin effect approximations when analyzing the bus performance relative to conductor heating in an attempt to eliminate hot spots.

A finite-difference frequency-domain (FDFD) scheme is derived to simulate the current distributions on non-segregated phase bus structures. The FDFD scheme, which exploits the quasi-TEM approximation for the multi-conductor transmission line, proceeds in three basic steps. First, the ideal TEM model of the phase bus (lossless conductors, lossless insulating medium) is solved via FDFD. According to the quasi-TEM approximation, the transverse fields surrounding the imperfectly conducting and nonmagnetic conductors of the actual multi-conductor transmission line are accurately approximated by the corresponding fields of the ideal transmission line. Second, using the continuity of the transverse magnetic field across the conductor/insulator interfaces of the bus bars, the longitudinal electric fields at the outer surface of each bus bar are determined according to Maxwell's equations. Third, the internal current distribution in each conductor is determined by solving the TM Helmholtz equation for the longitudinal electric field internal to the lossy conductor via FDFD. The longitudinal electric field on the outer surface of each bus bar serves as the source excitation in the iterative solution.

The overall FDFD formulation is implemented as a two-dimensional solution appropriate for the current distributions away from the ends of the bus bars. Examples of bus bar current distributions are presented for different segregated phase bus geometries of interest. Results showing the interaction of the proximity and skin effects in the bus bar current distributions are examined for different conductor spacings.