Investigation of the transient response of cable screen protection systems using full-wave model derived macromodels to provide enhanced electromagnetic transient studies

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ABSTRACT

Electromagnetic transients pose a threat to cable systems. Arguably, the most susceptible are those that form specially-bonded systems, i.e. single-point bonded and cross-bonded systems. Identification of appropriate cable sheath protection is an essential part of the cable selection and installation process where specially-bonded systems are concerned. Sheath Voltage Limiters are commonly specified at joint bays for specially bonded systems, however, further assessment of their effectiveness often is neglected. In this paper, a detailed circuit model is explored for special bonding systems, with enhancements introduced through full-wave numerical model outputs. Furthermore, a 3D GIS cable termination finite element model is presented to further evaluate the impact of Very Fast Transients for GIS connected cable systems.

KEYWORDS

Insulation coordination, Finite Element Analysis, Very Fast Transients, GIS, Cross-bonding, Sheath Voltage Limiters, Cable Termination.

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INTRODUCTION

Special bonding practices are commonly adopted to achieve an increased ampacity. Their effectiveness is due to the inherent elimination of the induced (circulating) screen currents associated with solid bonding which contribute to cable heating. The limitation of single-point bonding is sheath voltage rise. For long cable routes, generally, those greater than 1km, single-point bonding can lead to sheath voltages in excess of safe touch voltage limits for normal, steady state operation. In these circumstances, a cross-bonding (transposition of sheaths) strategy is adopted to balance screen EMFs and eliminate circulating currents, resulting in an increased ampacity and a reduced sheath voltage. A cross bonded installation generally consists of a number of minor and major sections, determined by the total route length, environmental constraints and cable reel lengths. Depending on the degree of unbalance, it is sometimes necessary to transpose both the core and screen. At both ends of a major section, the screens are terminated to ground, whereas at minor section joint bays, the screens are terminated via SVLs, as shown in Figure 1.

The requirement for SVLs is usually identified during a cable ampacity or an insulation coordination study. A simplified assessment requires confirmation that the SVL MCOV is above the highest ground potential rise, while the residual voltage is below the cable jacket BIL. Further transient analysis is often deemed cost prohibitive, under the assumption that the relatively low cost SVL will function as intended, clamping the overvoltage to below the cable jacket BIL.

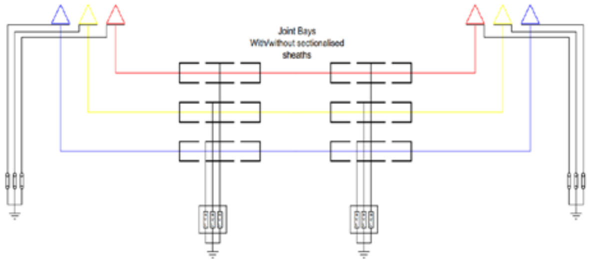

Fig. 1: Cross-bonding arrangement

Optimal functionality of the SVL is only achieved for a perfect ground termination. Grounding systems at joint bays are small; designed to be safe from a touch/step voltage perspective, with a resistance less than 20Ω [1]. For low frequencies, the earthing system response is fairly predictable, however for higher frequencies the response is complex. An example of the SVL response with a realistic high frequency grounding system representation is presented in this paper. The requirement for, in-depth, site specific insulation coordination is clarified through full-wave simulation and the subsequent enhancement of circuit based models.

Further complexity is apparent for the connection of circuits where at least one side is connected to a GIS. For GIS cable terminations, in an effort to reduce the risk to the cable insulation from VFTs/TEVs, cable screens are extended back away from the GIS-cable termination and are bonded to a local earth bar (non GIS enclosure), either directly or through SVLs.

MODELLING FOR HIGH FREQUENCIES

Modelling for high and very high frequencies usually requires careful consideration of the modelling domains, more specifically, electrical lengths. Analytic approximations can provide reasonable initial results, however, where information is available, detailed models, using geometric representations should be considered. Representation of cables and overhead lines according to their geometry is relatively straightford using a line and cable constant routine included in most EMTP softwares [2]. Cables built using these methods can include full frequency dependency using a frequency dependent line model such as the J Marti line . The J Marti line has limitations at high frequencies and can become unstable. The ULM, generally has improved stability, however, it is still under development in some EMTPs.

While line and cable based modelling of transients in EMTPs is generally useful for evaluating the impact of a