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Ground potential rise of multi-grounded neutral and shield wires in joint systems

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ABSTRACT

Power line faults create the ground potential rise (GPR) on both the neutral and shield conductors when the transmission lines (TL) and distribution lines (DL) are built on the same structures. The durations and magnitudes of resulting GPRs are unique for DL faults and TL faults because the corresponding fault currents are significantly different in terms of their magnitudes and durations. This paper analyzes and compares the safety impacts of TL faults and DL faults in the joint structures. Approximate formulas are established to describe the GPR characteristics. Computer simulation results are provided to illustrate the effects of different parameters on GPRs in various configurations.

1. Introduction

The overhead distribution lines (DL) are often built under the transmission lines (TL) on the same towers. The safety impact of such configurations under short-circuit conditions are difficult to understand because the DL-created GPR and TL-created GPR have unique characteristics. The shield wire of TL establishes the direct contact with the conductive towers which serve as grounding of the shield wire. On the other hand, the neutral wire on the same tower is provided with a separate dedicated grounding assembly, or is bonded with the shield wire. The conductors used for the neutral wire and shield wire are not the same. Generally steel is preferred for the shield wire and Aluminum Conductor Steel Reinforced (ACSR) for the neutral wire. Also the physical positions of these conductors on the same structure lead to varying degree of electromagnetic coupling with phase conductors under fault. Consequently, the resulting GPRs are affected even for the same amount of fault currents in TL and DL.

In the past, a lot of studies have been done for single circuit multi-grounded configurations and a great deal of literature is available [1–10], but limited work has studied the composite systems comprised of multiple multi-grounded conductors. Mostly computer-based methods were preferred for the studies of multi-grounded systems. Major shortcomings of such methods include inability to provide intuitive understanding on the interaction and effects of various factors. Alternatively, analytical methods can be developed to compensate such shortcomings. Computer models were used to estimate the GPR of the multi-grounded neutral (MGN) in [2–4] and power flow studies were performed in [5–7]. Analytical approaches for the GPR analysis were proposed in [8–10]. The GPR assessment of multi-grounded communication cable bonded with power line's neutral wire was performed in [9]. The principles of [9] can be applied to the joint transmission and distribution system with multi-grounded conductors. In our previous work, analytical methods were proposed to provide understandings of the characteristics of MGN lines [11]. The work done in this paper complements the previous studies as it is extended to the joint T&D systems.

It is generally agreed that the TL fault currents are larger, but are cleared faster than the DL faults. As a result, field engineers assume that the TL caused GPRs are less severe than the DL caused GPRs. As will be shown later, this assumption is wrong. Also effectiveness of bonding the neutral wire with shield wire for lowering the GPR level is not fully understood yet. This paper reveals a number of factors that play a crucial role in determining the GPR.

The main objective of this paper is to address the above-mentioned concerns by using the analytical formulas and computer simulation. An EMPT-based computer tool was used for the simulation. Since the power industry has accepted the associated techniques and models, they are not described here. Detailed models can be found in [12]. Sensitivity studies are performed to illustrate the effect of a number of parameters on the GPR. The reminder of the paper is organized as follows. Section 2 presents the problem and the system under investigation. Mechanism of GPR generation is presented in Section 3. Results are shown in Section 4 and the conclusions in Section 5.

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