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Using Real and Simulated Records to Design Transmission Line Traveling Wave-Based Fault Location Solutions

1. INTRODUCTION

Various traveling wave (TW)-based fault location (TWFL) methods have been proposed over the years and they keep evolving [1]. In recent developments, other TWs rather than the first incident ones are analyzed, such as ground mode and TWs reflected or transmitted at the fault point [2]. The detection of these waves is more challenging than the detection of the first incident aerial mode ones, so that having reliable real and simulated TW records during the design of TWFL solutions is of utmost importance to meet practical application requirements.

2. GOAL

Share experiences on the design of TWFL solutions using real and simulated data, highlighting important modeling aspects to obtain reliable simulated records.

3. SIMULATED AND REAL RECORDS COMPLEMENT EACH OTHER

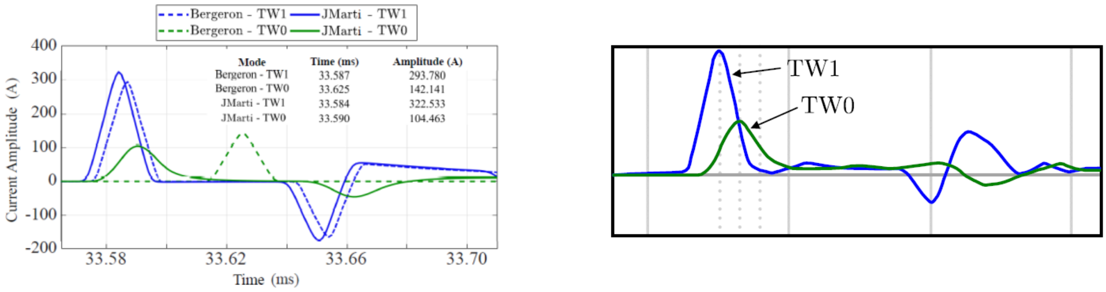
The design of TWFL solutions can be conducted by using real or simulated data. In each case, there are advantages and limitations. To explain such a question, consider that a TWFL solution is under development. Hence, the real fault position of testing cases is the reference information. Therefore, ideally, a wide variety of real fault records should be available, and, for each scenario, the exact fault point should be known. When the fault position is accurately identified in the field, a valuable information is obtained, such that TWFL strategies can be assessed without the need for approximated computational models to represent the monitored grid, such as those in Electromagnetic Transients Programs (EMTP). However, real records are usually available in a limited number, which limits the variety of fault scenarios that can be assessed. Moreover, not so rare, line maintenance crews register the fault position with some level of uncertainty. As a result, it can be difficult to use only real data during the design of TWFL solutions. In this sense, it is prudent to analyze firstly simulated faut records in a controlled environment and, then, once the theoretical TWFL accuracy is identified, to move on to the analysis of real records. Indeed, using both real and simulated data is recommended.

EMTP platforms have been used to simulate TW records. Thereby, EMTP models should be as realistic as possible, otherwise, simulations may be unrepresentative. Whenever it is possible, it is recommended to firstly identify TW features in real records, and then, to reproduce them in EMTP simulations. As a result, realistic EMTP models are obtained, allowing realistic and flexible simulations in which there is no uncertainty about the fault point.

4. EMTP MODELS FOLLOWING TWFL TRENDS

TWFL methods are evolving towards being parameter-free and independent of time synchronization [1]. It facilitates the practical application of modern TWFL. However, other fault-induced TWs than the first incident ones are required to be detected, such as those reflected/transmitted at the fault point, and ground mode TWs. These TWs must be realistically represented in EMTP, so that there are crucial modeling aspects to be considered.

1) Frequency dependence of line parameters: In Figure 1, aerial (TW1) and ground (TW0) modes TWs (obtained through Clarke's transformation) measured by means of an off-the-shelf TW filter are compared, considering simulated and real records from a single-phase fault case [3]. Two EMTP line models are analyzed, namely: Bergeron (frequency-independent parameters, set at the fundamental frequency) and JMarti (frequency-dependent parameters). It is noticed that, when Bergeron model is adopted, TW0 behavior in the simulated record is quite different from the one observed in the real record. Since mixing mode phenomena can also result in differences in reflected and transmitted TW1s, aerial mode can be also indirectly affected. Therefore, it is concluded that JMarti model is more realistic, attesting the importance of considering the frequency dependence of line parameters.



(a) (b)

Figure 1: Comparison between simulated and real TW records: (a) Simulated; (b) Real [3].

2) Earth resistivity uncertainties: Figure 2 shows the previous simulated example (using JMarti line model), but varying earth resistivity (ρ_e) [3], which usually consists in a typical source of uncertainties in line parameters. The results demonstrate that the behavior of TW0s is affected by ρ_e, since they present different time displacements for each ρ_e. In practice, it would result in uncertainties about the TW0 arrival times and ground mode settings. Moreover, due to mixing mode phenomena in grounded fault scenarios, TW1s can be also influenced. Thereby, accurate earth modeling is also important, especially if TW0 are under investigation.

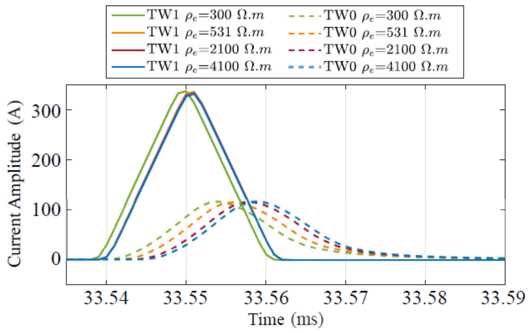
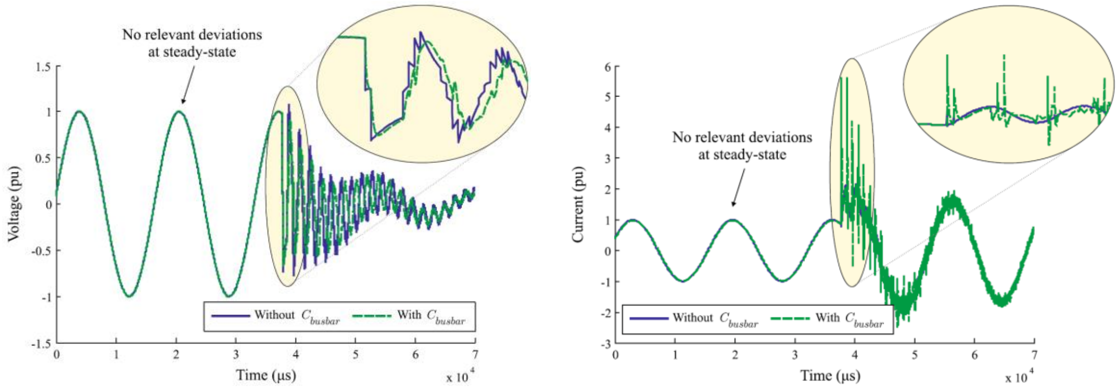


Figure 2: TW0 and TW1 for different earth resistivities [3].

3) Line termination features: TWs measured at line ends are given by the superposition of incident and reflected TWs. Since the reflection coefficient depends on the line termination, they dictate the waveshapes [4]. In lines surrounded by other lines, the equivalent characteristic impedance of adjacent lines is typically considered to determine the termination feature, leading other equipment to be less determinant in the reflection coefficient. However, for transformer-terminated lines, TW studies require busbar and/or transformer stray capacitances to be modeled, otherwise, simulated TWs become quite different from real ones. Figure 3 shows transients in a transformer-terminated line, with and without the busbar stray capacitance C_{busbar}. Differences between signals in each case are evident, and they attest the need for detailed termination representation when the monitored line has no adjacent lines.



(a) (b)

Figure 3: EMTP simulation of transformer-terminated line: (a) Voltage; (b) Current [4].

5. CONCLUSIONS

Using both simulated and real records is beneficial for TWFL design procedures. As a first step, real data supports realistic EMTP modeling. Then, using simulated data to provide flexibility in the variety of evaluated scenarios is suggested. Finally, once the theoretical accuracy of the TWFL solution is identified, real data can be used to validate the designed TWFL solution. It guarantees the robustness required for practical applications in the field. Even so, it is recognized that sometimes real records are not available. In these cases, using realistic EMTP simulations for TWFL design procedures is an acceptable alternative, but it does not exclude the importance of validation steps using real data.

7. REFERÊNCIAS

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