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Electromagnetic Time Reversal for Power System Reliability

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This paper introduces the results obtained so far using electromagnetic time reversal (EMTR) to locate partial discharges (PDs) in power systems, aiming to improve their reliability.
PD events, occurring inside insulator defects, can lead to faults or supply interruptions. Accurate PD localisation methods are crucial tools for protecting power systems and improving their resilience. In EMTR-based PD localisation [1], the measured PD signals are time-reversed and re-emitted back into the system model. During the simulation of the time-reversed signals, the maximum value of the signal is expected to occur at the source location. Results so far indicate that the EMTR method, using only one observation point (OP), exhibits significantly improved performance compared to classical approaches based on Time Domain Reflectometry. It has been demonstrated that EMTR is: 1. Robust in the presence of noise, 2. Effective in systems with multiple inhomogeneities, and 3. Capable of handling heavy distortion of the PD signal caused by interfering signals from the cable circuit. As evidence, Fig.1.a) shows the localisation results for a 2 km cable under noisy conditions [1], and Fig. 1.b) presents the results when the PD signal is distorted by interfering signals at the OP, in the Ring Main Unit (RMU), originating from the PILC circuit sections [2]. In the investigated straight system configurations, the method achieves PD localisation with a relative error of less than 1% of the total line length, using only one OP.

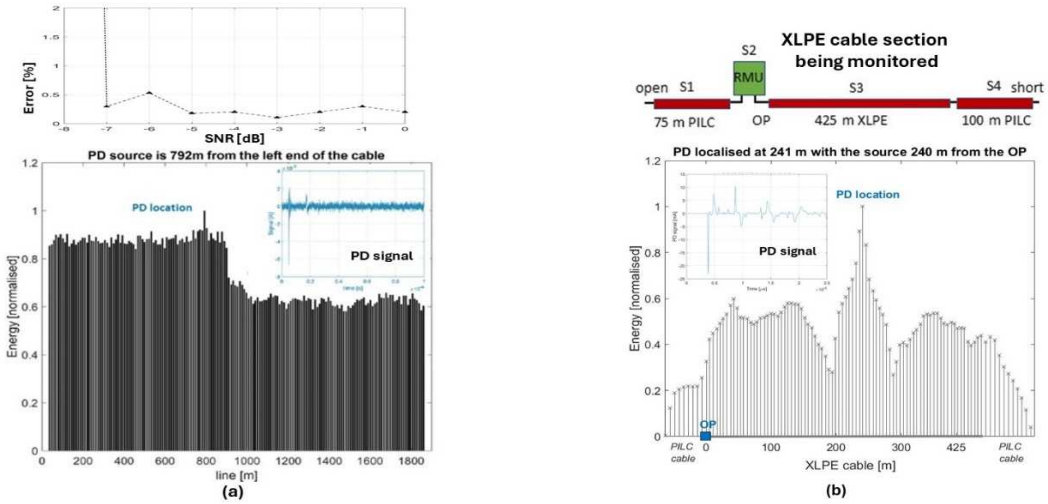

Figure 1. EMTR-based method results for PD localisation [2, 3].

The challenges in PDs localisation using EMTR involve its application in more complex power systems, such as those with multiple branches and ring structures, commonly used in transmission and distribution power networks or on-board systems in ships and aircraft, operating with both AC and DC supplies. For more complex structures, the use of additional OPs with synchronised measurements becomes necessary to avoid incorrect identification of multiple sources. By optimising the placement of the minimum required OPs, the process can be simplified, and the overall cost associated with the computational effort, sensor deployment and measurement equipment will be reduced. DC systems are of particular interest because of the increasing use of renewable energy sources (RES), to reach the Net Zero target. This trend is driving research in power generation, transmission and delivery in maritime, rail, aviation, and road transport. However, PD monitoring and localisation in DC systems remain still in an early stage of development.

1. A. Ragusa, H. Sasse, A. Duffy, M. Rubinstein, “Application to Real Power Networks of a Method to Locate Partial Discharges Based on Electromagnetic Time Reversal”, IEEE Trans. Power Del., Vol. 37, No. 4, Aug. 2022.

2. A. Ragusa, P. A. A. F. Wouters, H. Sasse, A. Duffy, Farhad Rachidi, Marcos Rubinstein, “Electromagnetic Time Reversal for Online Partial Discharge Location in Power Cables: Influence of Signal Disturbance and Interfering Reflections from Grid Components”, IET Sci. Meas. Technol.2024;1–8.