An Optimized Implementation of Online PD Monitoring for Large-Scale MV Networks

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ABSTRACT

Empowering sustainable electrification and digitalization calls for increased resilience and reliability of the cable grid and managing efficiently assets that passed their design lifespan. One way to comply with these demands is efficient maintenance of critical areas of the network, especially by controlling the insulation condition of the cables. Partial discharge (PD) monitoring provides an indication of the degradation of the electric insulation prior to failures and is considered an efficient method for condition monitoring of the cables. This paper explores the behavior of PD signals in medium voltage (MV) underground cables, which are prone to damage due to various types of stress. The most at-risk areas for insulation defects are cable joints and terminations. As insulation faults progress, they generate PD signals that are difficult to capture using online diagnostic methods due to the attenuation and dispersion schemes imposed by switchgears and transformers. The study examines the propagation of PD signals through a joint configuration and presents simulation-based results for PD propagation in a real MV underground feeder. These findings can enable the development of more efficient PD monitoring systems for underground cable networks.

KEYWORDS

Continuous monitoring, distribution grid, partial discharge (PD) monitoring, PD signal propagation, sustainable electrification , underground cables, proactive maintenance, lifetime extension

INTRODUCTION

The increasing demand of electricity, driven in part by the rise of electric vehicles and the growth of distributed renewable energy sources, has placed a greater emphasis on improving energy networks in France. In 2019, renewable energy accounted for 23% of France's electricity generation, with the government aiming to reach 33% by 2030 [1]. As urbanization continues to grow, there are increasing concerns about public safety, environmental impact, land value, and network reliability, leading to a preference for underground cables over overhead lines. For example, in the city of Lyon, the city government has launched an ambitious plan to remove overhead lines from its city center by 2026, and replace them with underground cables [2].

Partial discharge (PD) is commonly used to identify and follow weaknesses of the medium voltage (MV) cable grid, especially in the context of inherited installation quality issues, more severe climate events and flexible usages fo the grid. PD are usully generated when an insulation weakness appears and progress in the cable or accessories, leading ultimately to a breakdown. Tradional offline PD and tan delta (tanD) measurements with very low frequency (VLF) generators are well-established diagnostic principles for making a first assessment but have several limitation. Offline PD measurements require expensive equipment and experienced operators to analyze the results, and can only be performed when the cable is unenergized, limiting their ability to detect intermittent PD sources that may not present themselves during a regular (annual) measurement [3]. To overcome these limitations, online PD monitoring has been developed as a cost-effective and reliable alternative. Online PD monitoring systems can continuously monitor the insulation condition of MV cables during normal operation, detecting intermittent PD sources and providing real-time alerts for maintenance. For example, in a recent study in France, online PD monitoring was used to detect and locate PD sources in an industrial plant's MV cable feeder, allowing for efficient maintenance of the system [4]. Other studies have also shown the effectiveness of online PD monitoring in detecting insulation defects in MV cables [5], and the use of advanced signal processing techniques to enhance the accuracy of online PD monitoring [6].

PDs induce high-frequency current pulses on the cable conductor and metallic screen, which can be detected using high-frequency current transformers (HFCTs) located at the end of the cable sections [7]-[9]. The use of HFCTs for PD detection is an effective and reliable method for condition monitoring of underground MV cables; they work by capturing the small electrical currents generated by the PD activity. It is usually placed around the cable and is designed to capture this pulse. The signal captured by the HFCT is then processed by a PD detection system, which analyzes the frequency and magnitude of the signal to determine the location and severity of the PD activity.

For HV underground cables, HFCTs are usually installed in joint pits accessible through manholes, but this is not a common practice in underground MV cable systems as these joints have usually no screen interruption and are often buried without a known location, making it challenging to install sensors without disrupting the cable system. Instead, since MV cables are usually terminated inside substations or ring main units (RMUs), the only place to detect PD signals propagating through these cables is at the cable terminations [3]. Therefore, PD monitoring systems can be installed at predefined locations inside substations, reducing cost and effort as compared to monitoring single cables with multiple HFCTs.

Large substations are typically composed of various complex components, including switchgear (SG), transformers, and MV cables. The load impedance as seen by a PD pulse coming from a cable does not match the cable's characteristic impedance due to these components. When a PD pulse that travels through the cable being tested reaches an RMU or substation, some of the pulse will reflect and some will transfer to the next MV cable(s). This causes a change in pulse shape and amplitude, which can affect the sensitivity and accuracy of PD detection [8].