Effective Noise Suppression for Online MV Cable Monitoring Using Double-sided Measurement and PD Pulse Characterization

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ABSTRACT

On-line Partial Discharge measurement is an effective asset management tool for underground power cables. Double-sided measurement with synchronized sensors can be used to locate pulse origin (potential weak spots), which aids in removing disturbance signals from outside the circuit under monitoring. To further improve the analysis under increasing amounts of disturbance-like signals, a novel concept of introducing wave-shape information from pulses is introduced. Signal features for PD recognition have been developed based on a large dataset.

Data evaluation from live circuits based on principal component analysis shows good separation between PD-type pulse and disturbances – allowing enhanced PD detection.

KEYWORDS

Online Partial Discharge measurement; Medium Voltage Power Cables, Big Data analysis, Machine learning, Noise suppression.

INTRODUCTION

At the Medium Voltage (MV) cable grid, limited redundancy, congestion, aging cables, and resource constraints can challenge the energy transition. The MV grid is a critical link to establish connectivity for facilitation of de-central generation and increasing residential electricity usage. However, this grid is often built on ageing infrastructure previously designed on outdated load assumptions. It is also widely spread among neighbourhoods and dense cities, so increasing capacity by placement of new cables is time-consuming and resource intense. Maximizing the usage of the current assets is therefore desirable, however with cable ages reaching many decades, care needs to be taken not to compromise quality of service [1].

Good insight into cable condition is a pre-requisite for maintaining service quality (SAIDI/SAIFI) balanced against the need for capacity expansion: one would want to replace weak spots timely but keep (old) existing connections in service as long as possible. This even before potentially considering to stretch cable loading further than (legacy) default limits to extended (dynamic) ratings.

Condition based maintenance is used to plan replacement and expansion strategies with accurate condition data. Partial Discharge (PD) measurement is an established technique for accurate cable condition information with the benefit of having data with located PD, which allows focused replacements of weak spots. For instance, a weak spot on a joint does not always mean the cable needs replacement over a long length. Furthermore, the severity of the weak spot may allow to postpone repair until convenient or at times when risk is limited [2].

PD measurement can be performed offline or online, where the latter has the benefit of providing data continuously, thus providing more timely information as well as the opportunity for trending. Continuous online measurement can provide vastly more insight, which allows to detect a weak spot as soon as it is measurable and to track its activity over time. Not only does this reduce risk of missing a defect when it arises between intervals of (singular) measurement, but it assists in understanding the development of the weak spot. The development can be related to the component type, environmental parameters (e.g., soil, temperature) and the way the cable is operated. In the first place this can establish knowledge about development towards failure. Secondly it can be used to estimate risk of failure based on trending data (e.g., increasing PD charge levels or density), not just a single threshold for criticality. Eventually, the data collection (learning) on defects can assist risk assessment, therefore incrementally reduce uncertainty.

A challenge with online monitoring, however, is that background noise and disturbance signals in a live operating power network must be considered. Proper signal capture (sampling) and filtering is critical to control effective monitoring. Common statistical approaches can be used, where random signals can be ignored. The use of location (determining signal pulse origin in the network) gives an effective approach to filter noise and disturbance signals from e.g., ring main units. However, with substantial amounts of disturbance signals - e.g., found with power conversion systems in the network - it can be challenging.

In this paper, a novel approach for 'enriching' pulse measurements with useful data about its pulse shape is described. The method can be used to separate PD pulse from disturbance pulses. In the next section, basic measurement principles with respect to online PD monitoring are given, followed by exemplary considerations for noise aspects. Next, the method of pulse characterization is described, followed by examples in PD detection charts. Exploratory analysis based on principal components is described. Finally, conclusions and future work steps are given.

ONLINE PD MEASUREMENT PRINCIPLES

A PD source in the middle of a cable system (typically caused by a defect in the insulation) will induce a pulse that is injected towards both directions away from the source. This pulse can be detected at terminals of that cable, using a (high frequency) current transducer. The pulse, which is in the order of dozens of milliamperes near the source, will be subject to attenuation and dispersion while it travels through the cable system from the source to the transducer (sensor). At the sensor position, the pulse signal must be detected against the background noise in a live network. In a power network, however, many other components