HV CABLE DIAGNOSTIC BY TIME DOMAIN REFLECTOMETRY OR FREQUENCY DOMAIN ANALYSIS?

A COMPARISON OF SENSITIVITY TO FAULT IMPEDANCE AND CABLE LENGTH

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ABSTRACT

Frequency domain analysis (FDA) and Time Domain Reflectometry (TDR) are two cable fault localization methods. FDA and TDR employ changes in the impedance of a cable caused by damages or aging. Those changes might be very small or far from the position of the measurement devices and reach the physical limitation of applicability of these methods. In this paper measurements and simulation results are presented, which evaluate the limitations of both methods in identifying of deviations in cable properties, detectable fault impedances, and measurable cable lengths. Moreover, this contribution gives a theoretical and practical comparison of FDA and TDR method.

KEYWORDS

Cable Fault Localization, Frequency Domain Analysis (FDA), Time Domain Reflectometry (TDR), HVDC Cable Systems

INTRODUCTION

Cable diagnostic and fault localization methods are used to estimate the condition of this asset and to detect faults in an early stage. Consequently, this leads to the reduced downtimes imposed by sudden cable faults as well as the consequent unplanned repairs. There is a variety of methods for the detection and localization of faults in cable systems. Some of these methods e.g. dissipation factor measurement can just detect aging, but not localize the faults. Some other methods use high voltage impulses to localize the faults, which can damage the cable. In contrast, two methods namely Time Domain Reflectometry (TDR) [1, 2] and Frequency Domain Analysis (FDA) [3, 4] can detect and localize some types of faults in cable systems using very low voltage signals. Both methods have significant advantages despite their weaknesses. The basic principle of the TDR method is injecting and measuring a voltage impulse in the conductor of a cable and accordingly measuring the reflections of the injected impulse resulting from a cable fault. The FDA method measures the complex input impedance or the transfer function of a cable as a function of the frequency. With both methods the cable characteristics are determined and evaluated with the help of the transmission line equations.
The input impedance depends on the material properties, the dimensions and the length of the cable. If these parameters change along the cable, for example due to damages, amplitudes and phase angles of the frequency-dependent complex impedance change. As a result, both damages and impairment of the conductor as well as the insulation and metal screen could be detected. TDR and FDA employ changes in the impedance of cable system caused by damages or aging. Those changes might be very small and alternative methods are needed to identify those minor changes, or when they are far from the position of the measurement devices. In this paper evaluations are presented, including the limits of both methods for the identification of small deviations in cable properties.
A drawback of both methods is the physical limitation of signals being attenuated up to a degree, where measurements are not possible any more when travelling through a cable. The major differences between TDR and FDA in their physical limitations have been investigated.
Another problem which involves both formerly mentioned methods is their sensitivity to fault impedances. Localization of low ohmic faults is less complicated than high ohmic faults, which in some cases could not be identified. In this contribution, the performance of both methods for detecting different types of failures was studied on several medium voltage (MV) cables with different lengths. The failures have been created artificially, which allows to identify the degree of sensitivity to the fault impedance.
It is common to consider faults in the cables as just a pure resistance, but in the reality, most of faults in cables cause a deviation in geometry of the cable at the fault position. It can be interpreted as a change in the capacitance, inductance, and conductance of the cable. These variations in the cable parameters have to be taken into account to localize the faults precisely. Some of these deviations are high enough to be detected by the fault localization methods, and the others are very small so that a precise method is required to detect and localize them.

THEORETICAL BACKGROUND

In the following the theoretical background is presented, that is essential for understanding the behaviour of an electrical line. The chapter is therefore a basis to understand the subsequent practical experiments as well as to evaluate the measurement results.

Frequency Domain Analysis (FDA)

FDA is a method to classify and to localize the faults in both HVAC and HVDC cable systems with a large measuring range from some meters up to some hundred kilometers [3, 6]. This method works on the principle of the transmission line theory and measures the complex input impedance of the cable as a function of the frequency. This input impedance depends on the material properties, the dimensions and the length of the cable. The frequency response of the injected sweep voltage is dependent on electrical parameters of the cable.

If these parameters change in the cable, for example because of aging or damages, the position, amplitude and phase of the frequency-dependent complex impedance