A defect location method for underground cables based on indirect power spectral density

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ABSTRACT

In order to improve the accuracy of frequency domain reflection (FDR) method in locating defects of underground cables, this paper proposes a defect location method for underground cables based on indirect power spectral density. In this method, the reflection coefficients of underground cables are self-convolved to reduce the influence of spurious peaks generated by multiple reflections on positioning, and the self-convolution of reflection coefficients is processed by the fourth-order Hamming self-convolution window (HSCW) to reduce the spectrum leakage of FFT. Then, the power spectral density (PSD) spectrum is estimated by FFT, and the corresponding frequency is found by spectral peak search to complete the soft fault location. Finally, the effectiveness and practicability of the proposed method are verified by comparing the positioning results of the FDR method on the simulated 2000 m cable and the measured 9.7 km submarine cable.

KEYWORDS

defect location, power spectral density (PSD), underground cable, frequency domain reflection (FDR.

INTRODUCTION

In recent years, cross-linked polyethylene (XLPE) power cables have been widely used in urban power transmission and distribution systems [1-3]. However, these cables have some disadvantages, including damage by external forces during laying, corrosion in harsh operating environments, and local temperature rise of the cable insulation layer. These factors can cause the local electrical parameters of the cable to change slightly, resulting in weak local defects [4-5]. If the local cable defect cannot be detected quickly, the cable insulation will eventually fail under the action of the electric field. Such failures create the risk of unstable or unsafe cable operation. Therefore, it is essential to efficiently detect local cable defects.

The defect location method based on traveling wave theory is favored by scholars. Among them, time domain reflectometry (TDR) [6-8] and frequency domain reflectometry (FDR) [9-11] have been widely used in the field of cable defect location. The TDR method locates the defect by injecting a pulse signal into the cable and estimating the delay between the incident signal and the reflected signal from the defect . However the TDR is not able to detect and localize the soft faults like as frays or chafes that produce small anomalies[12-13]. On the basis of TDR, many improved methods have been proposed, such as the time-frequency domain reflectometry (TFDR) [14-16], the spectrum time domain reflectometry (STDR) [17] method and the spread spectrum time domain reflectometry (SSTDR) [18] method has proposed. The TFDR selects the chirp signal as the incident signal and Wigner-Ville distribution (WVD) as the kernel function of time-frequency analysis, and location defects by time-frequency cross-correlation function. However, the reflection signal is the superposition of multiple reflections, and the WVD does not satisfy the linear superposition principle, which produces severe cross terms in the localization spectrum [19]. The STDR and SSTDR are few studies on locating soft faults in long cable with these methods [20].

The FDR method injects sinusoidal sweep signal into the cable to obtain the reflection coefficient information of the cable, and obtains the localization spectrum of the defect by fast Fourier transform (FFT). However, spectrum leakage occurs during FFT, which leads to inaccurate defect localization by FDR. Moreover, multiple reflections lead to pseudo peaks in the FDR spectra, which interferes with the judgment of defects [20].

In this paper, a defect location method for long underground cables based on indirect power spectral density is proposed. In this method, the reflection coefficients of underground cables are self-convolved to reduce the influence of pseudo peaks generated by multiple reflections on positioning, and the self-convolution of reflection coefficients is processed by the fourth-order Hamming self-convolution window (HSCW) to reduce the spectrum leakage of FFT. Then, the power spectral density (PSD) spectrum is estimated by FFT, and the corresponding frequency is found by spectral peak search to complete the soft fault location. Finally, the effectiveness and practicability of the proposed method are verified by comparing the positioning results of the FDR method on the simulated 2000m cable and the measured 9.7km submarine cable.

BASIC PRINCIPLES

Transmission line model of cable

Transmission line is a distributed parameter network, which is described by the electrical parameters of the line distributed on the transmission line. According to transmission line theory [21], when the cable length is much larger than the signal wavelength, the cable should be represented by the distributed parameter model as shown in Fig. 1.