Condition Assessment of Overhead Line Insulators using Advanced Techniques

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Abstract

The insulators utilized on overhead lines come in various types and are made from different materials that help to prevent current flow from their surface towards the ground. Outdoor insulators face numerous external hazards, which degrade their life span. In addition, insulators provide mechanical support to the overhead lines. Failure of the overhead line insulator leads to a raised threat of power disruption in the system. Environmental pollutants cause surface degradation of overhead line insulators. Premature failure can be seen on the overhead line insulators because of the surface contamination severity. To keep the system healthy, the condition of overhead line insulators should be monitored regularly. The analysis of leakage current is one of the condition assessment techniques and it is a well-known method for investigating the surface condition of overhead line insulators.

In this thesis, the data analysis models of leakage current signature have been implemented for forecasting the condition of in-service overhead line insulators. The thesis work has three main parts: collecting data, finding important features from the data, and inferring the degree of contamination on overhead line insulators by utilizing those features. Besides that, in this thesis work, different types of signal processing models such as mathematical morphology, hyperbolic Stockwell transforms, and cross-hyperbolic Stockwell transforms are used to detect the condition of overhead line insulators, which will help to avoid premature failure of the insulator.

Chapter 1 of the thesis introduces an elaborate discussion on the ongoing research for condition assessment methods of overhead line insulators and highlights the proposed research gaps.

Chapter 2 represents the overall laboratory-made hardware schematic of the thesis work. Furthermore, this chapter provides a detailed explanation of creating artificial samples following IEC regulations and recording surface leakage current signals for insulators used in overhead lines.

Chapter 3 discusses the proposed technique for examining the severity of the contamination accumulated on the exterior of porcelain insulators. This process involves measuring the amount of leakage current flows from the surface of the porcelain insulator. For this reason, at different degrees of contamination, an experiment setup is used to record the surface leakage current (SLC) of porcelain insulators. Besides that, the recorded SLC signals are studied using a mathematical morphology tool that processes the SLC signals and extracts the relevant features. Besides that, the proposed model can easily capture changes in the waveform of SLC signals with respect to the surface contamination of insulators as extracted features. Also, the performance of the morphological features-based framework is validated by a Random Forest (RF) classifier. Moreover, the proposed framework can precisely detect degradation levels of surface contamination of porcelain insulators using non-stationary SLC signals.

Chapter 4 represents hyperbolic stockwell transform-aided time-frequency domain surface leakage current analysis to predict the surface contamination of the overhead line Silicone Rubber (SiR) insulators. This framework transforms surface leakage current signals into a time-frequency domain image using the Hyperbolic Stockwell Transform (HST). Applying HST to the SLC signals generates a matrix known as the Hyperbolic Stockwell (HS) matrix, representing the SLC signals in both time and frequency domains. The matrix is separated into two components, namely the phase spectrum and the magnitude spectrum. Thereafter, it subsequently recognizes fifteen statistical characteristics referred to as HST features. The most optimal HST features are selected through LASSO regression. The four

machine-learning classifiers are employed to evaluate the level of contamination on the surface of polymeric insulators using the key HST features. Notably, through comparison with other time-frequency domain methods, the performance of the suggested framework has been tested. According to the outcomes, the proposed framework has achieved greater precision.

Chapter 5 presents a cross-spectrum-aided deep learning framework that automatically predicts overhead line insulators' surface contamination degree. In this research, the SLC signals of different surface contamination levels are converted into time-frequency domain images using HST. Thereafter, the converted time-frequency images are cross-correlated with a reference time-frequency image. Notably, the reference image selected from the time-frequency domain is a converted image of a non-contaminated SLC signal. For this purpose, the cross hyperbolic Stockwell transform (XHST) has been applied to the surface leakage current signals. After that, time-frequency cross-spectrum images are fed to a pre-trained CNN architecture (i.e., VGGNet-16). Furthermore, deep learning algorithms are associated with the proposed CNN model that can automatically extract the optimal (deep features) features from the cross-time-frequency spectrum and, from there, detect the surface contamination class of SiR insulators. Moreover, the model is able to capture non-stationary changes in time-frequency images with the variation of surface contamination classes. Lastly, the prediction of contamination severity by the proposed model has been verified with different dimension SiR insulators.

Chapter 6 summarizes the thesis work, such as research gaps, findings and comparison between existing research work and the proposed research model. The author describes the possible research opportunities and developments in the condition assessment study of overhead line insulators.