Abstract

The interfacing of renewable energy sources (RES) with the utility grid due to the growing demand for clean and cost-effective energy poses new challenges like power quality disturbances, unintentional islanding, change in fault levels, and fault current directions. These unpredictable events pose a significant threat to the continuous supply of loads, the safety of the equipment and personnel involved and also cause considerable economic losses. Hence, the proposed schemes must be able to tackle these challenges and to detect faults and islanding conditions at the earliest. In addition to fault detection and classification, fault location in the distribution system is also a challenging task due to short feeders, complex topology, various laterals, unbalanced operation, and time-varying load profile. Various signal processing techniques such as Wavelet Transform and S-transform, have been employed to extract time-frequency information to detect islanding and fault diagnosis. Empirical Mode Decomposition (EMD) is reported to be adaptive and overcomes the limitations of Wavelet transform (suitable wavelet selection) and S-Transform (non-adaptive selection of Gaussian windows).

This thesis proposes high-speed protection algorithms based on Empirical Mode Decomposition of three-phase current signals collected at the substation of a distribution network for detecting islanding and discriminating the same from faults. Fault classification and location have also been accomplished, followed by detection. The three-phase current signals collected at a substation over a moving window are decomposed using the EMD method to extract residues at various levels. These residues are utilized to detect the faults and classify them as LG, LL/LLG, and LLLG (L: line, G: ground). The discrimination between LL and LLG faults is achieved with the help of a neutral current.

The first algorithm utilizes the absolute mean (AM) value and Standard deviation (SD) of the first-level residue obtained from EMD to compute fault indices to detect and classify various faults and islanding by comparing with a threshold value within a half cycle. After fault detection and classification, the features of SD and AM from first-level residues are fed to a decision tree (DT) machine-learning algorithm to locate the fault. This algorithm has been successfully tested on IEEE 13 and 34 bus systems with DG penetration in the presence of noise with 20 dB signal to noise ratio (SNR).

The second algorithm proposed is based on a combination of EMD and Hilbert Transform (HT), widely known as Hilbert-Huang Transform (HHT), which extracts instantaneous features like instantaneous frequency (IF), instantaneous amplitude (IA), Standard deviation of instantaneous frequency (SDIF), and standard deviation of instantaneous amplitude (SDIA) from the first level residue. A fault index computed based on SDIF is proposed to detect and classify the faults within a quarter cycle by comparing it with a predefined threshold without DG penetration. A machine learning algorithm is proposed to avoid multiple thresholds in the event of DG penetration that requires islanding detection. The instantaneous features are fed to DT to classify faults and islanding. Also, the faulty zone is located using various ML models to evaluate their performance with varying capacities of DG using quarter cycle post-fault data (PFD) in the presence of noise.

In third algorithm, image-based fault diagnosis is accomplished by generating unique symmetrical dot patterns (SDP) with the help of monotonic residue after EMD. A novel protection algorithm based on SDP has been proposed with the alienation coefficient of SDPs after a fault and

normal conditions as fault index to achieve fault detection and classification. These SDPs, when fed to Convolutional Neural Network (CNN), removed the feature extraction process involved in distribution system fault diagnosis.

The proposed algorithms have been successfully tested by varying the type of fault, fault incidence angle, fault resistance, and fault location in the presence of noise. The selectivity of the proposed algorithms has been established by testing with non-faulty transients such as transformer excitation and de-excitation, feeder energization and de-energization, load switching, capacitor switching, and DG tripping in the presence of noise. Thus, the proposed algorithms using a combination of signal processing and machine learning methods can be implemented efficiently for the online monitoring of distribution systems.