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Full Length Article

A novel transmission line protection using DOST and SVM

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ABSTRACT

This paper proposes a smart fault detection, classification and location (SFDCL) methodology for transmission systems with multi-generators using discrete orthogonal Stockwell transform (DOST). The methodology is based on synchronized current measurements from remote telemetry units (RTUs) installed at both ends of the transmission line. The energy coefficients extracted from the transient current signals due to occurrence of different types of faults using DOST are being utilized for real-time fault detection and classification. Support vector machine (SVM) has been deployed for locating the fault distance using the extracted coefficients. A comparative study is performed for establishing the superiority of SVM over other popular computational intelligence methods, such as adaptive neuro-fuzzy inference system (ANFIS) and artificial neural network (ANN), for more precise and reliable estimation of fault distance. The results corroborate the effectiveness of the suggested SFDCL algorithm for real-time transmission line fault detection, classification and localization.

1. Introduction

Power system networks across the globe are transforming to smart grids with complex infrastructure. Exhilarating advancements in computational and digital communication technologies have paved the way for smart protection strategies like wide area protection systems (WAPS) for maintaining stable uninterrupted operation of smart grids [1–3]. Real time smart fault detection, classification and localization of the transmission line faults are the vital elements of WAPS. The development of global positioning system (GPS) synchronized remote telemetry units (RTUs) and high speed fiber optic links capable of transferring information over long distances with a sufficient channel capacity has paved the way for communication aided smart strategies for transmission line protection schemes. This has motivated researchers across the globe for developing smart techniques for transmission line protection in recent years [4–8].

Numerous methodologies for detecting, classifying and locating the transmission line faults in real time are reported in literature. Major contributions are reported here. Reference [9] proposed a wavelet multi-resolution analysis for fault classification in transmission lines fed at two ends. Although the methodology can classify the type of fault occurred, the phases involved in the fault were not discriminated. Reference [10] presented a fuzzy set based fault classification methodology for adaptive relaying; however, the proposed method was not capable of classifying LLL faults. Impedance based fault location technique based on one-end measurement was given in reference [11]. But the accuracy of the algorithm was seriously affected by fault resistance. This method calculates the fault location by measuring the impedance seen from the relay end to the fault point. Traveling wave based approach for fault location was presented in reference [12]. Yet the suggested technique was computationally intensive. Real time fault classification and location methodology based on Adaptive Neuro-Fuzzy Inference System (ANFIS) considering the outcome of power swing was proposed in reference [13]. Artificial neural network (ANN) based fault location approach was presented in reference [14]. However tedious training is demanded for the glide slope to achieve acceptable accuracy. Reference [15] proposed a Thevenin's equivalent system model based fault location technique. But the proposed approach was not studied for three-phase faults and two-phase to ground faults. The wavelet MRA technique has been taken over in reference [16] for real time transmission line fault detection and classification. Yet the proposed access was limited to fixed fault distances owing to very low sampling frequencies. Besides the approach requires zero-sequence elements to be estimated distinctly. Reference [17] presents a fault location technique based on estimating impedance from voltage and current measurements at the relay point with the aid of mathematical model of the transmission line system. Yet the suggested technique was highly vulnerable to model errors.

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This paper proposes a novel smart fault detection, classification and location (SFDCL) methodology for detection, classification and location of all types of fault that occurred on a transmission line fed from both ends. The proposed methodology deploys DOST on synchronously measured current signals from both ends of the transmission line. The current energy coefficients of the transient fault current extracted using DOST are found to have hidden information pertaining to the type and location of the transmission line fault that occurred. Support vector machine (SVM) has been employed for estimating the location of the fault from the exacted features. The most substantial interest of this theme is that the proposed methodology can accurately discover, classify and locate all transmission line faults that occurred at any fault inception angle (FIA). The following sections are organized as follows: Section 2 illustrates the proposed SFDCL methodology with a key insight into time-frequency analysis using DOST. Detection and classification of transmission line fault are discussed in Section 3. Section 4 depicts the fault location approach with various case studies. Section 5 discusses the results of the case studies conducted and Section 6 concludes the research work presented.

2. Proposed SFDCL methodology

The proposed SFDCL methodology utilizes GPS enabled RTUs at both terminals of the transmission line for acquiring synchronous current measurements. The synchronously measured current signals are transferred to the TCC by means of high speed broadband communication system. Acquired synchronous current samples are analyzed through DOST in TCC and the frequency coefficients extracted are found to have concealed information regarding the type and localization of the fault. This operational procedure has been elucidated in Fig. 1 for better clarity.

This section has been arranged as follows: analysis of synchronous current signals using DOST has been illustrated in Section 2.1.

2.1. Time-frequency analysis using DOST

Founded along the hypothesis presented in reference [18–20], by applying DOST to the current signals (measured at generator buses) of transmission lines, features have been drawn out. These features are used for fault detection, classification and location on a 300 km transmission line. To shorten the lengths of paper, condensed explanation of DOST has been made.

DOST is an orthogonal set of base functions that localizes the frequency spectrum and retains the advantageous phase properties of the Stockwell transform. Better clarity in the representation can be achieved through transforming N-point input time series transforms to N-point time-frequency representation with the aid of orthonormal transformation. Also, each point of

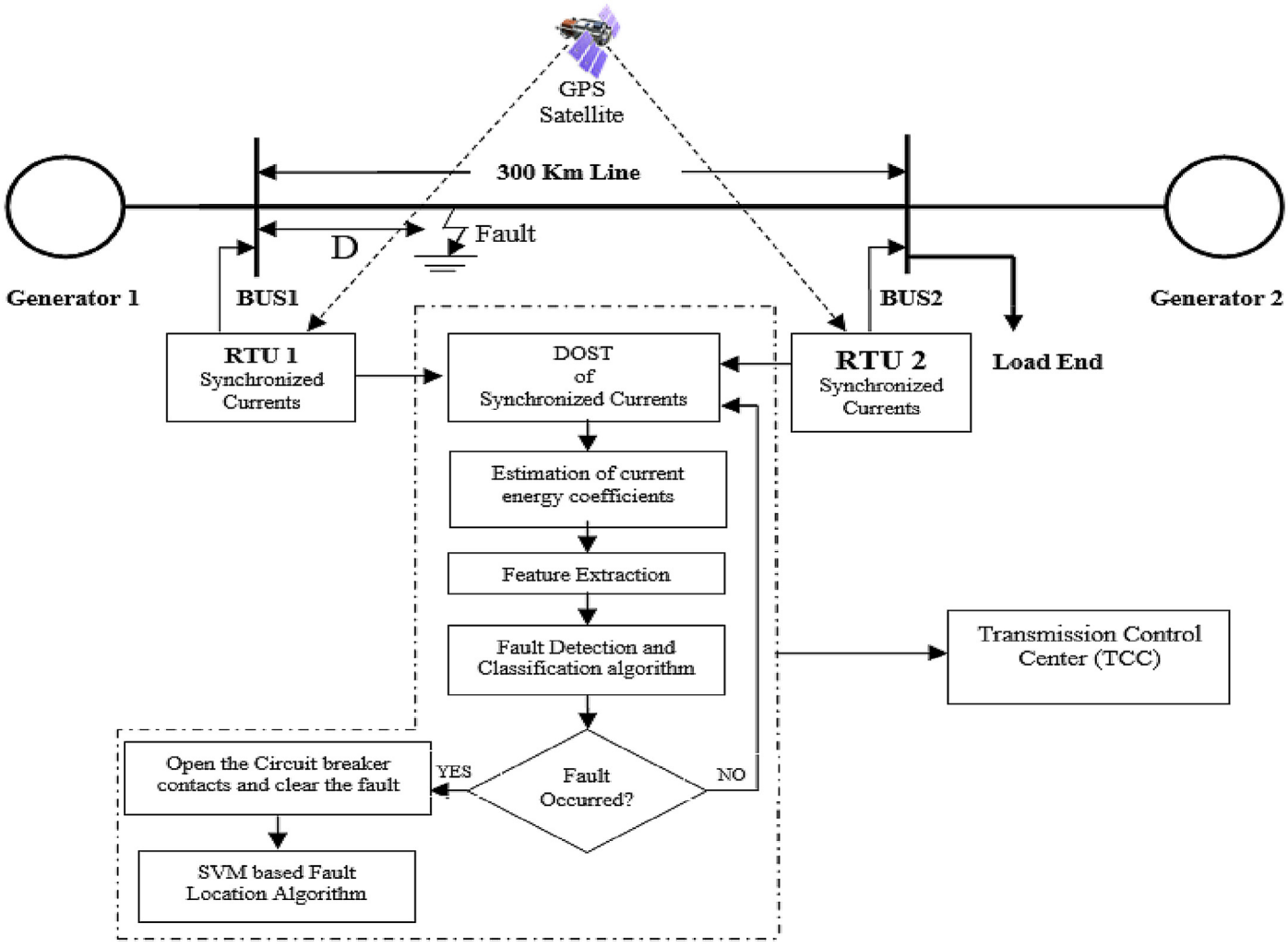

Fig. 1. Block diagram of the proposed methodology.