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A Novel Methodology for Identifying Cross-Country Faults in Series-Compensated Double Circuit Transmission Lines

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Abstract

In this paper, a competent mechanism for classifying cross-country faults in series-compensated (SC) double circuit transmission line (DCTL) is presented. Cross-country faults are usually different from frequently occurring short-circuit faults in the transmission system. The faults that strike up at the same time but on different positions in the transmission network and can involve same or different phases are termed as cross-country faults. An occurrence of such abnormality in the transmission network significantly hampered the functioning of traditional distance relaying. This paper presents a novel methodology for discriminating normal short-circuit faults and cross-country faults in SC double circuit power network based on empirical mode decomposition (EMD) and intelligent technique. The efficacy of the proposed mechanism for discriminating normal short-circuit faults and cross-country faults in the series-compensated DCTL system, various cases of normal short-circuit faults and cross-country faults (with varying system conditions) have been simulated in Real Time Digital Simulator (RTDS). The results acquired after performing several test cases reveal the practicability of applying proposed EMD and intelligent techniques based mechanism for classification of cross-country faults from normal short-circuit abnormality in the transmission network.

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Keywords: Transmission line protection; Cross-country fault; Empirical mode decomposition; Support vector machine; Naïve-bayes; PNN

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1. Introduction

Power transmission unit plays as a vital clinch between the power producer and its buyer. Double circuit transmission system along with compensation technology has been significantly utilized in the modern energy system. It not only helps in amelioration of the system reliability but also curtailing the burden of the transmission network. However, compensation technology and the addition of advanced electronic devices in the transmission network adversely affected the traditional distance protection management system [1]. Cross-country faults are the additional abnormality along with short-circuit faults (SCF) generally observed in double circuit lines. The cross-country faults (CCF) are defined as those faults that strike up at the same time but on different positions in the transmission network and can involve same or different phases. Conventional distance relaying management system finds limitations during cross-country faults and may lead to abnormal and unwanted operation of relaying unit. Hence a quick protection mechanism, well competent with changing conditions of the network is essential for conferring secure and hindrance free operation of power system. In a couple of years, considerable works have been proposed by several authors dealing aforementioned issues of protection. Major parts of the approaches available in the literature are based on wave theory, signal processing techniques [(i.e., Fast Fourier transform (FT), discrete wavelet transform (DWT)] and artificial techniques [2]. However, only a few researchers have focused on the issues of cross-country fault in the compensated double circuit transmission system. In [3] the effects of CCF on the conventional relaying system have been explained. In [4] the authors have discussed the consequences of CCF in power system and have proposed a methodology for identification of CCF in differential protection. The impact of CCF on current differential relaying mechanism has been analyzed in [5]. In [6] the authors have proposed a DWT with ANN based approach for locating CCF and evolving faults. However, classification of CCF with normal SCF has not been discussed. A fuzzy-based approach for directional relaying of parallel lines has been explained in [7-8]. In [9] a novel relaying algorithm has been presented for grounded CCF in parallel network

This paper proposes the application of EMD and machine learning (ML) technique [i.e., Support vector machine (SVM), Naïve-Bayes (NB), and probabilistic neural network (PNN)] for discriminating the cross-country faults with generally occurring short-circuits faults in the series compensated network. EMD has been applied for decomposing the 3-phase current samples for acquiring the intrinsic mode function (IMF). Afterward, the fault characteristic features are deduced in terms of energy of the selected IMF. Ultimately those features have been utilized as training and testing samples by the designed classifier models of SVM, NB and PNN for isolating CCF in SC double circuit system. For examining the efficacy and feasibility of the proposed mechanism for a series-compensated DCTL system, single line to ground fault and CCF (with varying system conditions) have been simulated in Real Time Digital Simulator (RTDS). The results acquired after performing several test cases reveal the practicability of applying proposed EMD and intelligent techniques based protection mechanism for classifying CCF with generally occurring SCF in a parallel transmission network.The rest of the paper is structured as: In the coming section, the procedure of EMD are discussed. The draft of the proposed methodology along with ML techniques fundamentals has been discussed in section three. Section four focuses on the simulated case study. Applicability and competency of the proposed approach have been explained in result and discussion section. Finally, section five concludes the paper.

2. Empirical Mode Decomposition

In recent years the application of signal processing techniques in the transient analysis of power system has been considerably increased. Several processing techniques peculiarly FFT, Wavelet Transform (WT) are applied in analyzing abnormalities in a transmission system. Although WT approach has been outperformed the limitations of FFT, it also involves a big concern, i.e., opting of appropriate mother wavelet and decomposition level. No such issues are evolved in EMD technique. EMD is an adaptive and highly competent signal decomposing algorithm. It locally decomposes the signal into a chain of various IMF's and final residual. Firstly Huang has introduced the idea of IMF and explained that the decomposed IMF's significantly reflects the physical characteristics of the original signal. In [10-12] EMD has been applied for abnormality detection in a transmission system. The two mandatory criteria of IMF are as follows: