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Wavelet entropy based algorithm for fault detection and classification in FACTS compensated transmission line

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ABSTRACT

Distance protection of transmission lines including advanced flexible AC transmission system (FACTS) devices has been a very challenging task. FACTS devices of interest in this paper are static synchronous series compensators (SSSC) and unified power flow controller (UPFC). In this paper, a new algorithm is proposed to detect and classify the fault and identify the fault position in a transmission line with respect to a FACTS device placed in the midpoint of the transmission line. Discrete wavelet transformation and wavelet entropy calculations are used to analyze during fault current and voltage signals of the compensated transmission line. The proposed algorithm is very simple and accurate in fault detection and classification. A variety of fault cases and simulation results are introduced to show the effectiveness of such algorithm.

1. Introduction

In recent years, it has become more difficult to construct new generation facilities and transmission lines due to energy and environmental problems. Hence, it is required to enhance the power transfer capability of existing transmission lines instead of constructing new ones. Because of all that, it became more important to control the power flow along the transmission lines to meet the needs of power transfer. On the other hand, FACTS devices have received more attention in transmission system operations as they can be utilized to alter power system parameters in order to control power flow. With FACTS technology, such as static var compensators (SVCs), static synchronous compensators (STATCOMs), static synchronous series compensators (SSSCs) and unified power flow controllers (UPFCs), bus voltages, line impedances and phase angles in the power system can be flexibly and rapidly regulated. In addition, the FACTS devices have the capability of increasing transmission capabilities, decrease the generation cost and improve the security and stability of power system [1,2]. During fault, the presence of compensating devices affects steady-state and transient components of current and voltage signals which create problems with relay functionality [3,4].

Fault classification and section identification in a transmission line with FACTS devices is a very challenging task. Some researchers used current and voltage signals to determine the fault location and fault resistance only without attempting to find the fault type and phase involved [5]. Earlier an adaptive Kalman filtering approach has been proposed for protection of uncompensated power distribution networks [6] and compensated transmission system employing an advanced series compensator [7]. However, the Kalman filtering approach finds its limitation, as fault resistance cannot be modeled and further it requires a number of different filters to accomplish the task. Different types of neural networks (NN) based pattern recognition procedures [7–9] were proposed which need large training set generation, large training time and design of a new neural network for each transmission line. Different attempts have been made for fault location and classification using numerical methods, wavelet transform, S-transform, TT-transform, fuzzy logic systems and support vector machines [3–15]. Most of these attempts were trying to classify the fault and identify the faulted section in a transmission line compensated either by series capacitor protected by metal-oxide varistor (MOV) or compensated by thyristor-controlled series compensators (TCSCs) protected by MOV or compensated by both.

In [5], authors took advantage of the post-fault voltage and current samples taken synchronously from both ends of the line to build a recursive optimization algorithm to find the distance to fault in a transmission line compensated with a series FACTS device. The proposed algorithm in [5] is independent of the FACTS device model. However, it aimed only to the location of fault without trying to find its type.

In this paper, we are interested in two of the most important FACTS devices; the SSSC and the UPFC. The SSSCs are FACTS devices for power transmission line series compensation. It is a power electronic-based voltage source converter (VSC) that generates a

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