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Performance of communication networks for Integrity protection systems based on travelling wave with IEC 61850

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ABSTRACT

Smart grid system protection can be divided into wide area network, WAN, and substation area protections. The IEC 61850 Ed.1 standard contains models for SV and GOOSE messages that can be used in intra-substation protection. This paper investigates the WAN and substation area protections based on a travelling wave with IEC 61850 that have not been used in a product since 2016. The high sampling frequency for processing the travelling wave may block the communications channel and reduce security. In order to address this problem, an approach is proposed that is based on using real-time travelling wave signal packing with lossless compression and travelling wave feature extraction. The performance of these techniques has been tested using an OPNET modeler, while their validity has been tested through computer simulation. The application of WLAN based on transient travelling wave for real-time protection has also been investigated. The lower sampling, or transformed, data can be used for the applications of transient waves in digital substations. The comparison protection based on travelling wave between the Ethernet and second-generation WLAN results has also been discussed. An IED design is proposed for fast tripping that can be used in WAN protection based on the travelling wave. This work paves the way for other research to start developing fast protection systems based on travelling wave with IEC 61850.

1. Introduction

A wide area protection (WAP) system can be classified as centralized or decentralized and provides comprehensive protection over a wide geographical distance of interconnected power systems. A centralized WAP offers easy data access, but is prone to single node failure. On the other hand, decentralized WAP offers high reliability, but involves high communication costs and a limited extent for stability analysis. The IEC 61850-90-5 standard offers a wide-area protection system that is primarily based on phasor measurement units (PMUs). The PMU method requires a full cycle for accurate phase estimation, thereby resulting in delays of more than 20 ms that violate the delay requirements of the IEC 61850-5 standard.

The objective of power system protection is to isolate the faulted section of electrical power systems without any severer damage due to fault current. The main components of the transmission network are busbars and transmission lines, therefore fast clearing of fault and location is necessary. The conventional techniques for transmission line protection includes differential protection, over current and distance protection relays. The principle of the impedance method is simple but suffers from a low accuracy. Given its immunity to voltage variations, differential protection is widely used in power system protection, especially for bus-bars, transmission lines, and transformers. In addition, differential protection on long power transmission achieves low communication link latency by comparing the measurements that are received from the local and far ends of the terminal. A transient travelling wave is used in protection to evaluate the fault location and line. Ultra-high speed power system protection analysis based on IEC 61850 protocols present a topic that has not been investigated in the literature.

A travelling wave (TW) based method uses the incident and reflected travelling waves at both ends of the line. Faults on the power transmission network cause transients that propagate on the transmission lines as travelling waves that involve high frequency components and travel with a speed that is close to speed of light. Initially both incident and reflected transients exist on the line that causes these transients. However, only the transmitted transient exists on other

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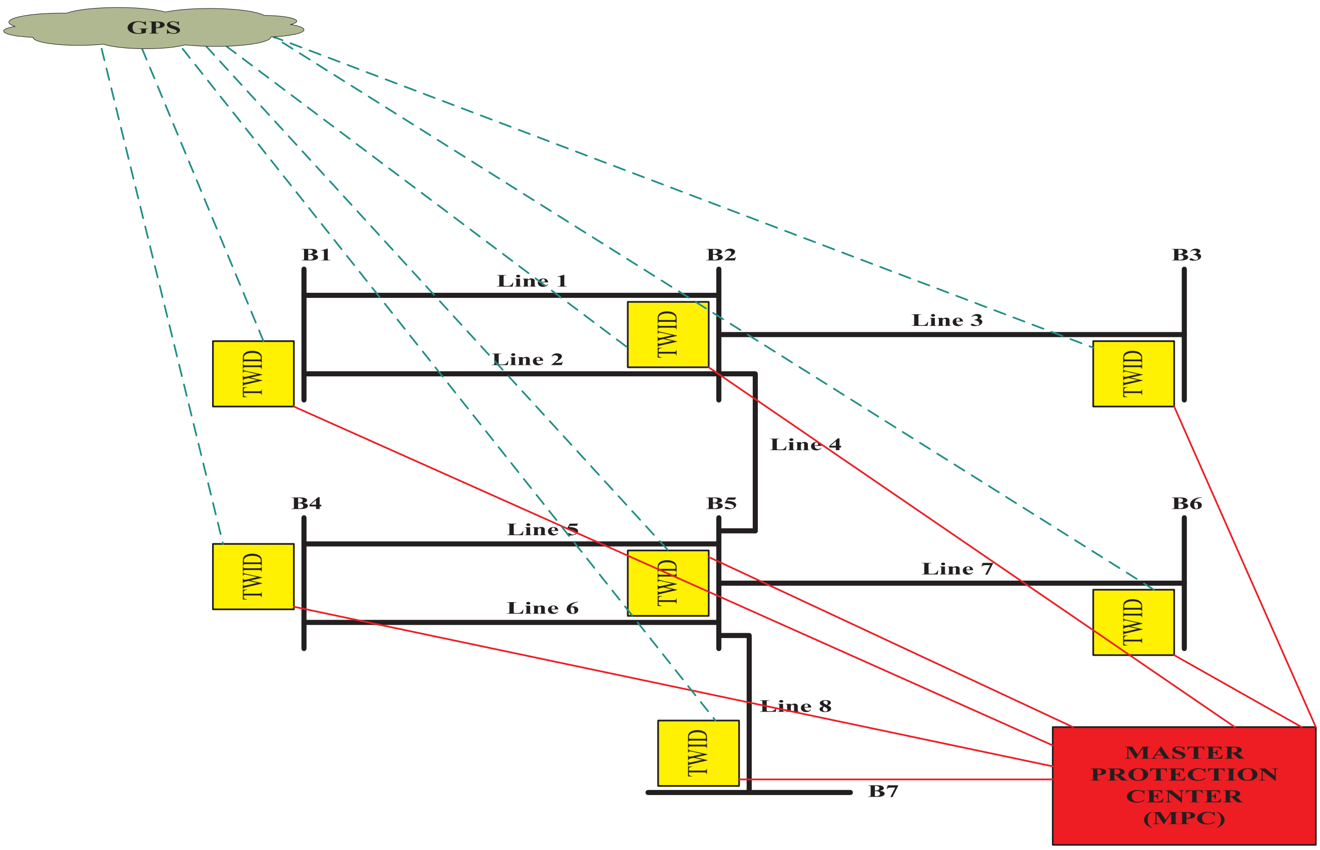

Fig. 1. Proposed WAP based on travelling wave.

transmission lines, which propagates away from the substation busbar. As shown in Fig. 1, the proposed system protection comprises travelling wave intelligent electrical devices (TWIEDs) that measure the fault-generated travelling wave, a master protection center (MPC), and a wireless communication backbone network. Given that this system uses data from neighboring buses, the failure of one TWIED does not necessarily result in the failure of the entire system protection. The IEC 61850-90-1 standard uses a proxy gateway, or tunneling data communication, among substations to implement a long transmission line protection that is similar to differential or distance protection. By contrast, the IEC 61850-90-5 standard maps GOOSE and SV messages with the UDP/IP layer, and then transfers these messages to other substations in WAN. The current power systems have become highly complex by integrating Distribution Energy Resources (DERs) with distribution systems, thereby introducing new challenges in the effective control, measurement, management, and protection of distribution systems. Fast tripping presents a useful technique for non-traditional sources because of its low dependence on sources and high dependence on the network [1]. As an emerging technique, ultra-high-speed line protection offers a novel way to trip line faults within a few ms [2]. The lower sampling data or transformed data must be used for the application of transient waves in digital substations. The different communication protocols in smart grids have also introduced new challenges. IEC 61850 is a worldwide protocol known for its flexible configuration, functional allocation, and ability to determine the interoperability of devices from different vendors. The National Institute of Standards and Technology identify IEC 61850 as one of the key enabler standards for smart grids.

The first edition of IEC 61850, which was in effect between 2003 and 2005, guided the use of communication protocols in substations. The second edition, which was in effect between 2008 and 2012, guided the use of IEC 61850 for communication in power utility automation and smart grids. Editions 2.1 and 3 have been designed to introduce further improvements for communication in the smart grid domain. The IEC-61850-based substation protection has numerous applications in different disciplines including automation and control systems, integrated communications, computing and many more. Fault protection and location can be performed using IEEE 802.11n WLAN or Ethernet in compliance with IEC 61850. The impedance method reveals the high bit rate of these methods. Fast protection systems based on travelling waves have attracted wide usage because of their high immunity to CT saturation, system oscillation, transition resistance, and neutral point operation modes. Protection is a time critical event that requires a fast and reliable communication network.

The travelling wave must have a sampling frequency ranging from 200 kHz to 1 MHz to obtain a highly accurate and valid sampling data. Multiple MUs sharing the same process bus are similar to a video conference with multiple terminals via a video conference [3,4]. Sending high-definition video signals from these terminals will result in a long delay that does not meet the requirements of IEC 61850-5 [5]. Similarly, when multiple MUs share the same process bus, using a high sampling frequency will result in long delays that do not meet the protection and control requirements of IEC 61850-5.

This paper proposes two ways to address this problem. First, the travelling wave signal must be assembled and compressed. Second, the travelling wave with feature extraction must be used. This paper advocates the wide application of travelling waves in digital substations with IEC 61850.

The performance and limitations of WLAN in fast protection systems based on travelling wave are investigated in detail in [6], while the different industrial applications of this technology are cited in [7–14]. However, no survey has examined the application of fast tripping systems in substations, WAN, and WLAN based on travelling waves. Furthermore, using second generation IEEE 802.11n supporting IEEE 802.11i with enhancement MAC Layer the advanced security and QoS can be achieved using wireless communication technology.