Name of the Research Scholar: Saeed Roostaee

Supervisor: Prof. Shabana Mehfuz **Co-supervisor**: Prof. Mini S. Thomas

Department: Department of Electrical Engineering, Faculty of Engineering and Technology, JMI

Title: Reliability and availability assessment of Transmission line protection functions based on IEC 61850 standards

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The objective of this research work is to investigate the transmission line protection and operation functions with the aim of improving the reliability of the power system, and at the same time to increase the flexibility of functions by the utilization of the IEC 61850 standards.

IEC 61850 brings a new era in the development of power system. It affects not only the designing of the substation automation and protection but also the designing of the secondary system. IEC 61850 GOOSE and Sample Values (SVs) provide status, measured current and voltage values communicated between devices connected to the substation network. The second edition of IEC 61850 has been extended for the communication in the power system. The advantages of adopting IEC 61850 for developing protection and operation functions are to achieve flexible and reliable functions in power system automation which are not easily feasible with the traditional methods.

To meet the challenges of integration of distributed functions into the existing substation automation system, the innovative methods should be developed, implemented, and evaluated in a laboratory environment. This will ensure the compatibility of the distributed functions in a practical case.

An extensive literature survey in the thrust area had revealed that communication technology has been developed very fast and smart devices like IEDs are using IEC 61850 for communication. With such a technology, distributed functions based communication can be developed. However, there is less research over the distributed functions and practical consideration of them. As a result, much work is required to be done in this area.

Considering these aspects, the significant contributions of this Ph.D. thesis are as follows

Developing a laboratory setup to do the experimental study in transmission line fault location and protection: This testbed comprises of industrial grade equipment such as IEDs (SEL-421, SEL-2407), secondary injection test kit (Omicron CMC 256-6 plus), PSCAD simulator. Based on the developed lab setup, the PSCAD simulator is used for modelling of the power system. The recorded signals and status data of power system transients is stored as COMTRADE format and they can play back into the real IEDs using Omicron CMC 256-6 plus. Hence, we can simulate any types of fault and inject the associated three phase signals to a relay IED and analysis the recorded event of the relay.

Evaluation of the existing technique for protecting and operating of a transmission line based on communication technology: In this thesis, we have proposed, in addition to the measured values in substation, to apply distributed current in the line too. In the proposed scheme, instrument transformers should be mounted in different locations on a line. The measured values can be sent throughout a communication channel to the substations at both the ends of the line with IEC 61850-9-2 LE format. Several faults with the different type, location and resistance have been simulated and the associated transient fault data are injected by OMICRON CMC 256-6 to the SEL-421. Thereafter, relay events have been analysed in the Trans view software. The experimental outcome proves that the proposed fault location scheme is more accurate than existed impedance-based fault location techniques.

Integrating of Travelling-Wave based fault location into the existing protection relays: TW-based fault location has been a standalone device which is not convenient in application. The combination of TW-based fault location with impedance-based fault location can reduce the costs, improve convenience, and provide a superior fault location function in a protection relay. To integrate TW-based fault location with impedance-based fault location, I_0 detection as the initial time of arrival of a ground fault wave is proposed in this research. This parameter is a digital value and easy to monitor with the high sampling frequency and it can be applied as an input to a relay. A laboratory setup had been developed not only to discuss the problems of existed protection relays for integrating with TW-based fault location but also to compare the accuracy of the proposed method with the impedance-based fault location methods.

Evaluating of IEC 61850 based accelerate distance protection: The advantage of adopting IEC 61850 for accelerated distance protection scheme is to achieve fast tripping for Zone-II relay based on transportation of high-speed GOOSE messages from the distant relay. This research work discusses adopting IEC 61850 to provide standardized and interoperable communication infrastructure for the accelerated distance relaying scheme.

Evaluating the performance of IEC 61850 GOOSE in WAN: The ETE delay performance of wide area inter-substation communication networks under different congestion levels is evaluated. Also, in order to tunnel GOOSE messages for inter substation communication; there is a challenge of configuring the different IEDs located in different substations. Hence, the details on the process of exchange of SCL files for configuring IED in different substations are presented.

Reliability evaluation of IEC 61850 based substation automation system and process bus: This research work presents the configuration policy for a substation automation system applying IEC 61850; also it presents an approach for reliability assessments of various substation automation systems. The reliability block diagram is applied to various substation automation architectures to evaluate the reliability. Thereafter, the demonstration and testing of different process bus communication topologies have been carried out on laboratory testbed. To evaluate different process bus topologies, several topologies have been implemented and tested in the lab.