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Title of the theses: Impact of IEC 61850 protocol on substation performance

ABSTRACT

The thrust area of research work for this Ph.D thesis is to investigate the impact of IEC 61850 communication protocol on the design, development, implementation, reliability and operating performance of substation applications. Substation performance is greatly influenced by the extent of automation of its functions and by the type of technology used. IEC 61850, the standard for "*Communication Networks and Systems for Power Utility Automation*", permits communication interoperability among substation devices through standardized integration and automation architecture. The standard eliminates the costly and complex hardwired interfaces in traditional Substation Automation System (SAS) with Ethernet based shared communication links, and thereby achieve flexibility in signal communications. Hence, IEC 61850 standard provides various opportunities to bring in a new era for the design and operation of real time substation applications.

However, the reliability and performance of Ethernet communication based SAS applications depend on communication network parameters, network load conditions and the processing capabilities of the Intelligent Electronic Devices (IEDs) used. Further, packet loss is a common phenomenon and plays a crucial role in the implementation of these Ethernet communication based time-critical real time protection applications. Hence, it is crucial to analyze IEC 61850-8-1 Generic Object Oriented Substation Event (GOOSE) and IEC 61850-9-2 Sampled Values (SVs) communication based digital substation protection applications from both the reliability and performance perspective before deploying them in field. Performance testing requires excellent understanding of the configuration process and functional specification of the system. Further, literature survey had revealed that existing communication infrastructure being used in electric power substations for the IEC 61850 SAS are lacking in terms of reliability, redundant design, and fault proof architecture. The SAS architecture should support high-speed peer-to-peer GOOSE and SVs data exchange among IEDs, over the process bus network in a reliable manner even under worst case scenarios. Thus, appropriately designed process bus based Substation Communication Network (SCN) architecture is vital in the reliability, availability and deterministic delay performance of the automation functions within a substation.

It was inferred from the detailed literature survey that the major technical challenges in implementing IEC 61850 protocols in real-time substation automation applications include:

- The successful configuration, implementation and performance testing of substation applications.
- Design of a suitable redundant process bus based SCN architecture and its impact on the reliability indices of substation protection functions.
- IEDs modeling for the real-time performance testing of time critical IEC 61850-8-1 GOOSE and IEC 61850-9-2 SVs messages over the process bus network for substation protection applications.

These major challenges have been addressed through this research work. The important contributions of this Ph.D thesis are as follows:

1. Impact analysis of IEC 61850 standard on the design and operation of economical and efficient SAS applications, and also on communication outside the substations contributing to utility automation.
2. Performance investigation of IEC 61850-8-1 GOOSE communication based substation protection applications through laboratory implementation.
3. Performance investigation of sampled values communication based *'all-digital'* substation protection applications through laboratory implementation.
4. Development of novel IEC 61850-9-2 process bus based redundant SAS architectures.
5. Dynamic modeling of IEC 61850 substation devices/IEDs for performance evaluation of SCNs.

The research work presented in this thesis is an effort to analyze the impact of IEC 61850 protocol on substation performance. Thesis work will be confidence building measure for power utilities to implement IEC 61850 communication standard technologies in designing modern SASs, and also advanced process bus based SCNs for real-time substation automation and protection functions.