



The 21st Century Substation Design

Final Project Report

Power Systems Engineering Research Center

*Empowering Minds to Engineer
the Future Electric Energy System*



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Power Systems Engineering Research Center

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Executive Summary

Many of the US substations are now more than thirty to fifty years old and may be in need of upgrade or replacement soon. The US National Institute of Standards and Technology (NIST) has recently published the smart grid framework release 1.0 document, which was in response to the Energy Independence Security Act (EISA) of 2007 and American Recovery and Reinvestment Act (ARRA) of 2009. A review of these documents indicates a need to develop standards for smart substations of the future.

The future substation design requires an understanding how both primary and secondary equipment may interact in the substation, how measurements from the primary system may be converted to secondary quantities by using multifunctional intelligent electronic devices (IEDs), and how the availability of new types of signal sensors may eliminate many of the drawbacks imposed by conventional instrument transformers.

The purpose of this study is to create a vision of the future substation. To create this vision, various technical, economical and environmental criteria, such as reliability, cost, interoperability, re-configurability, security, controllability and flexibility need to be considered. Those criteria require use of new design methodologies quite different from the existing philosophy. The design strategies are focused on reducing cost while maintaining the performance, or maintaining cost while improving performance.

Based on the considerations mentioned above, three design approaches to meet different scenarios requirements and needs are considered:

- Retrofit existing substation design. This approach assumes retrofitting existing substation communication protocol, intelligent electronic devices, power apparatus, and operating standards to improve the overall performance or reduce cost without disrupting the continuity of service. For this purpose, a comprehensive survey of new technologies is done and the cost benefit analysis is addressed. Two scenarios are discussed: upgrading and expanding the existing substation equipment using latest technologies. The emphasis is given to the use of wireless and optical fiber communication media when adding new equipments and using software integration of data when retrofitting existing design.
- Implement new substation design. This approach assumes designing the functionality and selecting the specific apparatus and IEDs to meet the demand of 21st century, using off-the-shelf products. In this approach, a new layout of substation equipment that illustrates innovative options for “fusion” between power apparatus and infrastructure for monitoring, control and protection is proposed. This approach requires field implementation that is different from the current practice and assumes availability of newly designed software modules for data acquisition and information extraction. New communication infrastructure to support exchange of information with the control systems and neighboring substations is also envisioned. The use of power flow controllers of various designs is highly recommended.
- Green field design. This approach assumes designing future substation that gives best solution to every criteria of the 21st century substation design including the

optimization of the profit and system operation/cost, using completely new techniques, protocols, and apparatus. Two novel technologies High Temperature Superconductor (HTS) and Solid State Transformer (SST) are envisioned. An Intelligent Economic Alarm Processor (IEAP) bringing the electricity market function into the future “Smart substation” is proposed. This creates an opportunity for better correlating the market activity with the physical system states in real time and sharing such information among market participants. Future “intelligent” substations should play an important role in the overall “Smart Grid” and be capable of providing such information.

Several issues are addressed but not explored in our research. Future work may include:

- Requirements of the software retrofit to satisfy the future needs and requirements;
- Cyber security model, detection and test plan for the new substation designs
- Comparison of different data communication bus structure for the new designs.
- Detailed cost-benefit analysis of the future design

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