Smart-Grid based Substation Testing Simulator Design for the South Korean Power Distribution System

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***Abstract*—In this paper, we present a smart grid (SG)-based substation testing simulator (STS) design for the South Korean power distribution system. The presented STS can serve as both a test bed for new devices and as a training facility for education. It features closed-loop testing, and reflects both control/protection functions within the substation and interaction with the Web or a telecontrol system (IEC61850, DNP, IEC60870-5, Modbus, etc). This STS can save certification time for the domestic/international standard fitness required for developed devices before a field test. The constituted algorithms have substation topology processing, relay action sequence, and state estimation. The substation data can be stored in a database management system (DBMS) after the effective analysis for the results of the SG-based STS. For the development of a new system and an educational environment, the concept of open systems is applied to a substation testing system. The proposed STS will be designed on a substation structure in the Korea Electric Power Corporation (KEPCO).**

***Index Terms*--Substation Testing Simulator (STS), IEC 61850, SG, DBMS, DERs, Korea Electric Power Corporation (KEPCO)**

I. INTRODUCTION

In a large-scale electric power system, the substation plays very important roles in managing the voltage transformation to provide safe and effective energy to consumers. In some cases, the operation and strategies in a substation can be influenced by structure modification to the power distribution systems, such as restructuring, decentralization, and open access of distributed dispersed energy resources (DERs), bidirectional demand response, and storage system operated in smart grids (SGs) or micro grids (MGs). Such changes have also been occurring in the South Korean power system. Under these environments, the smart substation concept has been introduced and built on the existing comprehensive automation technologies of substations [1]-[9].

The utilities are facing problems in determining standard integration architecture to meet specific needs, by extracting the desired operational and nonoperational information, and delivering this information. One currently available protocol for this purpose is IEC61850, which is used in many models used for online monitoring systems. Although originally created to be used within substations, its standardized object-model makes it uniquely applicable to entire power systems, ranging from telecontrol to the control of DERs [1]-[5].

To test and to demonstrate the control and protection functions within a substation, a substation testing simulator can serve as both a test bed for new devices and as a training facility for education. A substation simulator (STS) process comprises instantaneous line-currents, bus-bar-voltages, and the status of circuit-breakers, which is generated by a process-simulator, and is communicated to secondary equipment. The STS must satisfy conditions of safe, reliable, and economic operation of power-systems, and coordinate protection/control functions inside substations and interface with superimposed applications such as IEC61850, DNP, IEC60870-5, and Modbus [10]-[14].

To satisfy these requirements, the concept of open systems has been applied to substation testing. It is important to learn about the different relevant standards and then apply them so as to eliminate proprietary approaches. An open systems approach allows the incremental upgrade of the automation system without the need for complete replacement, as has happened in the past with proprietary systems. Systems and IEDs from competing suppliers can be interchangeable and could share information. The benefits of open systems include longer expected system life, investment protection, upgradeability and expandability, and readily available third-party components [1]-[4].

In this paper, we suggest an SG-based STS design for the Korean power distribution system.

II. THE SUBSTATION TEST SIMULATOR DESIGN IN THE SOUTH KOREAN POWER DISTRIBUTION SYSTEM

A. *The KEPCO Power Distribution Status* [14]

The Korea Electric Power Corporation (KEPCO) has highly credible power distribution systems that ensure a stable power supply. The rate of power loss during distribution was reduced to 3.99%, while the maintaining rate of power voltage requirements remains at 99.9%. The power distribution route length increased rapidly during the period from 1961 to 1990, and increased smoothly during the period from 1990 to 2010.

This work has been supported by KETEP (2011T100100152(S), 2011T100100144(H), 2011T100100212(W), 2010T100100415(G), 2011T100100241(LF), 2009T100100534(N)) and ETEP (I-2012-010-T5), which is funded by MKE (Ministry of Knowledge Economy).

978-1-4799-1303-9/13/$31.00 ©2013 IEEE

The number of installed power distribution transformers and the number of installed power distribution supports have increased gradually over time.

B. Necessity and Requirement for the Substation Testing Simulator

A substation plays important roles in voltage transforming to provide safe and effective energy to consumers, and in the restoration of a power system after faults. If the restoration cannot carry out follow-up measures approximately, the power supply system reliability can be badly damaged for a customer connected to the power system, as the power failure time is increased.

Fig. 1 represents a smart grid-based substation test simulator in the South Korean power distribution system. The protocols used are IEC61850, DNP, IEC60870-5, and Modbus. The STS plays an important role in meeting domestic/international standards for the performance and reliability for the designed equipment in the power system.

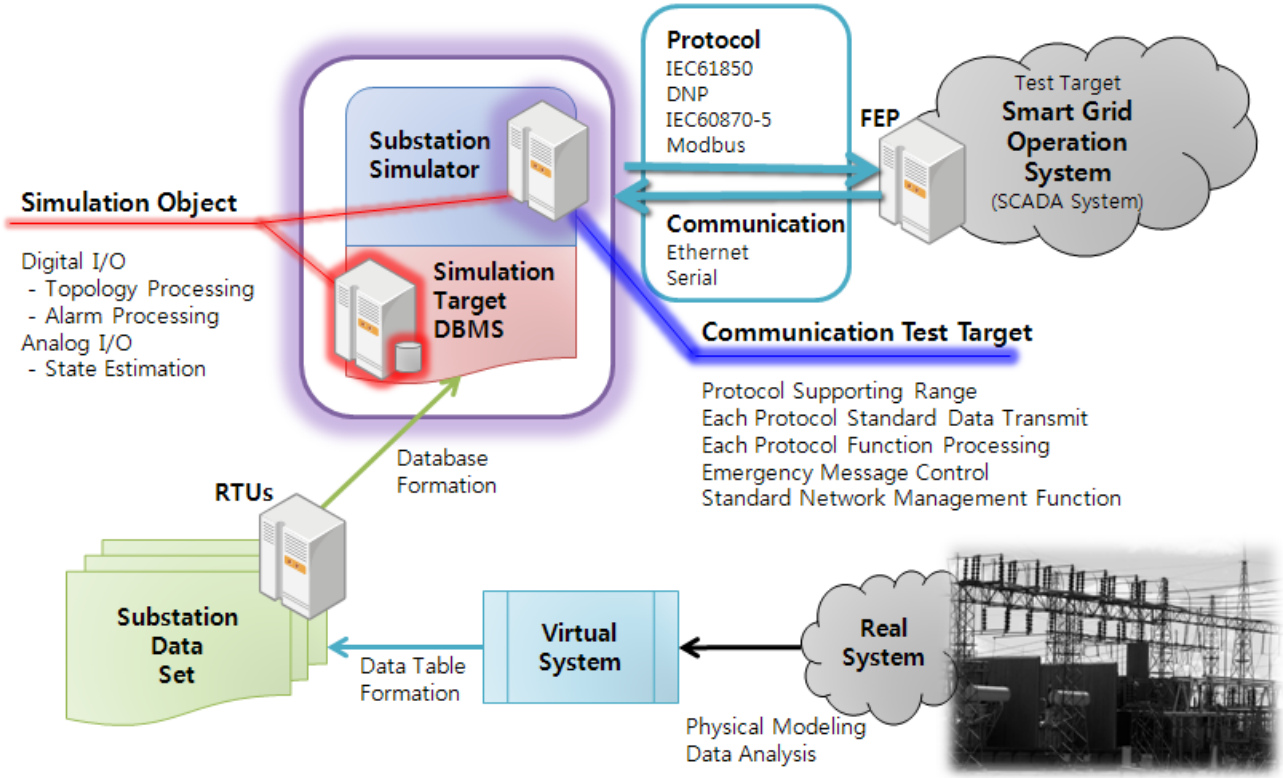

Fig. 1. A Smart-grid based substation test simulator in the South Korea power distribution system.

Also, the STS can save certification time required for satisfying these standards for developed devices before a field test. The developed STS system has the following merits:

- From a technical/industrial prospective, the STS plays important roles in testing for international standards and in the performance and reliability of designed equipment in the power system. A substation plays important roles in voltage transformation to provide safe and effective energy to consumers, and in the restoration of a power system after faults.
- From a common utilization perspective, it can provide the external companies with an opening system. Also, it is possible to certify the results throughout a simulation by receiving designed information from product makers. It can be used for validation by certifying the integrity and inter-operability between systems for either hardware or software products.

In addition, if this system can be commercialized by additional program development connected with external electric companies for technical/economic efficiency, effort and time can be saved in the development, based on the use of the conventional power system grid operation program packages [1]-[13].

C. Substation Testing Simulator Design

A substation testing simulator can serve as both a test bed for new devices and an educational training facility. The control and monitoring functions are implemented with two levels of architectures. Status and analog values are passed to the control and monitoring functions for the substation with a general-purpose microprocessor, on an exception basis, from the digital signal processor in the measurement and protection level. These control and monitoring functions are implemented in this level, because they do not require power system information as rapidly as the protection and measurement functions.

The IED is any device incorporating one or more processors with the capability to receive or send data/control to or from an external source (e.g., electronic multifunction meters, digital relays, controllers). The substation testing operation system consists of protection, control, and data acquisition functions in a minimal number of platforms to reduce capital, operating costs, and panel and control room space, and eliminate redundant equipment and databases.