The Integrated Electric Communications System Architecture

Society has entered into a new era of economics and social experience driven by digitally based technologies. Our world is more interconnected than at any time in history, utterly dependent on the integrity of complex networks, including the Internet, telecommunications, and electric power systems.

In many ways, the electricity network is the foundation of this interconnection. However, the electricity system – generation, transmission, distribution, and end use – is in serious need of upgrading towards an appropriate twenty-first century architecture if the benefits of interconnection are to be fully realized at both commercial and individual consumer levels.

Lack of critical infrastructure investment and surging demand for high quality, digital grade electricity has taxed the electrical infrastructure beyond its limit. Put simply, the current system cannot meet demand. EPRI research shows that U.S. electricity demand has exceeded transmission capacity by more than 15% for the last ten years. Most credible forecasts predict that this inequity will continue. Additionally, microprocessor-based technologies have radically altered the nature of the electrical load, resulting in electricity demand that is incompatible with a power system created to meet the needs of an analog economy. This has led to unprecedented electricity reliability problems, as well as low service quality responsible for hundreds of billions of dollars in losses to industry and society annually.

EPRI and the Electricity Innovation Institute have formed the Consortium for Electric Infrastructure to Support a Digital Society (CEIDS) to provide the strategic framework for this serious commitment to upgrading the electric system.

The Integrated Energy and Communications System Architecture (IECSA) project will develop an open, standards-based systems architecture for the data communications and distributed computing infrastructure that will enable the integration of a wide variety of intelligent electric power system components. This infrastructure will build upon prior industry infrastructure work, leverage the newest communications and distributed computing technologies available and will provide the interoperability/interworkability foundation for system development. This infrastructure will enable innovative services such as real-time pricing and energy management.

The goal for IECSA is to develop an overall integrated energy and communications system architecture for the data communications networks and intelligent equipment necessary to support a self-healing grid and the integrated consumer communications interface.

Project Objectives

- Develop a complete set of systems requirements and architecture documents to support industry-wide enterprise architecture for a self-healing grid and integrated consumer communications interface.
- Contribute project results as appropriate to relevant standards development organizations and industry consortia to effectively move the development of key open standards forward to develop a robust industry infrastructure.
- Apply systems engineering to the development of the architecture including but not limited to: the elicitation and management of system requirements, analysis of requirements and development of proposed architectural designs, evaluation of architectural designs and the use of standardized industry notation for documentation of architectural views.
- Identify the potential for infrastructure sharing and synergy between power engineering operations and other application domains.

How the Architecture Comes into Play

In order to best understand the scope of the problem and application domains that a comprehensive utility communications, command, and control architecture must deal with, here is a fictional but realistic future scenario of how a fully deployed system might operate. This vision of the future of power system operations will serve as a basis for describing the technical approach to be used in defining the requirements for IECSA.

This scenario is designed to illustrate how IECSA can improve the reliability and performance of the overall system with communications and coordination all the way from power generation to end user facilities. It is only one of many scenarios where the architecture will support new applications that were previously not possible. Overall, the implementation can result in significantly improved reliability and power quality while achieving more optimum operation of the system at the same time.

The Scenario

This afternoon around 3:00 PM CDT near Nashville, Tenn. heavy thunderstorms roll into the area. The temperature is 99 degrees and the humidity is about the same - a new peak load record will be set today. High winds, heavy downpours, and significant lightning accompany the storms. At 15:12:10 CDT, lightning strikes a tower on the Tennessee Valley Authority 500 kV Roane-Wilson line - the major line serving Nashville from the east. This causes a flashover. This is reported in real time via the National Lightning Detection Network and reported automatically on the operator's SCADA display. The flashover results in the failure of one of the line insulator strings - a permanent fault.

The ensuing fault results in breakers opening at the Roane and Wilson stations. Due to a protective device configuration problem, the 1100 MW generating plant at Watts-Bar trips off-line. At 15:12:40 after unsuccessful re-close attempts, the breakers lockout due to the permanent fault. At 15:12:45 the automatic generation control for the area starts responding to a deficit of generation in the Nashville area because of the line outage and generator trip. Signals are automatically sent to other generators in the area using the newly implemented IECSA system to increase local generation. At 15:13:00 the Emergency Control System (ECS) module of the IECSA determines that there is not enough generation or line capacity to meet the generation deficit. The ECS evaluates the situation and decides that a combination of line reconfiguration, power flow controller operation, load reduction and dispatch of distributed generation resources in the area will make up the deficit. The system updates prices for the next hour for customers on hourly real-time pricing rate structures, sends interrupt signals to selected interruptible rate customers in the affected area, and initiates residential load control by sending signals to shut down water heaters and other non-essential loads for that time of day.

As generation starts to come on line and load is reduced several FACTS controllers in the area have also been commanded to divert power flow onto the TVA 161 kV lines to help make up the deficit. On-line power flow, stability and security analysis applications have re-calculated the optimum FACTS configuration.

In an industrial park in the Nashville area, a large, automated plastic bag manufacturing plant on a real-time rate has received the next hour's prices, which are very high due to the line and generator outage. Their energy management system has decided to shut down the plant to save money. Nearby, a semiconductor manufacturing firm has benefited from a temporary reconfiguration of protective devices in the area. When the local ECS determined that a storm was in the area (from the NLDN data) the re-closers instantaneous trip setting were temporarily restrained on selected feeders serving sensitive loads to minimize momentary interruptions and multiple sags due to multiple re-close attempts. A few more fuses would be sacrificed in residential areas to prevent the storm disrupting critical industrial loads during the day.

An Internet service provider in the affected area is on a feeder with distributed generation resources sufficient to meet the entire load in that area. When the ECS dispatched the generation, the local substation controller decided to temporarily island itself from the main utility grid to eliminate the impact of voltage sags from the transmission system.

By 15:15, the load/generation imbalance had been fully satisfied and a new, stable system configuration has been achieved. As the storm move through the area, small, local configuration optimizations were performed.

The storm dissipates by 15:45 and as local ECS controllers sense this through input from various distributed measurement devices, they begin restoring protective device settings back to normal. As work crews complete repairs on the transmission line a few hours later and put it back in service and the Watts-Bar generator comes back on-line, real-time prices are adjusted accordingly, generation re-dispatched, line configurations and FACTS controllers revert back to their normal, optimal configurations and islanded systems are re-synched to the grid.

By the next morning, several applications with access to the ECS database have automatically prepared reports on how the system performed, the total cost of the storm including incremental generation costs, repair costs, etc. Power quality and reliability performance reports were prepared for engineering and marketing personnel. Any system anomalies encountered during the storm were automatically analyzed, a maintenance plan prepared and e-mailed to appropriate personnel.

The IECSA system has resulted in preventing a wide area outage due to the generation deficit, has optimized the configuration of local distribution systems to deal with the storm, and has minimized disruptions that specific load centers are sensitive to.