ELECTRIC POWER RESEARCH INSTITUTE

Smarter Transmission

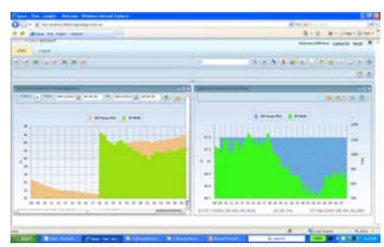
An EPRI Progress Report **November 2011**

ABOUT THE NEWSLETTER

This is the third edition of the "Smarter Transmission" newsletter. I want to thank those of you that have provided feedback and encourage others to provide feedback. In this edition we provide an update on the Asset Health Display project that is truly setting the stage for some interesting tablet displays. We also highlight some recent reports; first is a CIM Primer that is a very nicely illustrated and helps convey the fundamentals of CIM. The other is a PSERC report on online dynamic security assessments. There are also some highlights of recent events one on the CIM User's Group and also a recent workshop for Grid Transformation which is also the subject of our Feature Article this month. PSERC is also working on The Future Grid to Enable Sustainable Energy Systems funded by DOE that we are closely coordinating with. As always I appreciate your comments, suggestions, and contributions. Paul Myrda - Smarter Transmission Coordinator. pmyrda@epri.com

PROJECT UPDATE

Control Center Display of Asset Health Information – EPRI Supplemental Project



Significant progress has been made on this project since the last newsletter. The project uses real asset condition information from participating utilities that is sent to EPRI's Smart Grid Substations Lab where it is mapped into IEC61850 and the CIM standards (IEC61968 & 61970) as appropriate. The figures to the right are sample displays that have already been developed and linked to the standards based platform underlying this effort. The project will also investigate the feasibility of transferring the result to a tablet environment so that the display can be portable within the control center. One of the goals of this project is to explore the development of an "electric utility" application store. Keep an eye out for further updates in this newsletter.

USEFUL INFORMATION

Recent Publications

"Common Information Model Primer" – (EPRI_Report_1024449)

The Common Information Model (CIM) Primer explains the basics of the CIM (IEC 61970, IEC 61968, and IEC 62325). Starting with a historical perspective, it describes how the CIM originated and grew through the years.

The functions of various working groups of Technical Committee 57 of the International Electrotechnical Commission (IEC) are described. The processes of IEC standard creation and extension are also outlined. The basics of the Unified Modeling Language (UML) are detailed to introduce the reader to the language of the CIM. Then, building on commonly understood objects (basic shapes), the concepts that underlie the CIM are carefully built step by step. The reader is then transported into the world of power systems where the concepts that were developed previously are applied to the complexities of the electric grid. UML modeling of the power system is explored including a detailed look at breakers, connectivity, transformers, assets, graphics layout and 3-phase systems. The use of profiles in interface definition, the expression of profiles in standard technologies (CIM RDF XML and CIM XSD messages) and the creation of CIM messages are explained in language understandable to utility operations professionals.

"Next Generation On-Line Dynamic Security Assessment" - (PSERC Report)

This PSERC project addresses five elemental aspects of analysis for the enhanced performance of on-line dynamic security assessment. These five elemental components include: a) A systematic process to determine the right-sized dynamic equivalent for the phenomenon to be analyzed, b) Employing risk based analysis to select multi-element contingencies, c) Increased processing efficiency in decision-tree training, d) Using efficient trajectory sensitivity method to evaluate ability for changing system conditions, and e) Efficient determination of the appropriate level of preventive and/or corrective control action to steer the system away from the boundary of insecurity.

Recent Events

CIM Users Group Spring 2011 Meeting Summary – (EPRI_Report_1024597)

The conference theme was "Role of the CIM in the European Commission Mandate for Smart Grid" and was held at the Diplomat Hotel, Prague, Czech Republic, May 10-13, 2011. A clear picture was painted by multiple presentations given by a variety of speakers: the Common Information Model (CIM) has an essential role to play in Smart Grid around the world. More than 10 presentations focused on utility efforts: some projects are in the design stage but many are in the deployment stage with utilities developing CIM expertise and with the CIM facilitating information sharing. A surprising number of countries are viewing the CIM as a basis for national standardization efforts and have an interest not only in locally leveraging the CIM but also in sharing their work back to the International Electrotechnical Commission (IEC) Technical Committee (TC) 57 standards Working Groups.

Grid Transformation Workshop 2011 – (Report ID 1024659)

On November 1-2, 2011 over 40 people from 25 organizations participated in an interactive workshop to help confirm the direction of the EPRI Strategic Technology Innovation project "Grid Transformation". The workshop began the process of detailing out the features and benefits of four core research areas that are being proposed within the project. These areas are:

- Seamless geospatial three phase power system model requirements concept
- Seamless power system analytics requirements development.
- Integrated energy management system coupled with the above analytics and grid measurements
- Setting-less protection method

Workshop pre-reading material can be found online in report 1024659

Additional information about the project can be found in the Feature Article section later in this newsletter.

Technology Innovation

The Future Grid to Enable Sustainable Energy Systems

The Power Systems Energy Research Center (PSERC) has been awarded a $5.5 million grant from the Department of Energy to investigate requirements for a systematic transformation of today's electric grid. The future grid needs to support high penetrations of highly variable distributed energy resources mixed with large central generation sources, energy storage, and responsive users equipped with embedded intelligence and automation. These sustainable energy systems require more than improvements to the existing system; they require transformative changes in planning and operating electric power systems. An overview of the Future Grid Initiative is available at the PSERC website.

Upcoming Events

IEEE Power System Relaying Committee - PSRC

The IEEE Power System Relaying Committee (PSRC) will meet in Garden Grove, CA on January 9 - 12, 2012. It will be held in conjunction with the 2012 IEEE PES Joint Technical Committee Meeting so if you are planning to attend the JTCM stop by and check out the PSRC. The PSRC has a number of sessions that are dealing with a number of transmission related smart grid standards activities. Many of these topics are discussed under the C subcommittee for System Protection such as C2 - The Role of Protective Relaying in the Smart Grid, C4 – Guide for Functional Requirements for Phasor Data Concentrators, C5 - Guide for Synchronization, Calibration, Testing, and Installation of Phasor Measurement Units and also the H subcommittee for Relaying Communications such as H5 – Common Format for IED Configuration Data, H6 – Ethernet LANs in Substation Protection and Control and H17 – Establishing Links between COMTRADE, IEC 61850 and CIM. . http://pes-psrc.org/

Grid-Interop 2011

Operating with the guiding principle of implementing interoperability through collaboration, Grid-Interop brings together a true cross-section of industry stakeholders to ensure rapid development and implementation of Smart Grid interoperability standards. In 2011, the focus will be on implementation progress to date -- with a real focus on demonstrating successes and progress. As the birth place of the Smart Grid Interoperability Panel, Grid-Interop creates dialogue among the key stakeholders shaping and driving the progress of standards development, including:

- Standards development organizations.
- Businesses that use and implement these standards.
- Regulators that oversee the implementation of standards-based technologies.
- Product designers, system integrators, and consultants who put the standards to work in real-life applications.

Also, the Grid-Interop Plug-In will demonstrate interoperability success stories in a working environment, providing a literal show-and-tell of standards-based interoperable products and systems today. http://www.grid-interop.com/2011/#home

North American SynchroPhasor Initiative – NASPI

The next North American SynchroPhasor Initiative - Working Group Meeting is scheduled for February 29 - March 1, 2012 in Orlando, Florida. The meeting theme will be Research and Operator Training. For the latest information please visit https://www.naspi.org

Innovative Smart Grid Technologies (ISGT 2012)

The third IEEE PES Conference on Innovative Smart Grid Technologies (ISGT 2012), sponsored by the IEEE Power & Energy Society (PES), will be held January 16-19, 2012 at the Washington Marriott Wardman Park in the District of Columbia, USA. The Conference will be a forum for the participants to discuss state-of-the-art innovations in smart grid technologies. The Conference will feature plenary sessions, technical papers, and tutorials by international experts on smart grid applications. http://ewh.ieee.org/conf/isgt/2012/

Adaptation of EPRI Report "Needed: A Grid Operating System to Facilitate Grid Transformation "– (1023223)

Energy management systems (EMS) are computer-based systems used today to operate the complex electric power systems around the world. These systems assure that the power system or "grid" operates properly and that consumers enjoy reliable electricity supply at the lowest possible cost. These systems operate by balancing the demand for electricity with generation resources. However, the rapid growth of renewable power generation, the increased use of electric vehicles, and increased need to integrate customers with the power system are rendering the current generation of EMS systems obsolete. This article examines the evolution of today's grid operating system and outlines the development of a new grid operating system which will facilitate the transformation of the grid. Without the development of an advanced grid operating system, the full value of a lot of individual technologies like electric vehicles, electric energy storage, demand response, distributed resources, and large central station renewables such as wind and solar will not be fully realized.

Background

Grid Operating System 1.0

One of the first challenges which both Edison and Westinghouse faced in the operation of either the first direct current (DC) power systems or alternating current (AC) power systems was to enable reliable operation through control such that in any instant the total generation in a power system was "balanced against" total load. Balancing ensures the generation which is running at any point in time be equal to the total load or demand for electricity at that same moment (see sidebar). When generation is not balanced with load, the system becomes unstable and can collapse. In the 1800s when the first of the Pearl Street Generators was placed in service, this balancing act was a relatively simple endeavor primarily done through control systems in generators. This was a primitive form of a grid operating system which can be labeled as Grid Operating System 1.0.

Grid Operating System 2.0

As power systems evolved, they became larger, more complex, and increasingly more difficult to control. Balancing multiple generators with a network of loads located throughout a city or across town and into the countryside could not be facilitated by generation control alone. By the mid 1950s, some of the first Supervisory Control and Data Acquisition (SCADA) systems were being deployed within power delivery systems. Grid Operating System 2.0 grew out of the understanding of these SCADA systems.

The first SCADA systems utilized data acquisition by means of panels of meters, indicator lights, and strip chart recorders. The power system operator manually controlled the power system by turning various knobs or activating switches which in turn sent signals to open or close circuit breakers or to start up generators. These SCADA systems are still used today to do supervisory control and data acquisition in some small utilities, older power plants, and industrial facilities. These primitive SCADA systems were technically simple; they did not require computers or digital sensors. However, the quantity and type of data were minimal and rudimentary. SCADA systems became popular for two principal reasons: they minimized blackouts, and they could significantly increase the utility bottom line through effective dispatch of generation and the marketing of excess generating capacity.

By 1962, there were several large interconnected power grids in the Midwestern, southern, and eastern portions of the U.S. These were the largest synchronized systems in the world. A large blackout in 1965 prompted the U.S. Federal Power Commission to recommend coordination between these systems. As a result, the Electric Power Reliability Act of 1967 was passed, and subsequently, the National Electric Reliability Council was formed.

Late in the last century, the Federal Energy Regulatory Commission (FERC) passed a series of laws which enabled wholesale electricity markets (for example, FERC Order 888 in 1996). Accordingly, many of the grid operating systems in the nation were modified so as to incorporate connection to an increased number of market participants. For some systems, this meant increasing from a few dozen transactions per day to hundreds.

These actions, coupled with an overall concern within the industry that more needed to be done to assure reliable electricity supply, led to the invention of Grid Operating System 2.0. This system was a computer-based operating system and, although enhanced repeatedly since then, is the basic system in use today. During this period, the grid operating system came to be called energy management system or EMS. The major difference between Grid Operating System 1.0 and 2.0 is the capability to balance supply and demand between many market participants, multiple bulk power central generation resources, and a wide ranging control with numerous interconnections area using today's high-voltage grid. In addition, Grid Operating System 2.0 used a much more sophisticated mathematical technique to estimate the condition of the system.

System 2.0 allowed the system operator to estimate the condition of the system at any point in time. Often referred to as real-time monitoring and control, the grid operating system operates in near-real time using data coupled with input from sensors to estimate the condition of the grid 20 to 30 seconds after the fact. A unique development in Version 2.0 was the ability to "fill in" or estimate data from missing sensory inputs. System 2.0 is complex, uses rather sophisticated applications software, and has a large number of input/output (I/O) points and a substantial number of remote terminal units (RTUs). The most prevalent type of intelligent electronic devices (IEDs) which communicate with System 2.0 are reclosers, protective relays, substation controllers, and phasor measurement units.

Tectonic Changes in the Electricity Grid

The power system is revolutionizing at an exponential pace into a highly interconnected, complex, and interactive network of power systems, telecommunications, the Internet, and electronic commerce applications. Virtually every element of the power system will incorporate sensors, communications and computational ability. No longer will society depend primarily on central station power and what is essentially one-way flow on the grid, since the use of distributed generation and distributed energy storage will proliferate. At the same time, the move towards more competitive electricity markets requires a much more sophisticated infrastructure for supporting myriad informational, financial, and physical transactions between the several members of the electricity value chain that supplements or replaces the vertically integrated utility. Although reliability is now and will remain critical, this complexity will naturally create more opportunities for nodes of failure and potentially allow for increased risk from cyber attacks and coordinated physical and cyber attacks.

Today's power system is largely comprised of large central station power generation connected by a high-voltage network or grid-to-local distributions systems which serve homes, businesses and industry. Electricity flows predominantly in one direction using mechanical controls. The Grid Operating System 2.0 supports this power system.

Tomorrow's power system will still depend on the support of large central station generation, but it will increasingly include renewable generation and electric energy storage both at the bulk power system level and in the local distribution system. In addition, tomorrow's power system will have greatly enhanced sensory and control capability configured to accommodate electric vehicles and allow direct engagement with consumers and their appliances and devices. Tomorrow's power system will require a grid operating system which is secure against cyber intrusion and can assure reliable long-term operation of an extremely complex systems comprised of an array of distributed components.

Some technologies having profound impacts on the generation, delivery, and use of electricity that require engineers to rethink the way the grid is currently operated are: Variable Generation, Demand Response , Electric Vehicles , Smart Meters , Distributed Generation , PMUs and Communications

Grid Operating System 3.0

The present grid operating system was not designed to meet the increasing demands of a digital society or the increased use of renewable power production. There is a national imperative to modernize and enhance the power delivery system. That modernization must include a new grid operating system. Tomorrow's grid operating system must facilitate high levels of security, quality, reliability, and availability of electric power; improve economic productivity and quality of life; and minimize environmental impact while maximizing safety.

The grid operating system must monitor, protect and automatically optimize the operation of its interconnected elements – from the central and distributed generator through the high-voltage network and distribution system, to industrial users and building automation systems, to energy storage installations, and to end-use consumers including their thermostats, electric vehicles, appliances, and other household devices.

Tomorrow's grid operating system must manage a two-way flow of electricity and information to create an automated, widely distributed energy delivery network. It must incorporate into the grid the benefits of distributed computing and communications to deliver real-time information and to enable the near-instantaneous balance of supply and demand at the device level.

A next-generation power delivery operating system, referred to here as Grid Operating System 3.0 or Grid 3.0 must be developed to provide for seamless integration and interoperability of the many disparate systems and components, as well as enable the ability to manage competitive transactions resulting from competitive service offerings that emerge in the restructured and distributed utility environment. Figure 1 illustrates the challenges Grid Operating System 3.0 faces.

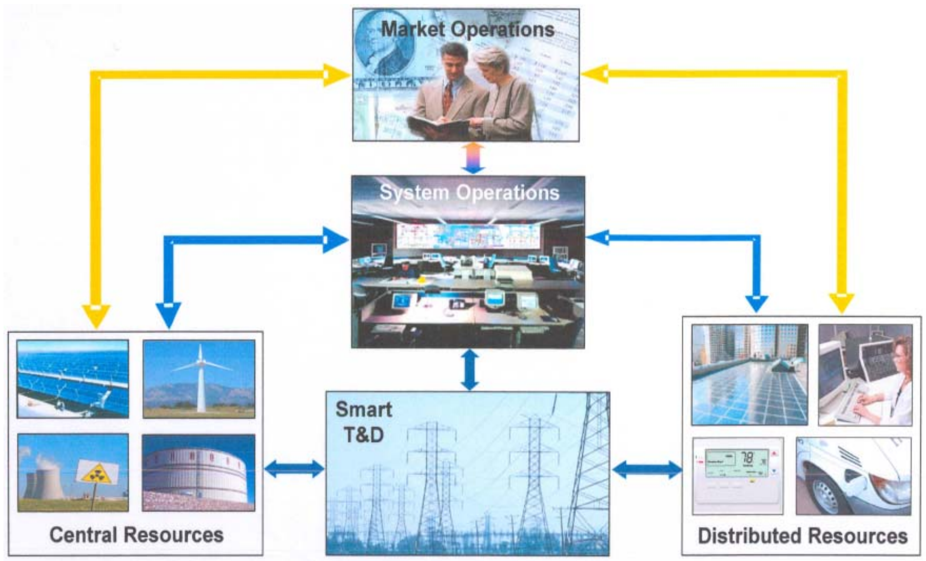


Figure 1
Grid Operating System 3.0 Challenges: Integrate Systems and Components

Realizing Grid 3.0 depends on developing the architecture – namely the functional requirements and the design requirements based on an open-source design, which can facilitate the informational, financial, and physical transactions necessary to assure adequate security, quality, reliability and availability of power systems operating in complex and continually evolving electricity markets. In addition, the architectural requirements will be designed to support multiple operational criteria including analysis and response to electrical grid contingencies, pricing, and other market and system conditions. The goals of the architecture are to allow for interoperability and flexibility of the power system operations while at the same time facilitate and enable competitive transactions to occur. Interoperability can be enabled by the use of open communication protocols developed in EPRI's IntelliGrid Program. Flexibility can be provided by the specification of user-defined business rules which capture the unique needs of various service offerings.

The concept of Grid 3.0 provides a new perspective on how to manage transactions given the nature of the existing and emerging distributed, heterogeneous communications and control network combined with the extensive use of new innovations on the power system. What is needed is an architecture that allows future developers to access this framework as a resource or design pattern for developing distributed software applications, taking into account the core concepts of interoperability and support for multiple operational criteria including business rules.

Grid 3.0 must increase the independence, flexibility and intelligence for optimization of energy use and energy management within local energy networks at the building level, at the local level, at the distribution level, and then integrate local level devices to the Smart Grid. As such, energy sources and a power distribution infrastructure can be integrated at the local level. This could be an industrial facility, a commercial building, a campus of buildings, or a residential neighborhood. Using Grid 3.0, these "local energy networks" are interconnected with different localized systems to take advantage of power generation and storage through the Smart Grid enabling complete integration of the power system across wide areas. This includes control of building energy and thermal storage systems. Localized energy networks can accommodate increasing consumer demands for independence, convenience, appearance, environmentally friendly service, and cost control.

While some of these local energy networks can operate in a stand-along mode, integration into the distribution system using Grid 3.0 allows interconnection and integration with technologies that ultimately enable the next generation of the Smart Grid.

Fundamentally, tomorrow's grid operating system will need to handle millions of intelligent electronic devices located through the power system from the generation switchyard through to end-use energy consuming devices and appliances on the consumer's premises. In addition, tomorrow's grid operating system must have the following functionality:

- **Geospatial Power System Model Database –** Tomorrow's grid operating system must have a hierarchical geospatial data acquisition and maintenance architecture. Geospatial power system model database feeding would allow the power system models to be derived directly from detailed geospatially correct computer-aided design (CAD) models. Increasingly, transmission utilities are analyzing their transmission lines using an optically remote sensing technology known as light detection and ranging (LIDAR) technology in order to measure the dimensions of, and the physical features of, a transmission corridor and its lines. With over 400,000 miles of lines greater than 100 kV in North America, some many decades old, there are discrepancies between design and actual field conditions. Also, many of these lines are in hard-to-reach places. LIDAR permits easy assessment of these lines. This data can be post-processed into CAD models like power-line systems – computer-aided design and drafting (PLS-CADD) tools (see www.powline.com.) These models use the LIDAR data to accurately model lines. These CAD files can then be used as input into line constants computer programs which give accurate transmission line ratings and loading. Geospatial feeding would integrate all of these steps and seamlessly calculate a more precise set of line parameters eliminating many of the assumptions used today. The output would be put into common information model (CIM) formats easily interchanged between systems. These physically precise models could also be used to develop screen interfaces much like those that have been made popular by Google Earth and other geospatial systems.

- **Integration of Traditional and Non-Traditional Data** – Integration of traditional utility operating data along with non-operating data such as smart meters and distributed sensors can be "mashed up" with readily available internet features such as Google Earth. It can provide very useful visual displays of information within geospatial context. Figure 2 is a Google Earth illustration of 1000,000 meter voltages on a hot summer day.

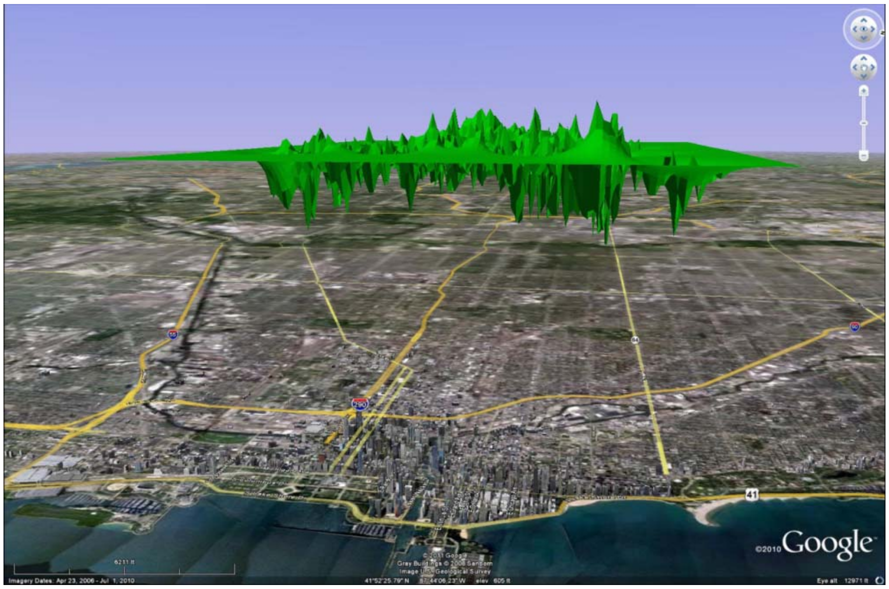


Figure 2
Illustrates 100,000 Meter Voltages

- **Advanced Protection and Control Functions –** Tomorrow's grid operating system must have advanced protection and control functions which shall include coordination, execution, and confirmation of all necessary actions required to prevent the power grid from entering into an irreversible degradation in performance. The process of advanced protection and control used today is becoming unmanageable and will not support many of the smart-grid concepts. Grid Operating System 3.0 migrates protection properties further down into the hardware and software on the power system and greatly simplifies the technical skills needed by protection engineers. The existing system of using many, greatly distributed intelligent agents are unmanageable for the long term. Hardware is obsolete by the time normal upgrade cycles of 10 to 15 years are completed on large systems. Protection schemes in Grid 3.0 need to be aligned with the current NERC philosophy regarding special protection schemes.

- **State Measurement with Look-Ahead Capability –** Tomorrow's grid operating system must have a forward-looking state measurement and a decision support tool that can help grid operators manage severe operating condition with future situational awareness. As technology enables synchronized measurements to be collected, power systems shall lead to a linear, non-iterative state measurement – as opposed to the conventional non-linear and iterative– state estimator which will be free of convergence problems. The state measurement is also expected to eliminate or minimize the effects of missing measurements, erroneous measurements, errors in network topology, etc. Furthermore, since synchronized measurements can be obtained much more frequently than conventional measurements, state measurement must have the capability of capturing slow dynamics associated with the states and predict state trajectory which possibly indicates some instability scenarios.

- **Cyber Security –** Cyber security will be an essential element of Grid 3.0. The North American Electric Reliability Corporation (NERC) has created eight Critical Infrastructure (CIP) Standards. These include standards for Critical Cyber Asset Identification (CIP002) and Security Management Controls (CIP003) as well as others. Meeting these standards will be part of Grid 3.0 including emerging security standards like NIST's Smart Grid Interoperability Standards Framework and AMI-SEC System Security Requirements, for end-to-end security of the Smart Grid. Grid 3.0 will likely use a system of systems approach to cyber security by deploying International Organization for Standardization and International Electrotechnical Commission (ISO/IEC), National Security Agency InfoSec Assessment Methodology (NSA IAM), Information Systems Audit and Control Association (ISACA), and International Information Systems Security Certification Consortium (ISC2). Cyber security will be part of every input/output (I/O) function for interfaces with IEDS and systems as part of Grid 3.0 including:
    - Market Participants including third party Demand Response providers
    - Central station generation resources
    - Advanced metering infrastructures
    - Plug-in electric vehicle (PEV) management systems
    - Distributed generation and storage
    - Distribution operating systems including distribution automation and Local Energy Network Controllers
    - Substations which are automated and fully instrumented
    - Fully instrumented transmission lines and corridors
    - Detection and prevention services (IDS/IPS) as well as security information event management (SIEM).
- **Enable Active Participation by Consumers** – The grid operating system must facilitate interaction with and include customers who are an integral part of the electric power system. Tomorrow's consumer must be informed, modifying the way they use and purchase electricity. They have choices, incentives, and disincentives to modify their purchasing patterns and behavior facilitated by the grid operating system.

- **Accommodate All Generation and Storage Options** – The grid operating system must accommodate all generation and storage options. It must support large, centralized power plants as well as distributed energy resources (DER). DER may include system aggregators with an array of generation or storage systems or individual consumers with a windmill and solar panels.

- **Enable New Products, Services, and Markets** – The grid operating system must enable a market system that provides cost-benefit tradeoffs to consumers by creating opportunities to bid for competing services. As much as possible, regulators, aggregators and operators, and consumers can modify the rules of business to create opportunity against market conditions. A flexible, rugged market infrastructure exists to ensure continuous electric service and reliability, while also providing revenue or cost reduction opportunities for market participants. Innovative products and services provide third-party vendors opportunities to create market penetration opportunities and consumers with choices and clever tools for managing their electricity costs and usage.

- **Optimize Asset Utilization and Operate Efficiently** – The grid operating system optimizes assets and operates efficiently. It dispatches an array of generation, storage and load technologies to ensure the best use of assets. Assets operate and integrate well with other assets to maximize operational efficiency and reduce costs.

- **Anticipate and Respond to System Disturbances (Self-Heal) –** Tomorrow's grid operating system independently identifies and reacts to system disturbances and performs mitigation efforts to correct them. It incorporates software designed to enable problems to be isolated, analyzed, and restored with little or no human interaction. It performs continuous predictive analysis to detect existing and future problems and initiates corrective actions. It will react quickly to disruptions in service and optimizes restoration exercises.

- **Operate Resiliently Against Attack and Natural Disaster** – The grid operating system must resists attacks on the cyber-structure (markets, systems, software, and communications). Constant monitoring and self-testing are conducted against the system to mitigate malware and hackers.
- **Effectively Integrate Local Energy Networks** – The grid operating system must effectively integrate local energy networks with central station power generation and the Smart Grid. Local Energy Networks are combinations of distributed technologies at the building, community, or distribution level which will increase the independence, flexibility, and intelligence for optimization of energy use and energy management at the local level; and then integrate Local Energy Networks with the bulk power system.

Background by Others

Several organizations have work underway which relates to Grid 3.0 which will be very helpful in the development of this system.

CIGRÉ has published a set of information technology (IT) requirements which will be useful in outlining some of the communications and IT requirements for Grid 3.0. CIGRÉ has outlined the real-time and near-real-time systems which will be part of future developments (CIGRÉ 2011).

The International Electrotechnology Commission (IEC) has a working group, TC-57, coincidentally working on standards which build off of several existing IEC Standards, several of which used foundational work by EPRIU including: IEC 61970 – Common Information Model (CIM); IEC 60870-TASE.2 – Inter Control Center Protocols (ICCP); and IEC 61850 – Communications Networks and Systems in Substations.

The IRC (ISO/RTO Council) in North America has recently established an EAS project (Enterprise Architecture Standardization) with an objective of reducing IT costs of ISOs and RTOs.

Developing Grid Operating System 3.0

The industry has a unique opportunity in developing Grid Operating System 3.0. Rather than each control area operator, independent system operators, and regional transmission operators separately contracting with different EMS vendors, this development could begin with the collaborative engagement of stakeholders to develop the functional and design requirements on an open source basis. In this process, there is a need to engage experts from all domains. Specifically, this entails characterizing what all types of input and output communications need to be and to identify all of the actors in the ultimate operation of the grid operating system. These actors are the suppliers of data and the users of data and information. Actors can include devices like individual sensors, smart meters, reclosers and PMUs. This process will identify “use cases” which clearly state the characteristics of data and information and its intended parameters. Once developed, individual vendors can offer bids which respond. By making these uniform requirements available, it is expected that innovative adaption of new systems will result as well as economies in the cost of development. In particular, the ultimate developers will need a combination of traditional EMS and power system vendors coupled with those having expertise in networking, data management and security.

There are early signs of the development of some of the advanced attributes needed in Gird Operating System 3.0 in pilot projects underway in several U.S. states as well as a few European countries. These are early stages of Grid 3.0 in action in pilots and in distribution-level EMS systems. Examples include Hawaii, Illinois, and a series of demonstrations being coordinated by EPRI.

On the Hawaiian island of Maui, the General Electric Company, in cooperation with Hawaiian Electric Company and its subsidiary, Maui Electric Company, Ltd., are testing its smart-grid technology. This application involves development of renewable and distribution system technology integration. It includes an intermittency management system, demand response, wind turbines, and dynamic systems modeling. The distribution operating system under development will include the standard applications of network management, SCADA, outage management, and network analysis, but will also be enhanced with features which enable demand management, Volt/VAR control and transmission-level grid support while enabling two-way communication with Local Energy Networks and distribution IEDs including buildings, distributed energy resources, capacitor banks, load-tap changers (LTC), voltage regulators, and wind turbine generators.

At the campus of Illinois Institute of Technology (IIT) in Chicago, a Local Energy Network is being created which incorporates advanced (smart) metering and sub-metering, an intelligent “perfect power” controller, and an on-site gas-fired combustion turbine power generator, a demand-response controller, and an uninterruptible power supply with electric energy storage. Perfect power is defined by IIT as always on, digital-grade power needed for its various laboratories. The features included in the perfect power controller will contain many of those needed by the master controllers needed to support Local Energy Networks operating as part of Grid 3.0.

EPRI is involved in a massive Smart Grid Demonstration Initiative involving a number of ongoing projects to demonstrate the potential for integrating distributed power generation, storage, and demand response technology into "virtual power plants." Demonstrations include both utility-side and customer-side technologies and are intended to address the challenges of integrating distributed energy resources (DER) in grid and market operations, as well as in system planning. This includes aspects required for Grid 3.0, including:

- Demonstrating effective operational strategies for integrating different forms of distributed resources.
- Demonstrating multiple levels of integration and interoperability among various components.
- Exploring existing and emerging information and communication technologies required for tomorrow's grid operating system.

The demonstrations are taking place at a number of U.S. locations and will include a variety of feeder constructions, climate zones, and technologies. Individual demonstrations are focused on the integration of specific feeder types used in residential neighborhoods, in a mixture of residential and commercial customers, and in areas with mostly commercial customers.

These developments are in their infancy in terms of how such distributed systems will become part of a hierarchical-based system by seamlessly integrate the different domains as highlighted in the Smart Grid Conceptual Model developed by EPRI for the National Institute of Science and Technology (NIST.)

Transitioning to Grid 3.0

Replacing the operating system in today's increasingly complex grid is like replacing an engine on a jet plane while it is flying at 30,000 feet. Much like the plane, the grid needs to be "on" all of the time. There are two issues to look at regarding the power system being on all of the time. The first one relates to the inherent complexity and potential to disrupt the system during transitions from one operating version to a newer version. While many aspects of upgrading the power system have become routine, such as new line extensions and public improvement projects, other projects are more complex, such as upgrading a control system or its many parts that are critical to the minute-to-minute operation. The other issue is the ability to simulate or model the power system at a sufficient scale (e.g., in the eastern interconnection) and behavior (daily, weekly, seasonal modes) so that extensive recursion testing of system can be accomplished prior to actually putting a system in service in a real operating environment. This very issue has been one of the roadblocks to widespread phasor measurement unit deployment.

Collaboration to Develop Grid 3.0

EPRI can be a catalyst in the development of Grid 3.0 by becoming a facilitator among the stakeholders leading to development of the architecture and functional specifications. EPRI held its first industry gathering for this effort with a design validation workshop with the industry's best minds to review the preliminary plan help put together a comprehensive plan (see Grid Transformation Workshop 2011 above). That plan will develop a 24-month vision of a full architecture and a requirement driven specification. This will be conducted in an open environment such that the implementation and ultimate innovative development of products and systems can be conducted by vendors. It is critical that the industry respond to this call for action to embrace this innovation challenge to develop Grid Operating System 3.0. EPRI will provide seed funding for the first phase of this effort from its Technology Innovation Program. Additional R&D funding resources and dedicated researchers from key institutions will ultimately be needed to make Grid 3.0 a reality.

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