The Integrated Energy and Communication Systems Architecture

Volume II: Functional Requirements

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Cosponsor

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EXECUTIVE SUMMARY

The foundation of an architecture begins with a collection of requirements that span the scope of the energy industry enterprise. As the Intelligrid Architecture is envisioned to span from the energy trader's desk to the thermostat in the home, the requirement space and subsequent stakeholder community was extensive. Volume II covers the requirements development processes and resultant requirements content that the team has gathered within the Intelligrid Architecture project.

The requirements gathering process was structured and based on the IEC standard "Reference Model for Open Distributed Processing – RM-ODP". This standard identifies the fundamental information needed for architecture development, such as "who" is involved in an activity, "what" data is being exchanged, and "how" the data is being exchanged (i.e. – communication Quality of Service requirements). The requirements gathering process was facilitated by a "Domain Template" developed by the team, which then solicited information based on the RM-ODP guidelines. In particular, the template format (included in Appendix C) starts with a narrative that describes, in plain language, the particular function being detailed. The template then proceeds to guide the stakeholder through the identification and definition of the various entities (actors) involved in a process, the data exchanged between the actors, the sequence of steps involved in the data exchange, and the communication requirements (such as data speed, reliability, security, etc.) for the data exchange.

As many "pieces" of the Intelligrid Architecture architecture are in place and operating as "legacy" systems, the requirements gathering focused on "new" and "architecturally challenging" applications. However, several "baseline" applications were detailed and subsequent gaps and seams in the existing architectures, functionalities, and technologies were identified. An application was deemed architecturally challenging if it pushed the boundaries of current technology with regard to performance, reliability, security, configuration (number of devices with which to connect), data management, etc. To this end, requirements gathering focused on four areas that were identified as migration areas for the power system of the future, namely: Market Operations, Wide Area Measurement and Control (WAMAC), Advanced Distribution Automation (ADA) / Distributed Energy Resources (DER), and the Consumer Interface (including Real Time Pricing). It should be noted that these focus areas "cut across" multiple power system domains such as generation (primary and distributed), transmission, distribution, and consumer services.

During this phase of the project and throughout the project in general, the team made use and took significant advantage of existing materials. Team members did extensive use and review of existing documents. Specific documents reviewed included many from EPRI as well the FERC SMD, NERC operating guidelines, TC 57 documents, internal design documents from various utilities, paper reviews, and other documents. A complete listing of these documents is included in Appendix B.

In addition to the power system and energy applications, it was determined that the next generation energy architecture would require a management system for the communication system itself. These network management requirements were often identified in the use cases and been identified as "Common Services", that is, services that span the entire architecture. These Common Services are detailed in Volume IV.

As mentioned earlier, in order to cover the extensive range of requirements, an equally extensive range of stakeholders had to be identified. To this end, a stakeholder identification and engagement process was prepared and undertaken, a process that is ongoing. Engagement took place on two fronts; namely, education and requirements capture, and included over 100 engagements with over 1000 individuals. Invariably, all engagements started with an educational presentation on Intelligrid Architecture. This educational presentation was prepared with each specific audience in mind, taking into account their specific background and experiences. With appropriately targeted audiences, detailed requirements gathering would be facilitated, typically resulting in the filling-in of a domain template resulting in a use case. In addition, the above-mentioned existing documents were used as references for the use cases. A description of the stakeholder engagement process can be found in Appendix A, and the list of stakeholders engaged and documents utilized to date can be found in Appendix B. A description of the domain template can be found in Appendix C.

The captured requirements should serve to further make the case for architecture development and larger scales of integration than is being either achieved or addressed within standards communities today. It must be kept in mind that these requirements are not exhaustive for every identified application that could use or be integrated with Intelligrid Architecture. In this way the associated common services and related architectural issues for the entire industry can be addressed by the Intelligrid Architecture's carefully selected representative sample of application requirements and associated analyses. In effect, this completed set of Intelligrid Architecture requirements will cover most of the major architectural issues likely to be encountered by any foreseeable application. It should be noted, however, that Intelligrid Architecture is a living document that will be periodically updated with new use cases and new technologies as identified.

CONTENTS

1 INTRODUCTION

Volume II presents the beginning of the architecture development process; that is, the collection of the function descriptions or "use cases" that the architecture needs to support, the process for identifying stakeholder and source information, and the process for capturing the functional requirements. The appendices of this document include lists of stakeholders engaged and the detailed information captured in the stakeholder engagements, along with descriptions of the functions.

1.1 Requirements Gathering Process

The requirements gathering process used an iterative and stepwise refinement-based methodology. In parallel with the main requirements development process, there was a constant stakeholder engagement and document review track that fed information into and out of the project as necessary. This approach facilitated the requirements gathering process by stimulating stakeholder interest, collaborating on new ideas, and obtaining stakeholder buy-in.

The stakeholder engagement process identified various kinds of stakeholders and different kinds of engagements. Note that besides the collection of information, a very important aspect of the stakeholder engagement process was education about the concept and process of building an architecture, as well as the goals and scope of Intelligrid Architecture itself. Numerous presentations to technical groups and individuals were made, along with detailed discussions with selected individuals and small groups. In addition, the team took advantage of existing published materials to augment the stakeholder engagements as well as to provide references and context to the engagements and resulting use cases. To date, over 100 engagements have been made to over 1000 individuals and hundreds of documents have been reviewed. Details of the engagement process can be found in Appendix A, and a list of the groups/individuals engaged, either actively or passively, as well as documents reviewed can be found in Appendix B.

The core requirements gathering process track started with a scoping exercise that resulted in the identification and documentation of over 400 existing and future utility functions at a preliminary level. Section 2 of this document describes this process in more detail and summarizes the results. Appendix E contains the details of the information captured, and the on-line version of the deliverable set provides hyperlinked documentation of these functions and their key attributes.

Early in the requirements gathering process, the entire energy enterprise was broken down into a few manageable pieces (domains):

- Generation
- Market Operations
- Transmission Operations
- Distribution Operations
- Consumer Services
- Distributed Resources

A preliminary analysis of these domains was done to describe the overarching challenges that need to be addressed to identify and associate core functions relevant to each domain. A preliminary analysis of these domains indicated a high degree of overlap and interdependence of the identified functions within the domains. Section 3 of this volume describes each domain including the key applications and architecturally significant issues that need to be addressed.

To focus on those functions that would set boundaries on the architecture, an evaluation was performed that examined performance, security, data management, and configuration requirements in the identified functions. The evaluation identified four primary areas for detailed study, namely: Market Operations, Transmission (Wide Area Measurement and Control), Distribution Operations including Distributed Energy Resources and Advanced Distribution Automation, and the Consumer Interface. In these four areas, those functions that, from a preliminary evaluation perspective, appeared to have "architecturally challenging issues" were selected for detailed analysis. Section 4 of this volume describes these areas of concentration.

In addition to the primary study areas, the need for services to manage the network was clearly identified. These services are extensive and cover areas such as time synchronization, network management, automatic configuration, etc. Details on these topics can be found in Volume IV.

The detailed description, requirements gathering, and analysis of the selected functions was structured through the use of a standardized format known as the Domain Template. The Domain Template solicited common information from each evaluated function, such as a textural description of each function, identification of "actors" in the function, the information exchanged by the actors, and the transaction sequences in which the information was exchanged. The process of filling out the Domain Template resulted in the creation of a Use Case.

Associated with each transaction sequence in a use case was a set of non-functional modifiers that quantified items such as the required quality of service, security, configuration, and data management expectations. This information was captured in an embedded spreadsheet in the use case document. The structured format of the use cases provided by the Domain Template enabled automatic importation of the various use-cases into a standard Universal Modeling Language (UML) modeling tool. Details on the structure of the Domain Template are found in Appendix C.

A Domain Expert thoroughly familiar with the topic about which they were writing typically filled in the Domain Template. The primary focus of the narrative development was to clearly illuminate the architectural issues associated with the use case in order to allow further architectural analysis. The narrative type of explanation also facilitated sharing scenarios with other related domain experts.

Having identified the information needed, the next step was finding sources for the required information. To this end, the document review and stakeholder engagement process described earlier was utilized. A printable form of the resulting use cases can be found in Appendix D. The use cases are best reviewed, however, within the hyperlinked electronic form of the Intelligrid Architecture final report. Only in the electronic version can the detailed attributes captured relative to quality of service, security, configuration, and data management be viewed. Also, the navigable model illustrates clearly the interdependencies between functions and domains.

The specific use cases captured during the project were used primarily to identify the key architectural issues facing the Intelligrid Architecture and to facilitate the development of the architecture to address them. It is intended, however, that this formal requirements and use case capture process be used during the development of an implementation of the Intelligrid Architecture architecture for a specific project.

The Intelligrid Architecture results are intended to be extensible; that is, as new concepts, features, and functions are developed, the Domain Template and subsequent model analysis tools can be used to extend the knowledge base by adding new use cases in order to keep pace with the changing times and technology.

1.2 Audience

This volume was designed as a tool for use by all prospective audiences, which include

- Utility system planners, designers, and executives.
- Regulators and auditors
- Vendors and suppliers
- Regional Transmission Organizations and Independent System Operators
- Industry groups, including utility associations and organizations
- Government institutions
- End user groups or organizations

- Standards making organizations
- The academic community
- The international community outside of standards making organizations

1.3 How to use this document

This volume discusses the process that was utilized to determine and describe the enterprise level functions, and discusses the power system domains and domain areas of concentration, as well as the application domains. These provide a high level overview of the scope and focus of the requirements, as well as an introduction to the use cases. In addition to serving an introductory role, this material can be utilized on a stand-alone basis to lay the foundation for the analysis covered in subsequent volumes.

The use cases contained in this volume – both in the form of the captured narratives in Section 5 and with the full documents contained in Appendix D – can be used by different individuals/groups, depending on their needs. Example applications include:

- Study of present baseline applications - For those individuals who wish to gain an understanding of how certain utility systems operate today, the narrative descriptions of the "baseline" use cases on SCADA, Market Operations, Contingency Analysis, etc are available.
- Identification of gaps/seams with existing implementations - For product planners or users planning new developments or new system installations, the use cases provide a baseline from which gap and seam analysis can be performed. This process entails identifying the deficiencies of existing installations and then identifying the enhancements to the products or systems that would eliminate or minimize the deficiency.
- Identification of functional requirements for specifications - For procurement personnel or anyone writing a functional specification, review of the functions performed and the services required in the identified use cases can serve as a guide for features and functions required in procurement. For example, a utility getting ready to issue a procurement for electronic home meters could read the scenarios and see that they might want to include intelligence for real time pricing, with perhaps the incorporation of a consumer portal for remote user access, secure communications with authentication, and the capability to add-on a wireless home communication port.
- Aid for the communication system architect - As the communication system architect lays out long term plans for his or her utility, a review of the detailed use cases can provide valuable information as far as the number of devices that must be connected, the level of communication system performance (e.g. point to point communication times) that will be required in the future, the degree of availability/reliability of the communication network, security requirements (including device access), the amount of data that will need to be managed, etc.
- Utility executive vision development - As many of the use cases address future utility functionality, the utility executive could use the narratives to help formulate a long-tern vision for his or her company.
- Aid for the power system planning/ design engineer - As the planners and designers set their sights on the future of the electric power grid, having knowledge of what is being done and what may be done in the future is valuable. For example, knowing that an inter-area oscillation can be damped through the application of a wide area closed loop control system could aid in solving a problem identified by the planner/designer.
- Checklist of system design issues - For any system designer, the narratives provide a convenient checklist of issues to address in their design. In particular, the Excel spreadsheet associated with the Domain Template provides over 400 check boxes of items to be considered in a design.
- Communication of Research Results - As a researcher develops a new concept for the protection, monitoring, or control of some element in the electric power grid, the use cases provide a standard mechanism of conveying the communication requirement that his/her design will require.

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2 IDENTIFICATION OF POWER SYSTEM FUNCTIONS

The initial task in developing the Intelligrid Architecture was to define clearly the scope of the architecture to be addressed in the project. Of particular importance was the identifying and addressing the industry-wide and enterprise-wide power system operation functions that carried architectural significance. The key to defining the Intelligrid Architecture Scope was to identify the major activities and categorize all of the stakeholders and their potential interactions for plausible operational and business scenarios. In addition, the team assessed the status of existing distributed computing and communications technology standards and the de facto practices used by industry in general and by the utility and in-building automation industries specifically.

The Intelligrid Architecture team began by drafting scenarios of current and future power industry operations and placing these descriptions into a format that could be carried forward into the requirements process. The purpose of these initial descriptions was to illustrate plausible future operations and to stimulate input from the stakeholder communities. There are many power system applications and a large number of potential stakeholders who participate in power system operations. There will be even more stakeholders taking part in future applications, spanning the enterprise from the energy producers to the end consumers.

To expedite this, the Intelligrid Architecture team developed business models identifying a strawman set of entities and addressing the key interactions between them. These models established a set of working relationships between industry entities in the present and the future, including intermediate steps from vertical operations to restructured operations. Within the context of these business models, the team created application descriptions (enterprise activities) that were carried forward into the stakeholder engagement/requirements gathering process as a framework upon which to build the architecture.

One of the initial steps was to identify a myriad of enterprise activities for present and future power system functions. The energy industry was organized into six (6) functional domains:

- Market operations
- Transmission operations
- Distribution operations
- Centralized generation
- Distributed energy resources
- Customer services

A seventh domain, federated systems management, was also identified, which consists of technological functions, such as network management and security, which cut across all of the other domains. This concept evolved to be the Common Services that can found in Volume 4.

Domain experts in the Intelligrid Architecture Team then developed draft lists of functions (termed enterprise activities) within each domain, defining present and future activities that involve electric energy operations. Ultimately, 80 high-level activities composed of more than 417 supporting activities were identified. These can be found in Appendix E. These descriptions helped define the scope of the project and served as a starting point for developing a more complete vision of future utility operations.

At the same time, architecture experts developed a set of key criteria (quality attributes) to analyze the significance of the impact of each function on the Intelligrid Architecture architecture. These key criteria are:

- **Communication configuration requirements**, such as one-to-many, mobile, WAN, LAN, etc.
- **Quality of service and performance requirements**, such as availability, response timing, data accuracy, etc.

- **Security requirements**, such as authentication, access control, data integrity, confidentiality, and non-repudiation
- **Data management requirements**, such as large databases, particularly, many databases across organizational boundaries, frequent updates, etc.
- **Constraints and concerns related to technologies**, such as media bandwidth constraints, system computational constraints, prevalence of legacy systems, unproven technology, etc.

Each enterprise activity within each domain was then briefly described. The description is at a high level since the initial goal was to develop a scope for the Intelligrid Architecture effort. Once described, each enterprise activity was evaluated according to the key criteria. The focus was to identify those key criteria that would be architecturally significant, and that will need to be taken into account as the architecture was developed.

The next step was to evaluate the impact of the key criteria for each enterprise activity, using a rating system of 0 (no significant architectural impact) to 3 (very significant architectural impact).

Then the team identified all activities that had ratings of 2 or 3 in any of the key criteria, and expanded on the exact nature of the significance. Thus, for one specific enterprise activity, a security rating of 3 might be expanded to indicate that confidentiality held the main significance, while a quality of service rating of 2 might be expanded to indicate that availability and response time were of key importance.

As the scoping effort progressed, a number of key issues were identified as being even more critical to the success of the Intelligrid Architecture project than were initially envisioned. This recognition led to the following recommendations for any review of technologies and requirements with a goal of additional focus in the key areas of:

- **Legacy Systems.** Coping with legacy systems within a state-of-the-art architecture, and developing migration plans for gradual upgrades of these legacy systems to the Intelligrid Architecture architecture technologies is vital to the acceptance of the architecture by the industry, which has an extensive infrastructure already in place.
- **Security Requirements.** The utility industry has become more aware that reliability of the power system is dependent on the security of the information and control of devices. The primary need is to assess the security requirements for the enterprise activities and the information assets, and develop practical, risk-based, and cost-effective solutions for meeting the security threats.
- **Data Management**. Automation of the power system operations, market operations, and customer services implies accurate information that is available at the right time in the right place. Therefore, it is crucial to understand the increasingly complex requirements for data management across disparate systems, and to develop methods for maximizing the accuracy and consistency of databases while minimizing the cost of ongoing database maintenance.

The development of the functions includes a complete traversal from the domain description of a business function through modeling of its details. In the course of this exercise, the following steps were executed:

1. *Enumeration* of as many utility enterprise activities as the Intelligrid Architecture project team could identify prior to consulting with stakeholders.
2. *Definition* of the utility enterprise activities in a manner illustrating the requirements they will place on the communications system
3. *Prioritization* of the activities, in two levels, to identify which activities are most likely to place the highest demands on the resulting architecture.
4. Detailed *description* of a "day in the life" use case for a single business activity that was identified as containing many architecturally challenging quality attributes.
5. *Validation* of the tools used to develop the architecture

The enumeration, definition and prioritization steps were applied to all enterprise activities and were used as a starting point for the definition of requirements, along with additional information gathered from stakeholders.

The results of this process can be found in Appendix E.

3 IDENTIFICATION OF POWER SYSTEM DOMAINS

The initial step in developing the Intelligrid Architecture involved defining clearly the scope of the requirements of the power system functions and identifying all the stakeholders. There are many power system applications and a large number of potential stakeholders who already participate in power system operations. In the future, more stakeholders, such as customers responding to real-time prices, Distributed energy Resource (DR) owners selling energy and ancillary services into the electricity marketplace, and consumers demanding high quality, will actively participate in power system operations. At the same time, new and expanded applications will be needed to respond to the increased pressures for managing power system reliability as market forces push the power system to its limits. Power system security has also been recognized as crucial in the increasingly digital economy. The key is to identify and categorize all of these elements so that their requirements can be understood, their information needs can be identified and eventually synergies among these information needs can be determined. Accordingly, the following power system domains were identified:

Market operations, including energy transactions, power system scheduling, congestion management, emergency power system management, metering, settlements and auditing.

Transmission operations, including optimal operations under normal conditions, prevention of harmful contingencies, short term operations planning, emergency control operations, transmission maintenance operations and support of distribution system operations.

Distribution operations, including coordinated volt/var control, automated distribution operation analysis, fault location/isolation, power restoration, feeder reconfiguration, DR management, and outage scheduling and data maintenance.

Customer services, including AMR, time-of-use and real- time pricing, meter management, aggregation for market participation, power quality monitoring, outage management and in-building services and services using communications with end use loads within customer facilities.

Generation at the transmission level, including automatic generation control, generation maintenance scheduling and coordination of wind farms.

Distributed resources at the distribution level, including participation of DR in market operations, DR monitoring and control by non- utility stakeholders, microgrid management and DR maintenance management.

A seventh domain, federated systems management, was also suggested, which consists of technological functions, such as network management and security that cut across all of the other domains, but it evolved to be the Common Services. The Common Services concept can be found in Volume 4. A detailed discussion of each domain follows.

3.1 Market Operations

With the advent of deregulation and market operations, utilities must develop an entirely new set of applications. These applications vary from utility to utility and from RTO to ISO, but generally can be grouped into the applications listed in Appendix E.

This list of applications illustrates the complexity of this new area of the electric power industry. Many of these functions were developed only within the last few years. Some may exist in name, but in reality are not yet concrete and or widely used. Others have been implemented, but then subjected to repeated ad-hoc modifications that cripple them for general use. This is largely due to the fact that market rules and the power system organizational structures have not yet stabilized. The FERC has mandated the establishment of four RTOs and propagated a Standard Market Design (SMD), but the established Independent System Operators have not evolved into full fledged RTOs and not all ISOs, RTOs, state regulatory bodies, and individual utilities have embraced either or both the RTO and SMD concept. This leads to a great gap in how these applications will work together, and how they are interfaced with each other. Some work has been started. Other work is ripe for the support of an information architecture, namely the Intelligrid Architecture, to guide developers using modern concepts and state-of-the-art technologies.

3.2 Transmission Operations

The purpose of transmission systems is to provide adequate, secure and efficient operating conditions when the power system is in the normal mode of operations, and to minimize the harm to the customers and the power system components when the system is in an emergency situation. The still-evolving market environment and uncertainty over the pace of restructuring and FERC regulation have set a much higher standard for existing transmission system operations and have generated a number of new capability requirements.

The specifics of these requirements, which will be imposed on the transmission systems by the energy market, are still in a state of flux. At the same time, it is reasonable to assume that eventually the market rules will incorporate all capabilities that provide value to the market participants. When the market rules were initially defined, some operational issues were simplified, creating discrepancies between the actual value of a capability and its representation in the market. For example, the currently accepted methodologies for accounting energy losses associated with energy contracts may create unfair advantages for some market participants and disadvantages for others. Future transmission system capabilities must be much more comprehensive, accurate and timely than the current ones.

The self-healing concept set other high standards for transmission operations, such as dynamic optimization of multiple criteria, prevention and fast response to emergencies, and rapid self-restoration of services. To meet these requirements, in addition to improving the performance of the current capabilities, new functions will be required. Currently, there are practically no fully automated (closed-loop) transmission operations. However, some new requirements cannot be met by using advisory modes of applications and supervisory implementation of the recommendations. In many cases, the operator will be outside of the real-time control loop.

3.3 Distribution Operations

Distribution automation is integral to the concept of a self-healing grid. Distribution automation applications improve the efficiency of system operation, reconfigure the system after disturbances, improve both reliability and power quality, and identify and resolve system problems. Many distribution automation applications can also be extended to coordinate with customer services such as time-of-use, real-time pricing and load management, and distributed resources.

Some distribution automation applications (such as many substation automation functions) can be implemented utilizing only local information. However, most applications that can improve performance of the overall distribution systems through centralized optimization require communications and information exchanges to monitor conditions at different locations in the system. Obviously, the systems architecture being used will play a critical role in future distribution automation applications that have been slow to develop due to the lack of communication infrastructure and standards.

3.4 Customer Services

Customer services consist of more than a meter reader walking past a house once a month to scan the meter from a distance. With the advent of deregulation, interacting with customers has suddenly become more important, for two major reasons:

- Customers can (and have) switch(ed) energy providers
- Customers can now be an additional source of revenue if new energy services can be sold to them, or if the utility rights within the customer premises can be used to sell access to other businesses

The expansion of coordination and control of system operations down to end user facilities is one of the main advantages of the Intelligrid Architecture. This offers a tremendous opportunity for improved efficiency of operation, improved control of customer processes based on supply system conditions, use of customer-owned and operated generation and power quality improvement technologies as part of the overall system management, and reduced costs to achieve the required levels of reliability and power quality at the end user level.

Applications related to customer service must be coordinated closely with the distribution automation applications and the distributed resource applications. Key applications include:

- Real time pricing
- Load management
- Residential customer applications
    - Load control in response to real time pricing incentives
    - Direct customer energy management and load control during emergencies
    - Automatic evaluation of and recommendations for increasing energy efficiency based on profiles of the customer site and loads
    - Control and performance evaluations for residential generation
    - Power quality assessments and control.

Also important are commercial and industrial (C&I) applications including commercial customer participation in energy markets through aggregation of backup generation and energy management, participation in ancillary services (such as volt/var control, harmonic control, and reserve generation), real time commercial facility power quality assessment solutions integrated with the distribution system operation and integration of real time information concerning system power quality and reliability.

3.5 Generation at the Transmission Level

As the power industry restructures, the role of transmission-connected generation has been moving away from the vertically integrated model where the owner of the transmission (and sometimes distribution) system also owns the generation. Now other utilities or independent power producers may own the generation, which raise challenges for both transmission and generator owners/operators. Issues such as market operations, dispatch, and availability have created a need for real time information flow between transmission owner/operators and generator owner/operators. Applications such as automated generation control (AGC) and generator maintenance and scheduling are becoming more widespread in restructured markets. The emergence of RTOs/ISOs reflects the changing relationship between transmission and power generation systems.

Another issue of concern/application is the increasing presence of bulk wind plants on transmission systems. The intermittent nature of this generation resource necessitates an additional set of requirements regarding the ability to disconnect the wind plant from the transmission system. Unlike many other generation sources, wind is not readily dispatched, so transmission system/market operators must treat it differently.

3.6 Distributed Energy Resources

The Intelligrid Architecture can have a major impact on distribution connected DR management. Few, if any, applications exist to analyze the impact of DR equipment connected to the distribution system. Primarily, some of the existing distribution automation applications for planning, analysis, and operational control will need to be modified significantly to take into account the impacts of DR.

DR devices are becoming functioning parts of distribution power systems, regardless of who owns or operates the DR devices. To derive maximum benefits from DR, avoid possible adverse system impacts and address safety issues, those utilities which are responsible for distribution operations will need the ability to monitor and control the DR devices in real time. Real-time management of these devices requires communications links and the exchange of information between the DR systems and the distribution operations centers.

DR will have increased impacts on the operations of distribution utilities, due not only to improvements in DR device technology, cost, and efficiency, but also to the rapid growth of the deregulated electricity marketplace. These deregulation forces have spurred interest in non-standard and dispersed sources of generation to meet increasingly competitive requirements for energy, ancillary services, and other energy services. Another consideration for the DR operations is that there are many stakeholders, particularly in deregulated electricity markets. DR stakeholders are the people or companies with a role in respect to the DR devices. These roles determine the information transactions, namely, what information they have and what information they need.

By managing these distributed resources effectively, distribution utilities can benefit from DR capabilities, including using DR for energy, reserve, backup, VAR control, and power quality enhancement.

4 AREAS OF CONCENTRATION AND ADDRESSING APPLICATION DOMAINS

To facilitate the requirements gathering process, the Intelligrid Architecture team felt it was useful to visualize a set of power industry activities that all have a common purpose or "theme". These areas of concentration represent \ a number of different activities, functions, devices, networks, organizations and people that are involved in these activities. The team used the functional grouping to prioritize the components of the power industry in order to tackle the significant architectural challenges first. Although there were four distinct areas of concentration, there is significant overlap, with many sharing the same, well known architectural issues. However, the distinctions between the areas represent really important issues that ultimately define the boundaries of the architecture.

In this way, the team analyzed the enterprise activities and identified four distinct areas that have complex requirements that aid in defining the challenging architectural requirements for Intelligrid Architecture. These areas of concentration are

1) Market Operations: Energy transactions, power system scheduling, congestion management, emergency power system management, metering, settlements and auditing.

2) Consumer Services: Real time pricing, integrated with market operations and consumer end use load control as well as power quality monitoring. This includes consumer dispatch of onsite DER in response to peak pricing/ancillary service provisioning.

3) Transmission: Wide area measurement, monitoring and real time control.

4) Distribution operations: This covers both distribution operations/automation and integration of DER integration and focuses on issues such as system protection integration, volt/var management and managed islanding.

Each of these areas feature distributed computing system administration functions, such as security, which were developed side by side with the power engineering application scenarios. This provided an overall context to explore both distinct as well as crosscutting requirements.

Once the team identified all of the activities and subsequent ratings followed by the selection of the areas of concentrations, the team needed to identify further application domains within each area of concentration on which to focus. This was done in order to select applications that would cover the architecturally specific items within each area of concentration.

As shown in Appendix E, there are sixteen top-level functions under the Consumer domain, with several to many sub-functions under each top-level function. Architecturally significant top-level functions were selected along with corresponding sub-functions for detailed analysis and use case development. Use cases were selected in order to cover most of the top-level functions as broadly as possible, and either directly or indirectly. Prior to the development of the use cases, a detailed baselining analysis was conducted. This baselining task resulted in a thorough understanding of what exists present day across the areas of concentration.

To this end, the team conducted a review of stakeholder internal project documents, internal standards and practices, as well as existing IEEE and IEC standards, EPRI reports, NERC and FERC standard market design documents and other documents. These documents by their nature of being documented standards and practices are representative of core requirements for the various domains that they represent. These documents were used to augment interviews with stakeholders, improve use cases and facilitate requirements analysis.

The reasons for this approach are two-fold. First, the magnitude and extent of the number of sub-functions dictated that careful selection of those for detailed analysis is made in order to cover the most areas, based on the project budget and schedule. Secondly, as mentioned earlier, there was significant overlap between areas of concentration, such that specific use cases would be applicable to several, if not many, different areas of architectural significance. Missing a single activity from the list would only be critical if that activity were composed of quality attributes not required by any other activity.

Following is a discussion of significant application domains under each area of concentration. Section 5 contains the narratives of the use cases described for each of these areas.

4.1 Market Operations

As the electricity industry is deregulated and as FERC defines more clearly what the market operation tariffs will encompass, market operations, which are essentially the rules that define how the Regional Transmission Organizations (RTOs) deal with each other, will become very important. This area of concentration deals with bulk power sales and transfers, and hence potentially involves millions of dollars. Since a lot of money could be changing hands on practically a real-time basis, data security and accuracy is critical, thereby putting extreme significance on the communication infrastructure.

Even though the final market rules and market operations have not been finalized, the team studied, in depth, how three possible RTOs in the Western Interconnection are developing seamless interfaces for market participants to submit energy schedules and ancillary service bids across these three RTOs. The three RTOs are California ISO (existing ISO handling the electricity market in California), RTO West (potential RTO of many northwestern utilities), and WestConnect (potential RTO of many southwestern utilities). These three RTOs are developing the requirements for the Western RTO functions.

For this area of concentration, six top-level functions were identified that were all related to market operations but organized and separated for convenience by timeline, i.e. real-time, day ahead, short term, long term, etc. Use cases describing these functions across each timeline were completed. These functions have never been implemented because the actual market rules have not been agreed upon, and are waiting for several general FERC decisions and some FERC RTO-specific approvals. Nonetheless, conceptually, the functions represent many of the key types of market operations that are needed in any electricity market, and therefore are applicable to all potential markets.

4.2 Consumer Services

As mentioned above, there are sixteen top-level functions under the consumer services domain. Of those sixteen, the team felt that three stood out as covering a wide range of architectural issues as discussed in the following paragraphs. The functions were responding to real-time pricing (RTP) signals, load control and power quality data collection.

RTP is important because it requires communication between the customer and the Electricity Service Provider (ESP), in terms of the ESP providing RTP signals to the customer and the customer possibly providing bids and forecasts back to the ESP. Quality of service, including high availability and timeliness of data, is crucial. Large numbers of customers possess sensitive information on pricing and usage; therefore security is a key consideration. Since future power system operating scenarios will involve more two-way communication with the customer and the ESP, RTP was selected for detailed analysis.

Additionally, a use case on load control was added near the end to account for demand response aspects, where instead of responding to price signals, the signal comes directly from the ESP to control customer loads. Customer-side load control covers a wide range of issues – especially security across organizational domains and the need for two-way communications to confirm load control actions for future advanced demand responsive systems.

The third important aspect is data collection from the consumer side. In terms of power quality data, the information is intermittent and sometimes infrequent, but timely, and communication and notification is very important when events do occur. Several use cases were written to account for the communication aspects associated with data collection from power monitoring instruments.

With these use cases, the emerging concept of the consumer portal can be addressed.

4.3 Transmission

The Transmission area of concentration focuses primarily on real-time network analysis and normal and emergency operation of the transmission grid, specifically known as Wide Area Measurement and Control (WAMAC). The team felt that these real-time top-level functions stood out in importance among the thirteen total top-level functions in this domain.

WAMACS Automated Control describes a set of functions that are typically automated within a substation, but are not directly associated with protection, fault handling, or equipment maintenance. In general, they serve to optimize the operation of the power system and ensure its safe operation by preventing manually generated faults. These functions include:

- Changing transformer taps to regulate system voltage
- Switching capacitor banks or shunts in and out of the system to control voltage and reactive load
- Interlocking of controls to prevent unsafe operation
- Sequencing controls to ensure safe operation
- Load balancing of feeders and transmission lines to reduce system wear and resistive losses
- Restoring service quickly in the event of a fault, with or without operator confirmation

In order to describe these functions, several use cases were written. The main objective of these was to evaluate power system behavior in real-time, prepare the power system for withstanding credible combinations of contingencies, prevent wide-area blackouts, and accommodate fast recovery from emergency to normal state.

Individual devices acting alone traditionally performed many of the functions described in the use cases. When implemented this way, they do not affect the communications system. However, in the last five to seven years, these functions have been distributed across the substation. That is, the software logic controlling the function now often resides on a different device than the one providing the inputs or outputs to the process. This change has taken place because the use of substation LANs has made it economical to place Intelligent Electronic Devices (IEDs) close to the equipment they are monitoring and controlling. Logic therefore has either been centralized with a single Substation Computer using the IEDs as remote controllers, or it has been distributed among the IEDs themselves. In either case, the communications system has now become part of the automation functions.

These functions are critical in avoiding another blackout like the one of the August 14, 2003, and hence are very important to the overall Intelligrid Architecture architecture.

4.4 Distribution Operations

The Distribution Operations area of concentration is actually comprised of two top-level domains, Distribution Operations and Distributed Resources. This combination allowed the team to address both of these domains, which cover extremely challenging areas such as system protection integration, volt/var management, and managed islanding in a very efficient manner. These domains were comprised of thirteen and eleven top-level functions respectively, which were further elaborated into many sub-functions.

Two large use cases, covering many sub-functions, were constructed to cover what the team felt were the most important top-level functions – Advanced Distribution Automation (ADA) and integration of Distributed Energy Resources (DER).

The first use case domain template consisted of a collection of use cases utilized to fully cover the ADA function. The objective of Advanced Distribution Automation function is to enhance the reliability of power system service, power quality, and power system efficiency by automating the following three processes of distribution operation control:

- Data preparation in near-real-time

- Optimal decision-making
- Control of distribution operations in coordination with transmission and generation systems operations

The second use case covered is Data Acquisition and Control (DAC) and is applicable to other domains, including transmission, as well as consumer services. The DAC function is made up of myriad mechanisms for data retrieval from field equipment, and the issuing of control commands to power system equipment in the field, including

- Field devices
- Between-field devices and systems located in substations
- Between-field devices and various systems (including, but not limited to, SCADA systems) located in DER and utility control centers and engineering/planning centers

The DAC function provides real-time data, statistical data, and other calculated and informational data from the power system to systems and applications that use the data. The DAC function also supports the issuing of control commands to power system equipment and the setting of parameters in IEDs and other field systems.

These use cases together cover a wide range of sub-functions in this area of concentration, which the team felt which the team felt were some of the most important in terms of the future application of Intelligrid Architecture.

5 USE CASE NARRATIVES

This section contains links to the use cases. Links are provided for both the detailed use cases, located in Appendix D, as well as the less detailed use cases that appear in Appendix F.

This is to allow the reader to get a feel for the breadth of use cases utilized for the analysis portion of the Intelligrid Architecture project and to serve as an example of how use case narratives can be written for a specific implementation project. As mentioned earlier, the detailed use cases were chosen to highlight architecturally significant issues to facilitate the development of the overall Intelligrid Architecture architecture and recommendations, and so are not intended to be a complete treatise on a particular function. The reader is encouraged to use them as a guide and to extrapolate them into use cases specific to the particular project/problem at hand.

A hyperlink to a report with the narratives are supplied on the following pages.

5.1 Detailed Use Cases

Note: Several of the detailed use cases cross domain boundaries and will appear more than once

5.1.1 Consumer

- Customer Communications Portal Management
- Customer Communications Portal Management-Security
- Customer Communications Portal Management-System
- Customer Communications Portal Management-Telecommunications
- Demand Response - Utility Commanded Load Control
- Distributed Generation Aggregator
- DomainTemplateEDFConsumer20040216
- Consumer Portal ScenarioP4_DomainTemplate
- Consumer Portal ScenarioP5_DomainTemplate
- Consumer Portal ScenarioP6_DomainTemplate
- Consumer Portal ScenarioP7_DomainTemplate
- Consumer Portal ScenarioP8_DomainTemplate
- Consumer Portal ScenarioP9_DomainTemplate
- Permanent Power Quality Measurement
- PQ Contracts
- RTP Baseline
- RTP Market Op Energy Services
- RTP Top Level
- RTP-BaseRTPCalc
- RTP-CustomerBAS
- RTP-DER Managment
- RTP-ESP Aggregation
- RTP-ESP Customer RTP Calc
- RTP-LoadForecasting
- RTP-Market Op Ancillary Services
- Wide-Area Wind Generation Forecasting

5.1.2 Distributed Energy Resources

- ADA Use Cases
- Data Acquisition and Control (DAC)
- Demand Response - Utility Commanded Load Control
- Distributed Generation Aggregator

5.1.3 Distribution

- Data Acquisition and Control (DAC)
- Distributed Generation Aggregator
- Permanent Power Quality Measurement
- PQ Event Notifications
- PQ Contracts

5.1.4 Enterprise Management

- EnterpriseManagementGenericUseCase

5.1.5 Market Operations

- Demand Response - Utility Commanded Load Control
- Distributed Generation Aggregator
- Market Operations - Day Ahead
- Market Operations - Long Term Planning
- Market Operations - Med-Short Term Planning
- Market Operations - Overview
- Market Operations - Post Dispatch
- Wide-Area Wind Generation Forecasting

5.1.6 Primary Generation

- ContingencyAnalysisBaseline
- ContingencyAnalysisFuture
- Data Acquisition and Control (DAC)
- Demand Response - Utility Commanded Load Control
- Permanent Power Quality Measurement

- PQ Contracts
- Wide-Area Wind Generation Forecasting

5.1.7 Transmission

- AdvancedAutoRestoration
- AutomatedControlBaseline
- Data Acquisition and Control (DAC)
- Demand Response - Utility Commanded Load Control
- EmergencyOperationsBaseline
- Inter-AreaOscillationDamping
- SAVC
- Self healing grid
- SynchroPhasorDomainDescription
- VoltageSecurity

5.2 Less Detailed Use Cases (top level)

Note: Individual use cases, although they may cross domain boundaries, are listed only once. If you are looking for a particular function and cannot find it, check the other domain areas.

5.2.1 Consumer

- Automatic meter reading (AMR) - Customer Services
- Building/Home Engergy Management - Customer Services
- Calculation of home R factor - Customer Services
- Customer Management - Customer Services
- Customer trouble call management - Customer Services
- Electric Vehicle / Home co-gen - Customer Services
- Energy efficiency monitoring - Customer Services
- ISP services to customer - Customer Services
- Indoor Air Quality - Customer Services
- Load management - Customer Services
- Power Quality - Customer Services
- Real-time Pricing (RTP) - Customer Services
- Third party Service Support - Customer Services
- Third party services - Customer Services
- Transmission and Distribution Operations Support - Customer Services
- Weather - Customer Services

5.2.2 Distributed Energy Resources

- Advanced Distribution Automation (ADA) with DR installed on distribution system - Distributed Resources
- DR equipment maintenance - Distributed Resources
- Demand Side Management (DSM) - Distributed Resources
- Dispersed Storage (functions unique to this form of DR) - Distributed Resources
- Interconnection planning (months to years ahead for new construction) - Distributed Resources
- Market operations - Distributed Resources
- Non-grid connected generation (monitoring for safety) - Distributed Resources
- Post operations - Distributed Resources

- Real-time interconnected DR management (micro EMS concept) - Distributed Resources
- Residential generation devices - Distributed Resources
- Wind-related issues/functions/applications - Distributed Resources

5.2.3 Distribution

- Automation of distribution operations - Distribution Operations
- Construction management - Distribution Operations
- Dispatcher Training Simulator - Distribution Operations
- Distribution Asset Management - Distribution Operations
- Engineering - Distribution Operations
- Long term distribution planning (1 year to 5 years) - Distribution Operations
- Operational planning (1 day to 1 week ahead) - Distribution Operations
- Post operations - Distribution Operations
- Power system equipment maintenance
- Power Quality Management - Distribution Operations
- Real-time emergency operations - Distribution Operations
- Real-time operations - Distribution Operations
- Short-term distribution planning (1 week to 1 year) - Distribution Operations

5.2.4 Market Operations

- Day Ahead Market (24 hours to 48 hours ahead) - Market Operations
- Long Term Planning (1 year to 5 years) - Market Operations
- Medium Term Planning (Weeks Ahead to One Year Ahead) - Market Operations
- Post-Dispatch (last hour to prior months) - Market Operations
- Real-Time (actual time to next hour) - Market Operations
- Short-term Planning (48 hours- one month) - Market Operations

5.2.5 Primary Generation

- Commissioning planning - Primary Generation
- Construction management planning - Primary Generation
- De-commissioning planning - Primary Generation
- Generator equipment maintenance planning - Primary Generation

- Long term planning (Years ahead) - Primary Generation
- Operational planning (1 day to 1 month) - Primary Generation
- Real Time Commitment - Interface to RTO/ISO - Primary Generation
- Real Time Contingency Operations - Primary Generation
- Real Time Dispatching - Interface to RTO/ISO - Primary Generation
- Real Time Maintenance Control - Primary Generation
- Real Time Plant Operations - Primary Generation
- Real Time Scheduling - Interface to RTO/ISO - Primary Generation
- SECURITY (generation specific issues) - Primary Generation
- Short-term planning (1 month to 1 year) - Primary Generation

5.2.6 Transmission

- Black Start - Transmission Operations
- Construction management - Transmission Operations
- Engineering - Transmission Operations
- Long term transmission planning (1 year to 5 years ahead) - Transmission Operations
- Medium-term planning (1 month to 1 year) - Transmission Operations
- Network Analysis (real-time) - Transmission Operations
- Operational planning (1 day to 1 month) - Transmission Operations
- Operator and SCADA/EMS personnel training - Transmission Operations
- Post operations - Transmission Operations
- Power system equipment maintenance (mobile enabled work force) - Transmission Operations
- Real-time emergency operations (system protection level) - Transmission Operations
- Real-time normal operator actions (Using SCADA/EMS) - Transmission Operations
- SCADA/EMS Maintenance - Transmission Operations

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