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A Sofware Engineering Approach For Realizing Smart Grids

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Abstract

Smart grid engineering is advancing around the world. It is an emerging solution for meeting increasing demand for electricity power and the aging power. Smart Grid has the advantage of bi directional communication (2-way) and utilizes the modern technologies in sensing computational intelligence and system control. Different nations are contributing to change the respective customary power grids into Smart grids. In recent past a few models namely Smart Grid Interoperability Maturity Model (SGIMM), Smart Grid Investment Model (SGIM), Smart Grid Maturity Model (SGMM) and Smart Grid Conceptual Model(SGCM) are in access. This paper gives a review of smart grids and their utility of current in Industries. Many technologies of smart grid are briefed in the discussion, with emphasis mainly laid on the concept of automated demand response. A case study of four different industries namely a processing unit of aluminum, a cement industry, food Process Company, and industrial cooling plants are discussed. The future scopes of various inter operative standards, advancements in demand response system which is automated, and many effective and dynamic marketing strategies are discussed.

Key Words: Smart Grid, software models, Smart Grid Interoperability Maturity Model, Smart Grid Investment Model, Smart Grid Maturity Model and Smart Grid Conceptual Model.

Introduction

The main function of power grid is to deliver power from generating source to the consumer. This methodology is carried out primarily in two essential systems namely, the Transmission System (TS), Distribution System (DS). The power is transferred from generating plant to the distributing substation by the TS and then it is distributed to the end consumer by the DS. Customarily, the power grid is an interconnectivity of transmission system utilizing analog technology. Similarly, Smart Grid is a modern term involving multiple functionalities steering to modernization of the power grid. Basically, digital communications and control systems are used by smart grids for monitoring and controlling the flow of power, aiming at transforming the power grid much flexible, improving efficiency and improving cost effectiveness. Smart Grids enhances the interconnectivity, automation and proper correspondence among suppliers, the consumers and the network by the concept of modernization of grid characteristics which deals with effective management having good demand, power generation, pricing in real-time applications and automatic activation of meter and reading [1].

Information Networks

Smart Grid is an interconnectivity of multiple systems and multiple subsystems, and also connectivity of one network of networks. i.e, multiple systems with different owners and managing organizations are connected to each other to facilitate end-to-end services among and within stakeholders and also between smart devices. Figure.1 shows the smart Grid network for information exchange. The clouds in the figure represent show the networks handling both-way communications among the end points of the network of seven distinct domains, as shown in rectangular cuboids in the figure .Every individual domain is taken as an environment that uses distributed computing which is unique and contains its own sub-network for meeting the exceptional requirements of communication for that domain. In ever network, a hierarchical structure containing technology related to the network, such as Home Area Networks, Personal Area Networks, Wireless Access Networks, Local Area Networks, and Wide Area Networks, can be implemented [2].

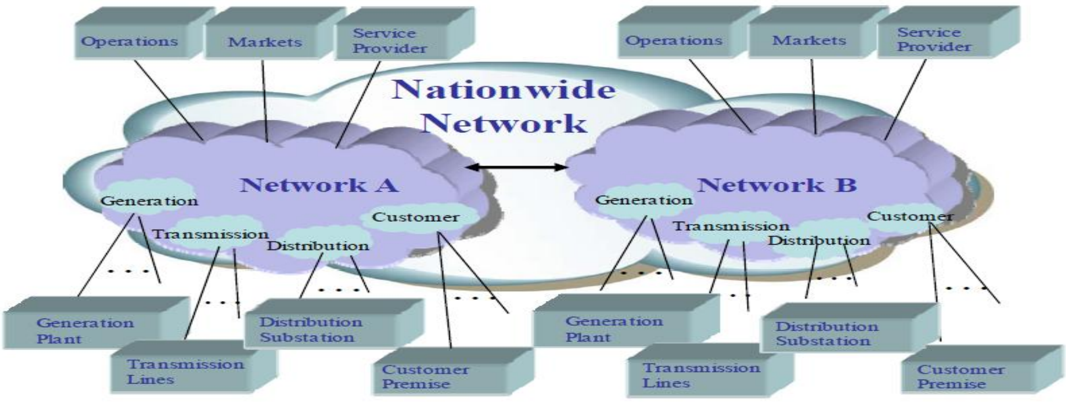

Figure 1: Smart Grid Network for information Exchange

As the time progresses Smart Grid engineering is drastically developing its intricacy in dealing with the power grid which is additionally expanding. As on today number of models is available for observing and measuring the improvement of the development of an association towards number of similarities like productivity, automation, joining, unwavering quality and its economical impact[3]. These models reflect the present scenario of smart grid execution, examines and helps in investigation of feasible arrangements for improving the present to next stage to bring about the profits of the technology of smart grid.

Accessible Software Models

Most prominent software models which can be accessible are :

A. Smart Grid Interoperability Maturity Model (SGIMM)

SGIMM is designed to assist stake holders in achieving interoperability between devices and systems that support smart grid capabilities. It is team that is exploring ways to collaborate for the benefit of users. SGIMM has features such as:

- Status/advancement measuring measurements
- Gap examination
- Prioritizing endeavors for enhancing present status

Primary aim of SGIMM is designing a measuring model which will enhance the concept of interoperability in important regions such as evolution and configuration, performance and functionality and secured and safe electric power system[4].

Use of SGIMM

SGIMM is mainly used to assess the best performance of the context-setting framework. It is used for developing top level requirements for each framework level and cross-cutting issues improve detailed goals for each intersection, to formulate metric statements for goals.

Maturity Level	Community/ Governance	Documentation	Integration	Test/ Certification
Level 1: Initial	management is ad hoc	documentation is ad hoc	integration is a unique experience	testing is ad hoc
Level 2: Managed	managed by project agreement	documented in a project specification	integration is repeatable, with customization expected	tested to plan with results captured
Level 3: Defined	managed by community agreement	references community standard with some customization	integration repeatable with predictable effort	tests exist for community with certification Members claim compliance to standard
Level 4: Quantitatively Managed	processes ensure currency and interoperation	references a community standard w/o customization	integration metrics are defined and measurements collected reference implementations exist	community test processes demonstrate interoperability members claim interoperable conformance
Level 5: Optimizing	managed by a community quality improvement process	adopts an open, community standard	integration metrics used for improvement of the standard	test processes are regularly reviewed and improved

Figure 2: SGIMM levels

It is utilized to create a matrix of maturity characteristics and maturity-level statements for guiding in assessing maturity for each metric. It emphasizes on constructing an evaluation sheet to apply the SGIMM and capture interoperability maturity for an interoperability area. SGIMM helps to improve the nature of interface details that are included in smart grid technology.Figure.2 shows various SGIMM levels.

B. Smart Grid Investment Model (SGIM)

SGIM is a budgetary design, that benefits in figuring the effect of distinctive investment of smart grid , in addition to their methods. These aides in assessing the expenses and following the profits of investment of smart grid over the range of distribution. SGIM is designed for being used by electric cooperatives, municipalities, and other public and private sectors. It allows users in: (a) identifying the technology and program which fits within the purview of smart grid; (b) identifying the benefit of every technology or program which includes cost savings, peak kilowatts, and load profiles hourly over the coming twenty years; (c) identifying technology, installation, programming, and managing costs which are utility based and customer dependent; and (d) comparison of benefits and costs for determining returns in investment.

It gives peculiarities like:

- Complete structure for quarterly subtle elements of monetary expenses and profits reckoning.
- Forecasting the effects of smart grid usage programs on clients and end clients.
- Suggestions for a superior smart grid speculation investigation.
- Guidelines in regards to smart grid procedures that is financially savvy.

SGIM distinguishes the individual advances of smart grid what's more investigation the profits of every technology as far as expenses what's more profits parameters focused around the utility of them and end client's attributes for upcoming twenty years. This system makes a difference in examination of present status of smart grid speculation investigation applications by assessing distinctive speculation alternatives with their effect on recent utilities and interest reaction

C. Smart Grid Maturity Model (SGMM)

SGMM is an administrative tool for supporting utility smart grid planning and implementation. It refers interoperability as a key element of smart grid maturity. It does not focus on achieving the interoperability. It gives a common language and system for characterizing key components of keen framework change and helping utilities to create an automatic approach and keep tabs on their development. The SGMM was developed by the utilities to address the concerns of developing road maps, tracking the progress and understand their posture in comparison to peers. The main challenge of SGMM is changing from a customary to a progressive power grid. Modern grids reflect a time when energy was cheaper, the impact of power on the environment was not having much priority and consumers were not even part of the system. The world is using a smarter, much dynamic power grid which can effectively decrease losses and faulty defects, improves responsiveness, and develops handling capabilities of present and upcoming demand, improving efficiency and control cost.

Time line of SGMM

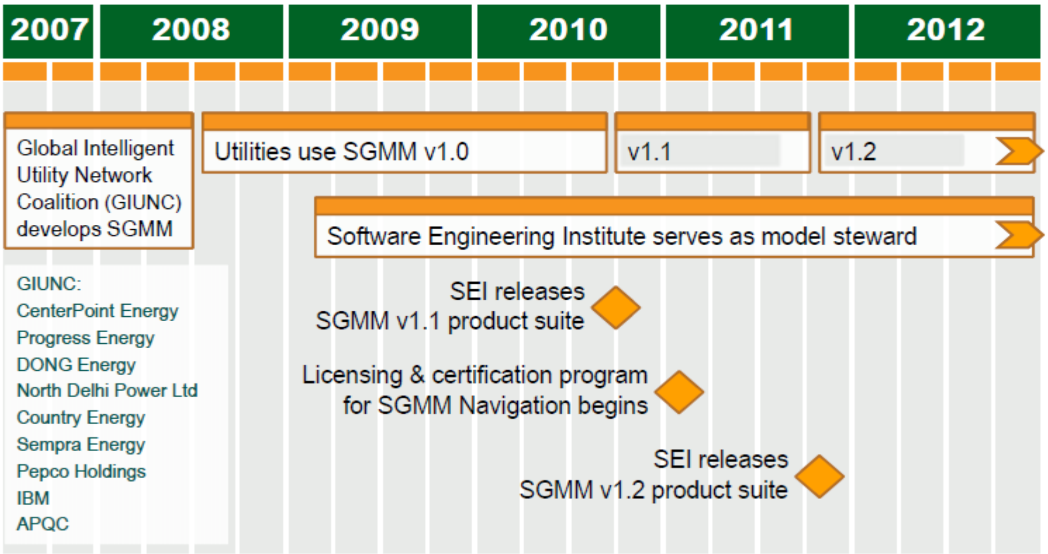

Figure 3: Time Line of SGMM

Figure.3 shows the timeline of SGMM. It is an administrative tool designed to assess the developments of smart grid usage formulated in eight domains(Strategy, Management, and Regulatory (SMR), organizations and Structure (OS), Grid Operations (GO),Work and Asset Management (WAM), Technology (TECH), Customer(CUST), Value Chain Integration (VCI), Societal and Environmental (SE))

It has characteristics such as:

- Designing a imparted vision for smart grid and rules to transform over the silarity.
- Correspondence with distinct stakeholders utilizing common platform
- Allotting diverse undertaking according to legitimate priority
- Monitor and evaluate advance in distinct domains
- Design and improve new and adjusted arrangements if any change is needed.

Smart grid Maturity Model levels

The smart grid maturity model describes features which are designed to look at each stage including the transformation. It utilizes observation indicators for progressing —measuring outputs which occur along with maturity[8]. There are 5 maturity levels of smart grid namely:

1. Exploration: The utility has started exploring the development towards a smart grid, and has a vision with an unclear strategic approach. At this instant, the key points are experimenting and evaluating the technologies and improving the business clients.
2. Investment: The utility is making investment and trying to implement at least single useful functional fields of smart grid. A few of them prioritize the

advancements in metering infrastructure (AMI). Others can initialize from the concept of demand-side management (DSM).

3. Integration: The smart grid components start to integrate with each other, providing inter link among two or many functional areas.
4. Optimization: Transforming and optimizing of the systems enterprise-wide appears, using advantage of integrated control across and in between functions of utility.
5. Innovation: The enterprise is ready to take advantage of the new business, operational, environmental and societal opportunities.

Figure 4: Levels of SGMM

SGMM is focused around compass review, including survey based evaluation study producing distinctive qualities. On the premise of these qualities, distinctive areas are evaluated from five distinctive levels of maturity (Initiation, Empowerment, Integration, Optimization and Pioneering).

SGMM Domains and benefits

The smart grid maturity model contains 8 domains, or logical groups for implementing functional components of a smart grid. It mainly focuses the point of utility based on:

1. Determination of strategies, managing skills and the process of regulatory investment.
2. Enabling of an strategy which is external and an organizational change strategy which is internal.
3. Preparation of a strategy which is based on cohesive technology, which includes information and integration of engineering, standards of operation and business analytical tools.
4. Formulating a strategic plan for "green" initiations, sustaining capability, alternate and distributed energy.

5. Empowerment of operating a grid with a basic foundation of grids components which are intelligent.
6. Operation and maintenance of assets which are based on latest updated and factual data performance.
7. Educating customers in selection of own choices in connection with energy utility and energy cost.

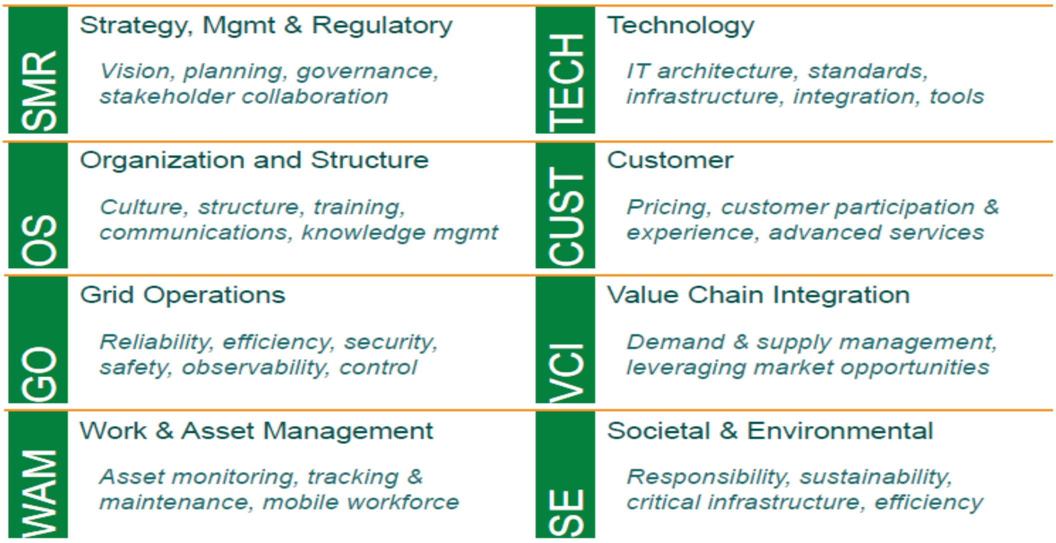

Figure 5: SGMM domains and Benefits

D. Smart Grid Conceptual Model (SGCM)

The SGCM is a framework to discuss the characteristics, applications, performance, interface details, requisites and various standards of the Smart Grid. It has multiple system architecture[5].

The general concepts related to Conceptual model are:

Loose Coupling: It is system in which two directional symmetry and multidirectional symmetric transactions can occur without elaborate pre-arrangement.

Layered System: It is a collection of symmetric functions in terms of concepts which renders services to the upper layers and receives services from simpler interfaces.

Shallow Integration: It avoids knowledge in depth regarding the components that are managed or configured.

The Architecture of Connectional model is shown in figure.5 [6]

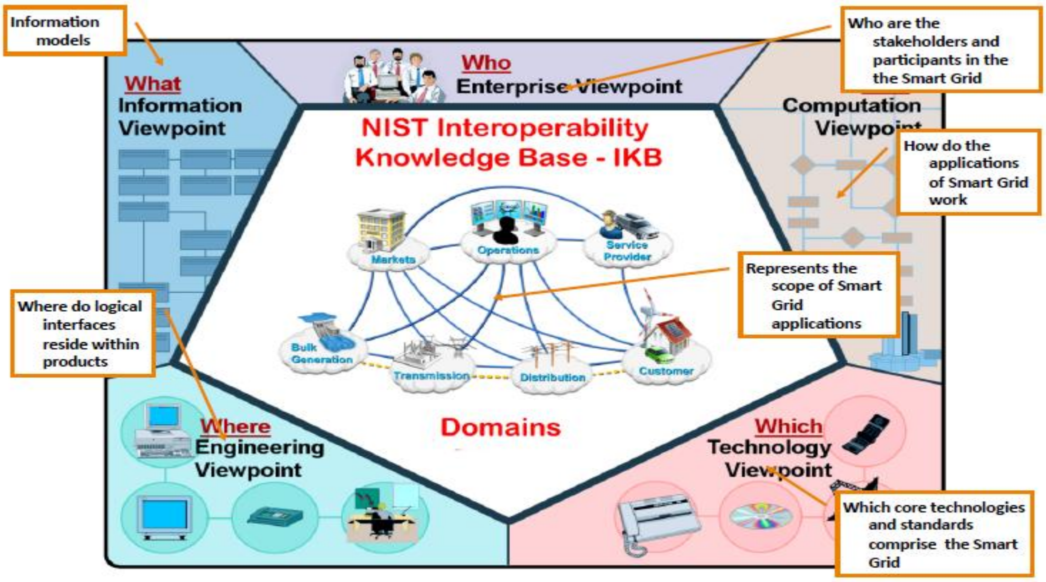

Figure 5: Architecture of Conceptual Model

The interface related properties of conceptual model are:
Symmetry: Each action can run both ways

Transparency: It has the property of transparency and audible chain of transactions

Composition: It develops interfaces which are complex from simpler interfaces.

Cyber Security: It is managed over the lifecycle of systems deployed, it manages risks effectively.

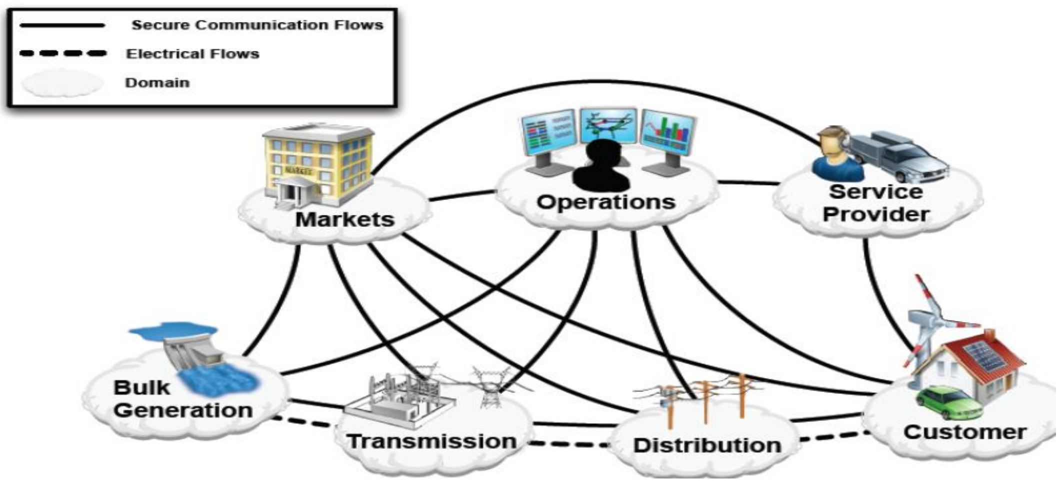

Figure 6: Interaction of different smart grid domains

Figure.6 shows the interaction of different smart grid domains. SGCM gives a pictured graph clarifying how distinctive segments of brilliant framework can be coordinated. It consists of 7 spaces (Customers, Marketing, Administration Providers, Operations, Generation in bulk, Transmitting and Distributing). Its main features are:

- It gives clear review of brilliant network improvement.
- It gives a setting to examination of distinctive standards and interoperations among them.
- It demonstrates the co-operations among distinctive spaces, that helps to achieve Distribution Management System (DMS) effectively.
- It likewise concentrates on digital security, system administration, information administration and application

Scope of Smart Grid Monitoring Model And Its Objectives.

SGMOM is a plan which comprises of a appraisal model focused around essential ranges such as innovative technologies, individuals also forms. It will help in appraisal of legitimate building and correspondence benchmarks for observing also administration advances so fitting displaying and recreation can be accomplished. It takes care of performing the following functions:

- Formalize recent understanding of the processing the system and framework methods.
- Identify linkages of methods crosswise over disciplinary limits
- Identifying limits and extent of arranging their interest that can help correspondence within researchers, supervisors, stakeholders, programming staff and client
- Exploring the relation between different smart grid framework sections Parts of Smart Grid considered as essential aspects of SGMOM are:

A. Technology

Accordingly SGMOM will stick to specialized procedure that can help in riskless achievement. It has ability to help in assessing the versatility, wellbeing, being modified and productivity of association's shrewd framework IT foundation. It aids in creating IT speculation plans in pertinence with industry measures. It incorporates appraisal of down to earth applications of different sensors and checking gadgets, correspondence gadgets, control frameworks, business discernment instruments and IT foundation required for Smart Grid. Sensing equipment and checking gadgets shall incorporate sensors introduced in force framework utilized to utmost current and voltage, sensors focused around methodology control prerequisites and condition observing which is critical, keeping in mind the end goal to keep up framework unwavering quality. Specialized gadgets will incorporate force line interchanges, mains correspondence; force line systems administration utilized for convey information required for force transmission. Control framework incorporates self-managing framework that reacts to digital security episodes and any unfriendly impact of the foundation. Accordingly the manner in which computerized control frameworks helps in enhancing the profit, adaptability, and unwavering quality of vitality frameworks can be evaluated [9].

B. People

SGMOM sticks to every dynamic furthermore detached members in Smart network change. It will incorporate the evaluation of effects on different crowds like electric force utilities, client, stakeholders, manager/administrators, standard advancement associations, scholastics, R & D associations of modern executions. It helps in creating new administrations with fitting security characteristics, effectiveness, controlling the values and customs.

C. Processes

SGMOM will cohere with every process of action included in end to end outline. It helps in evaluating exertion and advance in planning force system, discovering all the conceivable characteristics of shrewd lattice that will be given to the end host. It also helps in accomplishing hierarchical arrangement in a vital way, with the goal that noteworthy profits can be extricated. This segment will incorporate sub spaces such as end to end plan, authoritative arrangement, and documenting and venture structure.

Under the end to end plan, it helps to decide the offices of force system and accessing of the end terminal host accurately. Under the authoritative arrangement, it helps in human assets exercises of association to empower powerful representative's execution to accomplish visualization of the association.

The area of documentation helps in recording of all the obligations and objectives basic of any association. This helps in disconnecting missteps and repeating achievement. It will likewise help in ensuring association against the danger of conceivable case .The speculation system will help in overseeing forms inside characterized tenets.

Case Studies

The case study of four industrial organizations is taken as examples and their performance is analyzed. Alcoa, is an industry taking part in ancillary service markets since last few years and is providing power of70MW of service regulation to Midwest ISO; Amy's Kitchen, which is a industry is a food processing unit and is prominent in Pacific Gas and Electric Company's (PG&E) Auto-DR program from 2008; another few cases of industries from New York State, which include a an industry which is manufacturing cement.

Alcoa

Alcoa is the major customer and source of power supply in United States having more than 3 GW of power requirement and 1.4 GW of supply of power. To compete in the supplementary services market, Alcoa adapted a design called Alcoa Power Generating Inc. (APGI), a power system that works as a unit which serves load unit to supplying the mixed loads from the Warrick facility to MISO. About 70 MWs of power regulation has been obtained using this smart grid technology.Figure 7 shows the architectural design of Alcoa's role in power regulation outputss.

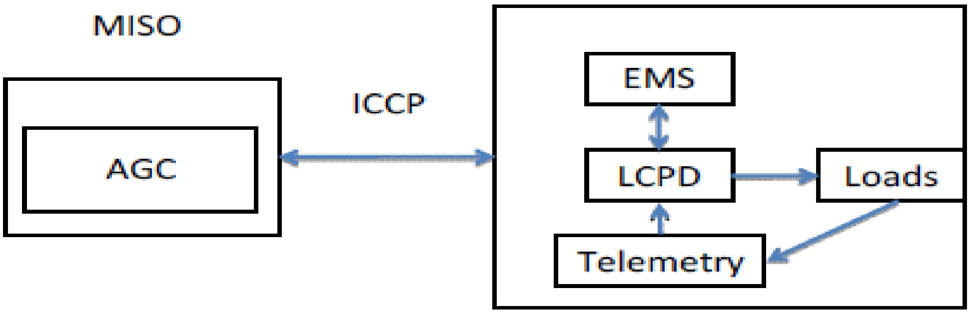

Figure 7: Information and control architecture for Alcoa case study (AGC 0

Regulation is a similar product in the MISO ancillary services market, which means that a generating source fixes a targeted output which will regulate and deliver power more or lesser than its normal operating threshold during the time it receives control commands from MISO. For this target to be achieved , the Warrick facility used an energy management system (EMS), smelter potline load control system (LCPD), and a system for metering and monitoring . These MW set-point commands are received by the EMS, convert them to a potline sequence of functions which operate to obtain the proposed target of set-point instruction, and sent to the LCPD, which will execute the sequence that is developed. This information is later transmitted back to the MISO that will then enables the visibility of the load response. The total expenditure of the whole system was about $700,000. With its high capabilities the system effectively adapts its self to favorable market rules, it can compete in the many markets and generates good revenue from all the markets.

Amy's Kitchen

Amy's Kitchen in Santa Rosa, California is system that will process raw food into delicious Veg- Meal which is very neatly packed. This is facilitated with many large cooling rooms, freezing chambers, blast freezers and a spiral freezer. There are many supporting loads like HVAC and lighting loads. In 2008, this system took part in PG&E's Automated DR (Auto-DR) program using OpenADR (Goli, McKane, and Olsen, 2011). The architecture of Amy's Kitchen participation in automated demand response is shown in Figure 8.

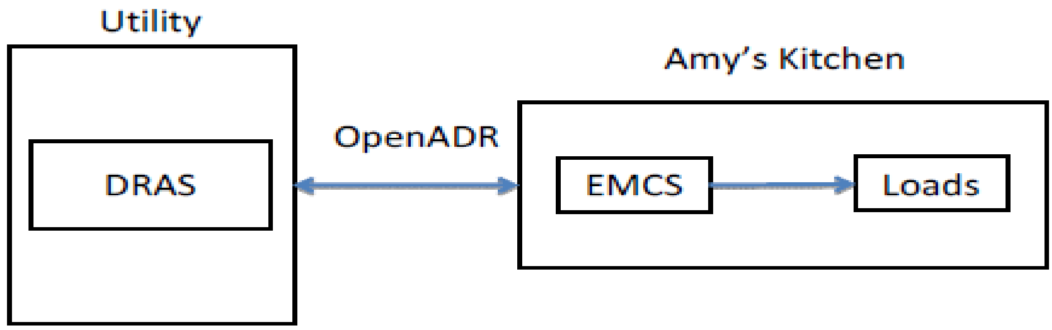

Figure 8: Information and control architecture for Amy's Kitchen case study.

The utility informs the consumer a one day in advance by announcement of the DR event duration using OpenADR. The facility EMCS, that is linked to an OpenADR client, receives these signals. An e-mail is also sent to the facility manager. The next day, as the DR event starts, the EMCS triggers pre-programmed DR strategies. With the facilities like shutting down a few freezers and battery chargers and increasing the set-points on other freezer and cooling rooms. This system had a total expenditure of $160,000.

Lafarge Building Materials

In New York State, NYSERDA and NYISO, a load reduction and demand response programs whichare best suited for providing the facilities of industry. The main organization which is benefited from these smartgrid technologies is Lafarge Building Materials, which is a cementmanufacturibg plant.

Cement manufacturing industry is highly energetic and requires huge amount of rock crushing and drying . On requesting from NYISO, Lafarge will close its crushing machinery, consuming 22 MW of "discretionary" load. On the onset of this inventory preserving capacity, the industry can continuously produce stockpiled rock which is crushed. The total load requirement is pre calculated and is automatically sent to NYISO. The payment is done according to NYSERDA's Peak Load Reduction Program.

Lafarge also takes part in NYISO's Day Ahead Demand Response Program. When the grid cost is very high, the plant can stop working and systems like maintenance of the equipment, cleaning the system can be adapted. The expenditure of this system was 2 millions.

All the equipment and amount required for these system was sponsored by NYSERDA. Even though it is expensive the benefits were very good along the returns related to finance. The expenditure for this system was approximately $2 million.

Ice storage at an industrial process

The last example taken is a New York State organization from NYSERDA's Peak Load Reduction Program. It is facilitated with an industrial plant with a high demand for process cooling demand in New York City (Epstein et al., 2005). Since NYC's has very poor connectivity to the grid it is very costly at peak times. This plant adapts a technique of creating an ice slurry during night with cooling agents in the tank. This slurry is utilized in day time for cooling refrigerants without operating electric chillers. About 5,000 ton-hours of cooling capacity is obtained. Power consumption of over 600 kW was obtained.

Smart Grid Monitoring Model Applications

The point of this exploration is planning a model for encouraging the working of system administration, information administration, application mix and security. This will help attaining to the execution peculiarities of a brilliant network like characterizing distinctive building guidelines, correspondence norms, checking and burden administration innovations, propelled parts and working ideas, displaying and recreation and Global Information framework. Building Standards incorporate the introductory structural structure and frameworks alongside its parts to empower the country's energy network. Supplies quality benchmarks, interface benchmarks, database having back-end and assessment criteria which ought to be institutionalized and brought together. Correspondence Standards incorporates the correct norms between association, stakeholders and clients. Checking and burden administration advances incorporate checking and control of modern/business/private loads for interest side administration. Demonstrating and Simulation incorporate the method of Planning and backing of the mode of operation backing for possibilities and aggravation occasions [10].

Worldwide Information System incorporates as utility for executing propelled programming frameworks for Smart Grid. It can be utilized as a part of mapping and examining the volumes of data produced by brilliant matrix engineering. The interconnectivity between different segments is indicated in figure.9

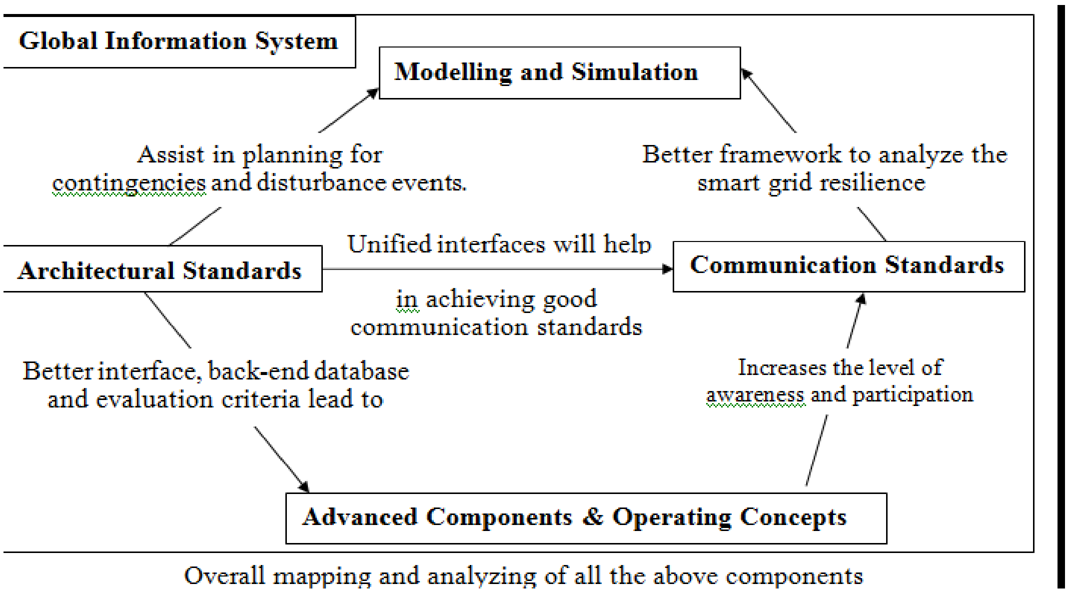

Figure 9: Interconnection between various components

Conclusion

New models can be planed and designed for providing a detailed framework to understand the advantages and capacity of using smart grids for the utilization of electric power. This helps in testing and intelligent monitoring of smart grid. The salient features of these models are as follows:

a. Innovative design of products with better services which help in improving the market value can be achieved by adapting good quality smart grids.
b. Quality power with the characteristic of abundant availability, stabilized voltage, resiliency and capability of healing by it self can be achieved by using smart grid.
c. Smart Grids can be utilized for integration of various power generating resources such as solar energy, wing energy, global thermal resources.
d. Smart Grids can be effectively utilized for avoiding disasters during power generation.
e. By smart monitoring and real time applications using smart grids, effective maintenance of equipment can be done which helps in improving the efficiency of the power system.

Ultimately at the end this will lead to a connection to securing key targets and execution plans that will support the modernization of grid.

Future Scope

Smart grids are “systems of systems.” Problem solutions can be obtained by integrating various components which are from different sources. These components need not be just physical products, they may be protocols for communication, information and models of data, implementing these models using software's etc. Hence it is very important that components and subsystems from different suppliers can work in an integrated manner (interoperability), with characteristics of plug-and-play fashion as adaptable feature and the system being consistently, more safe, reliable; also they rely on the concept of open, easily accessible interfaces and protocols (standardization).

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