Sample Survey of Smart Grid Approaches and Technology Gap Analysis

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Abstract—Research and development in the field of “smart grids” is advancing at an ever expanding rate, with an increasing number of industry participants and other key constituents internationally, including government entities and educational institutions. It is vital to understand the approaches being taken by these various entities in order to determine the optimal method by which to proceed with defining the smart grid and associated future developments. This survey was undertaken with the intent of determining representative approaches from various participants, and combining them into an overarching view of the industry as a whole. As a result, the more practical and efficient methods of improving the electrical grid were revealed, as well as gaps within the existing technology and standards. The most apparent gaps were determined to be in the following main areas: common communications; improved transmission and distribution controls; real-time information and incentives for both the end-user and the utility; self-healing grids; energy storage and renewable integration; and improved standards for the industry. In particular, future work into the development of improved control software for renewable integration utilizing energy storage is discussed, which will contribute to further research within the field.

Index Terms—Smart Grid, Renewable Energy, Energy Storage, Transmission, Distribution, FACTS, HVDC, Energy Efficiency, Substation Automation

I. INTRODUCTION

The intent of this paper is to undertake an international sample survey of the power industry as a whole and to determine what technologies for smart grid applications are provided by the various entities engaged in the industry. As such, an investigation was performed in order to determine the key smart grid offerings from various entities, as presented in section III – Industry Survey of Smart Grid Activities. All of the information collected was available via public access to company websites or through the publishing of journal articles or white papers, and only represents an overview of each organization’s involvement in the smart grid field. Key focal points were established to address how smart grid is being defined, which technologies could be used to achieve a smart grid system, and what would be the preferred method of achieving such a system.

By examining these traits, an appreciation was gained for the scope and direction of developments, offerings, and research in the field with the intent of finding gaps that would need to be filled in order to accomplish global energy goals of the future.

II. BACKGROUND

The development of a smarter grid network has become a topic increasingly being pursued within the power transmission and distribution industry. Advances are emerging in better transmission technologies, improved automation and controls, more reliable and efficient components, and real-time communications and sensors. [1] There are, however, hundreds of companies who are, or claim to be, involved in smart grid research and developments. These range from electric utilities to distribution companies to computing firms, many of whom are simply riding the marketing boost of the “smart grid” brand. It is therefore necessary to determine the validity of many of these claims, and evaluate the approaches these companies are taking, to ensure that the development of improved grid systems progresses in a productive and efficient manner. Additionally, many of these companies are working in the same areas of grid development, and are producing similar components and software for the same purposes. This demonstrates a need for the investigation of the best practices in each area, and a need for the development of standards which will govern continued development and integration of the various offerings. Finally, there is a divide between the goal of designing a smarter grid network and the existing technologies within the field. The undertaking of this survey provides insight into the missing gaps within each major segment of the industry, with the goal of identifying the most important for further research and development throughout the field. One discrepancy that is pervasive throughout the field is a single definition of the smart grid. The DOE and IEEE-PES have provided good definitions that encompass the key elements that are necessary for enabling smart grid infrastructure development. At the University of Pittsburgh, we have adopted a general description of the smart grid, with a consistent definition to the aforementioned organizations, as follows: “The implementation of various enabling power system automation, communication, protection, and control technologies that allow real-time interoperability between end-users and energy producers, in order to enhance efficiency in utilization decision-making based on energy resource availability and economics.” [2]
III. INDUSTRY SURVEY OF SMART GRID ACTIVITIES

A. Independent Organizations

1. U.S. Department of Energy (DOE)

The DOE provides funding and overarching goals for the energy industry. [1] Their stated goals are to fund research and provide support such that the grid has: self-healing from power disturbance events, active participation by customers in demand response, operating resiliently against physical and cyber attack, providing power quality for 21st century needs, accommodating all generation and storage options, enabling new products, services and markets and optimizing assets and operating efficiently. Emphasis is placed on monitoring and load management technologies such as fault detection, localization, prediction and power quality monitoring; as well as the monitoring and control of industrial, commercial and residential loads for demand side management. Advanced components and operating concepts like interconnection technologies and intentional islanding and Microgrids are discussed as possible topics as well. [3]

Furthermore, the DOE defines smart grid as an “…electric delivery network, from generation to the consumer integrated with the latest advances in digital and information technology to improve the electric system reliability, efficiency, security, and resiliency.” To support the emerging smart grid developments, the DOE has provided several funding opportunity announcements (FOAs) related to smart grid research, development, and demonstration aimed at fulfilling their mission in this area. [4] At the DOE National Energy Technology Laboratory smart grid work is being done on reviewing the potential benefits of modernizing a major electricity transmission and distribution grid using 8 categories of smart grid technologies affecting all aspects of grid operations from the consumer to the central power plant generation fleet. It is obvious that the DOE role is imperative to succeeding with the overall goals of the industry’s smart grid initiatives within the U.S.

2. IEEE – Power and Energy Society (IEEE-PES)

IEEE – PES is transnational in nature with members from all around the globe and currently serves as the world’s largest forum to share the latest and most exciting technological developments in the electric power industry. The society is also involved in developing engineering standards that guide the development and construction of equipment and systems, and for educating members of the industry and the general public. IEEE and NIST work hand in hand the area of smart grid research and development. IEEE has adopted the NIST SmartGrid Conceptual model which provides a high level framework that defines seven important Smart Grid domains: Bulk Generation, Transmission, Distribution, Customers, Operations, Markets and Service Providers.

It shows all the communications and energy/electricity flows connecting each domain and how they are interrelated one to another. At IEEE, the Smart Grid is seen as a large “System of Systems”, where each NIST Smart Grid domain is expanded into three Smart Grid foundational layers, which are the Power and Energy Layer, the Communication Layer and the IT/Computer Layer. [5] PES is also playing a leadership role in smart grid developments, including sponsorship of many smart grid related conferences and forums.

3. National Institute of Standards and Technology (NIST)

NIST plays a pioneering role in smart grid research and development. Under the Energy Independence and Security Act, NIST has the “primary responsibility to coordinate development of a framework that includes protocols and model standards for information management to achieve interoperability of smart grid devices and systems…” [6]

With industry, government, and consumer stakeholders, NIST is expediting identification and development of standards critical to achieving a reliable and robust Smart Grid. NIST understands that interoperability is vitally important to the performance of the Smart Grid at every level. It enables integration, effective cooperation, and two-way communication among the many interconnected elements of the electric power grid. NIST also has collaborated with businesses and standards organizations on guidelines and standards to protect industrial supervisory control and data acquisition (SCADA) systems and to secure their interfaces to the power grid. NIST know-how extends to standards and measurements for building control systems and their links to the grid. In partnership with the DOE GridWise Architecture Council, a body composed of users and suppliers of electric power, NIST created Domain Expert Working Groups that involve more than 100 organizations. Areas of focus are: Transmission and Distribution, Building to Grid, Industry to Grid, Home to Grid, and Business and Policy. [6]

4. Electric Power Research Institute (EPRI)

EPRI is involved in almost every area of research pertaining to smart grid technologies. As one example, EPRI and TVA are working together to develop and build integrated solar-assisted electric charging stations that will be used for electric vehicles. The smart model area range terminal stations will be used to gather information on energy usage and the amount of time that equipment is used for. [7] EPRI, along with a group of 20 organizations, has created an industry wide group with the intent to gather and interpret data from transmission lines, substations and grid operations in order to find benefits for using efficiency measures. [8] EPRI’s energy storage program looks to advance the understanding of the possible benefits of energy storage. EPRI’s future goal is for field demonstrations of energy storage programs. [9] Through their smart grid demonstration project initiative, EPRI is planning to set the purposes of distributed resources, find the needs for demand side integrations, and help facilitate the creation of standards to promote the use of distributed resources.

5. University of Pittsburgh

The electric power research group in the ECE department at the University of Pittsburgh has been working in various areas
of smart grid research. Supported by funding from the Pennsylvania Ben Franklin Technology Development Authority, the power and energy initiative team analyzed the need for high capacity power electronic technologies for integration of green energy management. In depth analysis was conducted on conventional AC transmission, HVDC, and FACTS compensation techniques as applied to both AC and DC transmission. This work helped present future applications, advantages, and development requirements for power electronics and control technologies in a diversified generation environment. [10] The team is also engaged in a Westinghouse Revolutionary R&D Program. Within this project, the market trends for domestic and international energy resources were analyzed and tied to how they specifically impact nuclear energy generation. The work also included categorization of issues with renewable resources to provide better understanding of the various challenges that are associated with integrating non-renewable resources with rapidly developing renewable forms of energy. The team further on developed a model to optimally integrate energy generated from nuclear, wind, gas and coal. [11]

Figure 2: Driving Factors for Smart Grid [12]

B. Manufacturers and Consultants

1. KEMA

KEMA is a global, leading authority specializing in energy consulting, testing and certification. In the field of smart grid technology KEMA understands that in order to achieve the goals for developing renewable sources of energy and standards around the world the grid must become far more flexible, controllable, and intelligently adaptive. This has resulted in a call for development and deployment of smart grid and smart metering around the world. KEMA is part of the leadership of the US GridWise Alliance and KEMA contributed to Department of Energy reports on Smart Grid and Storage. KEMA has identified the driving factors for the smart grid as shown in Fig. 2.

Figure 2: Driving Factors for Smart Grid [12]

KEMA has implemented a state of the art SCADA/DMS system for EEQ (Empressa Electrica Quito). EEQ is responsible for the sub-transmission and distribution of electrical energy in the city of Quito. EEQ is installing Intelligent Electronic Devices (IEDs) as parts of a system wide Substation Automation implementation. The communications media parts of the project include fiber optics, Wi-Fi radio and PLC to connect the master station with the substations. This will provide broadband common for multiples uses. [13] KEMA has also developed a new measuring system for the on-line monitoring and location of partial discharges (PD-OL) in medium-voltage power cables. [14]

2. ABB

ABB is a global corporation researching and producing a wide array of engineering products, including automation and advanced technologies for power transmission and distribution. ABB has developed automation software that is intended for use on the commercial or industrial level, and integrates various plant or building entities into one location that is easily accessible by operators. Entitled System 800xA, it observes power use, communications and safety and controls throughout the plant. It allows for a more efficient and flexible control of a plant’s systems, reduced power consumption, and increased productivity, stability and safety. This applies too to a larger scale at the distribution automation level, controlling the distribution of load on a substation. These technologies include SCADA systems which improve monitoring and control, along with many other technologies which provide better automation control mechanisms on a variety of levels. [15] In addition to their monitoring software, ABB produces High Voltage Direct Current (HVDC) transmission systems and the technology to integrate such systems with the existing grid network. The benefit to such a system is increased efficiency of the power transmission, with less loss of power from equivalent cable lengths when compared to HVAC. Additionally, HVDC lines are better suited to underground and underwater use over long distances. [16] ABB is also researching the improvement of existing grid networks with the addition of Flexible AC Transmission Systems (FACTS) allowing better control of AC systems and Wide Area Monitoring Systems (WAMS), which collect information from the grid in real time, providing grid conditions to an operator in real time. [15]

3. BPL Global

BPL Global is a company focusing extensively on smart grid solutions, especially at the substation and delivery level. They develop monitoring and control software for the improved efficiency of load management and power delivery. It begins at the substation level. They plan to place IEDs at multiple crucial points within a substation, to feed information about their respective components into a Substation Automation software system, which will improve electric service operations while reducing maintenance costs. This will supplement their Power SG Network Monitoring and Management, which is designed to monitor and manage the electrical devices for an entire electrical grid. [17] This includes monitoring the individual transformers on each feeder, and reacting fluidly to the changing load on each. Their Rapid Fault Locator will provide this system with the ability to quickly identify and locate faults within the system to more effectively control outages and voltage spikes. Additionally, development is under way on the incorporation
of efficient energy storage and renewable generation to the system and the grid. BPL is providing increased control for residential, commercial and industrial users in terms of the loads on their individual systems at any given time. This is achieved through improved device monitoring for the residential user, and integrated observation and load controls for the commercial or industrial user. [18] This building monitoring extends beyond power consumption, allowing the user to additionally manage water consumption and efficiency. Much of this communication is accomplished by their development of broadband internet connections over power lines, which will allow both quick observations at remote locations, as well as bringing broadband internet to users who previously had no means of access. [19]

4. Eaton

Eaton is focusing on comprehensive energy management solutions and increasing energy efficiency through use of variable frequency drives, uninterruptible power supplies, power factor correction capacitors and energy efficient and harmonic mitigating transformers. [20] Eaton’s power monitoring software solutions provide power assurance, visibility into power conditions, energy efficiency, energy cost allocations and proactive planning. [21] One such metering technology is the Powerware eNotify remote monitoring and diagnostic service. The software monitors compatible UPSs, and through daily trending and protective monitoring can alert the user of potential failures. [22]

Eaton's offerings of power monitoring are primarily on the end-user side. Potential points of installation for power meters are listed as the point of utility service entry into the building, support systems, critical equipment, primary power distribution panelboard or subfeed breakers, power distribution points throughout the facility or inside the enclosure. [21] To reduce downtime Eaton is researching paralleling switchgear and automatic transfer switches. Eaton is also researching green building technologies, and integrated facilities system which reduces both floor space and material needed for power systems over traditional installations. [20]

Eaton's world class Power System Experience Center, in Warrendale PA, is a unique facility that exhibits and demonstrates all of these and other smart grid, power quality, power management, and renewable energy solutions.

Eaton is also a major participant in the smart grid demonstration project with Portland General Electric. [23] This project will provide the ability to Island a feeder through the use of distributed generation as a proof of concept using technologies available today. [24]

5. General Electric

General Electric is incorporating a variety of smart grid technologies ranging from automatic transfer switches, uninterruptible power supplies and paralleling switchgear to monitoring and metering technologies like Power Reporting ITI and Industrial wireless MDS. [25] General Electric states that, “Every power distribution system that justifies the talent of a design professional should qualify for a meter.” [26] As stated GE feels that meters are a very important technology. GE also lists many metering functions that can be performed using the internet; such as, power management and energy monitoring. [27] Three of GE’s main families of protection, control and reporting systems, Mulitin, MDS and ITI are used for protecting, and monitoring all aspects of the grid system from generation to delivery. [26][28] GE is engaged in smart grid initiatives throughout the energy chain, from alternative energy solutions to smart meters.

6. IBM

IBM focuses on incorporating computing power into the smart grid. Many of IBM’s solutions make other smart grid technologies more efficient. One of their main efforts is to see real-time data across the grid and make decisions on this data instantaneously. IBM utilizes ‘stream computing’ which tracks stimuli and correlates them with other information in order to gain an in depth analysis of the real time happenings in the grid. Through greater computing powers many goals of the smart grid can be achieved including understanding demand in near real time, more effectively managing supply and demand and putting greater control of energy usage into the hands of consumers. Some aspirations of IBM include developing cyber security for smart grid networks and smart meters for consumers. These two ideas are mainly in the developmental stages, but they are projected to progress as interest and investment in the power grid increase. [29] IBM’s vision is to “enable the delivery of services on an on-demand basis, at competitive costs, and without requiring a large capital investment in infrastructure.” [30]

7. Lockheed Martin

One of LM’s main interests in developing the smart grid comes in the form of computer software aptly named Smart Energy Enterprise Suite (SEEsuite). This software suite allows companies to observe and manage their energy production/consumption through overarching control systems. Components of the program include SEEload, SEEview and SEEgrid; each offers a different perspective of the power grid. SEEload enables load control and event analytics. Also, it integrates all of a utility’s DR programs, customers, and aggregators into a single operational view to provide distribution network management. SEEview enables enterprise-wide situational awareness by providing decision makers with a real-time, integrated view of all key business and operational systems. And lastly, SEEgrid helps utilities and grid operators integrate and manage their fossil- and renewable-based generation mix, as well as balance overall system needs to improve grid reliability. [31]

8. Mitsubishi Electric

Mitsubishi Electric Corporation develops electrical and electronic equipment used in information processing and communications, space development and satellite communications, consumer electronics, industrial technology, energy, transportation and building equipment. With relation to the smart grid technology Mitsubishi Electric is beginning to invest a total of 7 billion yen by March 2012 in a project to build facilities within the company’s production sites in Japan for experiments designed to establish advanced smart grid technologies. The facilities will all be connected by a wide-area communication network and be remotely monitored. The
experiments are aimed at addressing global environmental issues by promoting the production of energy from photovoltaic, wind-power and other renewable energy sources as an alternative to fossil fuels. Mitsubishi Electric views the smart grid as an enabling technology that will help to integrate in the power system a large amount of renewable sources without negative effects on the stability and reliability. In addition, Mitsubishi Electric is heavily involved in HVDC, FACTS and automation and control technologies.

Figure 3: MELCO Smart Grid Technology Development [30]

9. Siemens

Siemens is active in a wide variety of smart grid research and development, from improved transmission capacity and reliability to more efficient substation use and better end-use management. Their products begin with generation itself, including gas and steam turbines and electric generators, in addition to the development of various renewable energy methods. Siemens is highly involved in HVDC systems and FACTS technologies, as well as the development of gas insulated transmission lines. These gas lines are ideal for use in areas which cannot have above ground transmission, or are very sensitive to electromagnetic fields, which are dampened by the gas insulator contained within the line. At the substation level Siemens produces high voltage components, including air and gas insulated switchgears, circuit breakers, bushings and capacitors, in addition to constructing whole substations. Siemens is doing research into the integration of eCar infrastructure to the grid. They are designing charging centers for electrical vehicles, in addition to planning for the incorporation of such facilities and the massive load they will incur to the system. Finally, Siemens is developing a set of monitoring components and software called Efficiency Network and Energy Automation Systems, which will observe and enhance performance of the electrical grid at all levels of transmission, from lines to substations to delivery. [33]

C. Utilities/Projects – North America

1. CenterPoint Energy

CenterPoint Energy, based in Houston, TX, has more than 5 million metered customers. As of March 2010 the utility received $200 million from the DOE under the American Recovery & Reinvestment Act to extend smart metering and self-healing efforts throughout their service area. $150 million is designated to accelerate smart meter installation and mitigate the price increase seen in user rates. Along with subsidized individual meter installations, a portion of the funds will be needed to install sensors on the T&D equipment. $50 million will be used to begin building a self-healing system which will improve efficiency and power reliability in Houston. CenterPoint Energy also incorporates wireless and fiber optic communications systems in their efforts to establish a smarter grid. [34]

2. Con Edison

Con Edision received $181 million in DOE stimulus money. This funding is being used to progress smart grid meter installations, in-home monitors, associated sensor installation and underground communications systems that will foster self-healing efforts. A $6 million dollar pilot is underway encompassing Long Island, Sunnyside, Woodside and Astoria. Con Edision is progressive on their efforts to incorporate renewables and energy storage. They are currently part of an initiative to construct a 700 MW wind farm on the eastern coast of the U.S. If the project is complete, this will become the largest wind farm in the country. Con Edision also has an effort developing smart charging for electric vehicles. [35]

3. Duke Energy

Duke Energy, serving 4 million customers located in five states throughout the Southeast and Midwest, is a leader in smart grid efforts as shown by the recent grant money won from the DOE to progress two projects. $204 million worth of stimulus money will be used to modernize systems in Ohio, Indiana, Kentucky and the Carolinas in forms such as smart meters, distribution automation equipment and communications infrastructure. [36] Duke Energy is also proactive in their renewable and energy storage technologies as seen in their efforts to build a large scale energy storage station at a wind farm in West Texas. [37] Another one of Duke Energy’s efforts is a pilot program in Charlotte, North Carolina involving 200 customers. The program involves many smart grid upgrades as well as battery storage for solar panel power generation. [38] The project is designed to build on what the utility has learned by conducting a small pilot program involving 33 customers in Cincinnati, OH. [39]

4. First Energy

After receiving federal grants totaling $57.4 million to introduce smart grid technologies in Pennsylvania, Ohio and New Jersey, First Energy is undertaking means to improve the reliability and interactivity of their electrical distribution infrastructure in those states. Working with one of their subsidiary companies, Met-Ed, they have introduced a voluntary load control program for 23,000 customers which will help reduce peak demand. This will be accomplished through an integrated system of load controls that includes direct control of air conditioners and other customer appliances during peak usage. It is supported by two-way communication networks that run to and from the end-user and the utility. Some of the technologies include distributed automation, direct load control, smart metering, voltage control, advanced protection devices and wireless security. Together, these technologies govern the distribution system, allowing for better load following, stability and security for the grid network as a whole. Additionally, First Energy is
working to planning the development of a 1700MW compressed air storage facility in Norton, Ohio. [40]

5. **PJM**

PJM coordinates the movement of wholesale electricity in all parts of 13 states and the District of Columbia. It acts independently and impartially in managing the regional transmission and wholesale electric market. PJM dispatches about 163,500 MW of generating capacity over 56,350 miles of transmission lines. PJM is working towards making the transmission system smart, efficient and more environmentally friendly by exploring and applying smart grid concepts such as synchrophasor technology, electricity storage, compressed air energy storage and plug-in hybrid electric vehicles. [41] PJM also supports the concept of price-responsive demand and demand response. PJM Interconnection supports projects of all types to expand the electricity storage capability of the electric grid. More storage capacity will be needed to deal with the forecasted major expansion of intermittent renewable energy sources and their potential impact on system reliability. [41] PJM as mentioned above is exploring new energy storage technology such as battery storage, compressed air energy storage, flywheel storage and PHEV to improve the stability of the grid after the inclusion of intermittent and stochastic natured renewable energy.

6. **Southern California Edison**

Southern California Edison provides electrical service to central, coastal and southern California. 16.7 percent of their power supplied is from wide range of alternate and renewable energy resources. SCE provides power to 180 cities which includes a demographic count of 13 million, 5000 large business and 280000 small businesses.

SCE is planning to complete installing smart meters to five million customers by the end of 2012. SCE is widely recognized as the leader in evaluating, adoption and implementation of advanced technologies. SCE have dedicated technical centers where in energy storage technology for plug-in vehicles and smart metering infrastructure and customer devices are tested. SCE sought and received authorization from the California Public Utilities Commission to spend up to $4.5 million to conduct feasibility studies and planning for renewable transmission solutions, as part of a statewide collaborative process. On the energy storage front SCE is actively supporting battery storage.

SCE also has been developing pilot programs for sustainable communities. These are “large, mixed-use, multi-family, or multiple building construction projects that are willing to commit to aggressive energy efficiency and sustainable design goals,” into which SCE is building smart grid infrastructure. These communities will provide real-world testing for the smart grid offerings from SCE. [42]

D. **Utilities/Projects – Europe**

1. **E.ON**

E.ON is a German power and gas company that operates in more than 30 countries worldwide and is becoming increasingly involved in smart grid development throughout the global market. E.ON has an extremely diversified energy portfolio. Alongside their conventional power generation, E.ON is heavily involved in developing alternative energy systems. They are leaders in on and offshore wind, solar, and tidal generation. They have built the world’s largest onshore wind installation in Roscoe, Texas, with 782 MW of generation serving around 230,000 homes. [43] Offshore, there are plans for the construction of a 1,000MW installation off the coast of England in cooperation with DONG Energy and Masdar. Additionally, E.ON is intensely pushing the development and use of smart metering in households throughout Europe. Already, E.ON has installed around 1 million smart meters in Sweden, with 752,000 to be fitted in Spain by 2014. In Germany, where informative meters are not yet required, it is planned to equip nearly 80 percent of households with smart meters by 2022. This includes a 10,000 home pilot in the E.ON Bayern region of Germany, which has shown that the installation of these smart meters can reduce the energy consumption of a home by 5 to 10 percent. [44] It is advances such as these that put E.ON on the forefront of generation and distribution technologies.

2. **EDF**

EDF is the world’s largest nuclear utility with solid positions in many major European countries. EDF has well-defined priorities that include being a major player in the global nuclear revival, promoting energy efficiency, and incorporating renewable energies and more environmentally-friendly technologies. [45]

EDF is undertaking a project which involves the island of La Reunion. The multi-faceted augmentation of the island’s energy system includes: updating hydraulic equipment at Rivière de l’Est to improve energy capacity of the hydro-power by 25%, introducing NaS battery injection to reduce reliance on generation created by fossil fuels, and plans to develop a smart grid prototype. The pilot incorporates installation of systems in the homes of volunteer private customers which combine solar cells, batteries and energy controllers, and fitting "Energy Boxes" into other homes, allowing them to monitor their electricity consumption in real time and thereby optimize it. [46]

3. **Iberdrola**

Iberdrola, with 43,600 MW of installed capacity as of 2009, is one of the top five largest energy companies internationally, and has a wide-ranging approach to smart grid integration that includes: construction of wind and hydroelectric and nuclear plants, intelligent networking to allow quick and safe means of producing real-time grid data, and the implementation of recharging networks for electric vehicle integration. [47] A recent initiative by Iberdrola is the PRIME (PowerLine Intelligent Metering Evolution) project, which was launched in order to assess the idea, define and test a new, future proof, PLC based, open standard that could meet the future requirements on customer real time interfacing and smart grid evolution. PRIME defines lower layers of a PLC narrowband data transmission system over the electric grid. [48] The end objective of the PRIME Project is to establish a complete set of standards on an international level that will permit interoperability among equipment and systems from different manufacturers. In this way, competition in the metering market will occur for the benefit of consumers. Working on
this project are some of the most important industrial leaders in the areas of metering, telecommunications and silicon manufacturing, such as Advanced Digital Design, CURRENT Group, Landis+Gyr, STMicroelectronics, Usyscom and ZIV. A large number of European utilities have already expressed their interest in joining the project. [49]

E. Utilities/Projects – Asia

1. Tianjin Electric Power Corporation (TEPCO)

Tianjin Electric Power Corporation (TEPCO) is a large, state-owned enterprise and a major contributor to the Beijing-Tianjin-Tangshan power grid in northern China. TEPCO is one of the key players in the forthcoming Sino-Singapore Tianjin Eco-city which is a strategic smart grid project between China and Singapore to improve the living environment and build an eco-culture starting April, 2010. The total load in Tianjin Eco-city is estimated at 411.25MW. The renewable generation will take 24.62% of the total generation to meet the planning requirements of the Eco-city. In addition, the project includes the following smart grid advancements: distributed power generation, intelligent and standardized transmission and distribution systems with energy storage and diversified access; smart end use containing information collection system, two-way interactive marketing system, intelligent power district, building, home and electric car charging/discharging station; a control and operation center with intelligent operational risk assessment, early warning and coordinated control of power supply security and optimal scheduling functions; and other aspects such as multi-dimensional visualization platforms. [50]

2. Korea Smart Grid Institute (KGSI)

KSGI was launched in Aug. 2009 by the Ministry of Knowledge Economy as the secretariat of Smart Grid Initiative and projects in Korea of which the most noticeable plan is the construction of a Smart Grid, Test-bed in Jeju Island. Jeju Smart Grid will become the world’s largest Smart Grid community that allows the testing of the most advanced Smart Grid technologies and R&D results, as well as the development of business models. A total of about $53.6 million will be invested between 2009 and 2013. From the national standpoint, this project aims to raise energy efficiency and implement green-energy infrastructure by building eco-friendly infrastructure that reduces CO₂ emissions. From the industrial standpoint, it seeks to secure a new growth engine that will drive Korea in the age of green development. And from an individual standpoint, this project is aimed at enhancing quality of life through interactive participation of consumers. [51]

F. Utilities/Projects – Australia

1. EnergyAustralia

EnergyAustralia is a State-owned corporation whose shareholder is the New South Wales Government – distributing electricity to the Sydney, Central Coast and Hunter regions in New South Wales. It has the largest energy network in Australia. It supplies electricity and gas, builds, replaces and maintains its electricity network, sells electricity and gas, and promotes energy efficiency and renewable energy alternatives. Energy Australia along with GE and Grid Net are spearheading one of Australia’s first commercial-scale smart grid projects using the high-speed next-generation wireless standard WiMAX. This $100 million smart grid project will include the rollout of substations automation and electric vehicles, as well as 50,000 smart meters and 15,000 home energy displays. It will also include integrator IBM Australia, utility AGL, transmission provider Transgrid and local governments. [52]

IV. Technology and Gap Analysis

Across the industries of power generation, transmission, distribution, and end-use there is a vast, encompassing push for real-time communications, more accurate controls, improved transmission systems, and integration software to coordinate the components of the system into a smart grid. While the term smart grid is defined differently by nearly every group working on solutions to the growing electrical needs of society, many of the technologies they are developing are extremely similar. HVDC systems and FACTS are providing more efficient methods of distributing power over large distances, essential to the incorporation of renewable energy sources, which are often in areas removed from where the power is needed most. WAM and PMU infrastructures are providing better means of visualization and operation of the grid. Improved protective technologies, from better components to improved cyber security and grid communications, are helping to increase grid stability and prevent outages. Advanced sensors are allowing grid operators to see real-time demand on the system, allowing more informed and efficient decisions to be made in order to maintain continued high levels of grid reliability. Also, the various automation and control software packages which are being developed by many organizations in the field will provide the means for the grid to become truly “smart” and “self-healing”, by reacting nearly instantaneously to changing grid conditions, from faults to load spikes to other major disturbances. These software systems will integrate and provide improved controls for network operations that fall under the vast category of the smart grid, and will tie those components together in a system which will be more efficient, more stable, and more fluid. Many of these goals and the full benefits promised by the smart grid paradigm are still far from realization. Continued collaboration among all constituents is imperative to achieving the objectives being set forth.

In addition, there are many gaps in the existing technologies and standards which must be bridged before these smart grid concepts can be fully realized. Firstly, and perhaps most importantly, common communications methods must be employed by the various organizations involved in the field. The objective of integrating grid communications on a national or even regional level is unattainable without the real-time information provided by standardized communications networks. This real-time information must then be made available to the end-user, the utility, and the energy provider alike, in order to allow informed decisions to be made on the timely use of power and to establish improved energy management practices. Choosing when and how to use power, however, will be irrelevant without the incentive of dynamic demand-based pricing, which will require more intensive
V. CONCLUSION

With demand for power increasing at a rapid rate worldwide, the efficient production and delivery of power will become more vital to the success of the power industry as a whole. To achieve more efficient energy utilization, smart grid components, such as improved communications systems, automation software, transmission technologies, and storage mechanisms, must be realized. Some of these, such as HVDC and FACTS systems, monitoring and automation software, and cyber security, are already being implemented. This sample survey of the approaches and technologies of the various international organizations involved in the field shows that there is a true drive towards a smarter grid on all continents, with emerging, enabling technologies to solve many of the challenges faced by the industry today. However, there are still gaps within those technologies and approaches; still communication barriers between the various controls and software packages offered by competitors; still a lack of incentive for both the end-user and the utility; and still a lack of standardization, all of which must be overcome before the system can realize its full potential. When these challenges are met, the smart grid will lead to more efficient energy utilization, more efficient distribution, better quality of service, and greater sustainability of precious energy resources.

VI. FUTURE WORK

As indicated in the gap analysis there are numerous organizations involved in smart grid research and development that address this goal in diverse ways. Hence, there is a need for methods and techniques that can bring about a standard and uniform outlook towards smart grid development. Furthermore, there is a need for development of advanced control methods for balanced integration of renewable energy resources into the power grid in real-time conditions. This, in turn, calls for further research into the various energy storage technologies, since storage plays a vital role in facilitating smooth integration of renewable energy with other forms of energy generation. With the development of advanced metering infrastructure there is need for development of more sophisticated software to improve SCADA applications at all levels of the grid i.e. generation, transmission & distribution and the end user level. In addition, further advancement in power electronics technologies (FACTS and HVDC) are necessary for improved dynamic grid control. All of these areas being pursued as part of the University of Pittsburgh’s power and energy research efforts.

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