Renewable energy based the smart grid technology

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***Abstract*—The Smart Grid can be shows the transparent, seamless, and instantaneous two-way delivery of energy information, enabling the electricity industry to better manage energy delivery and transmission and empowering consumers to have more control over energy decisions. Smart Grid which is also called intelligent grid or modern grid uses new technologies to reduce the environmental impact of power grid, energy conservation and increase efficiency, renewable energy utilization. A smart grid is a modernized electrical grid hat uses analogue or digital to gather and act on information, such as information about the behaviors of suppliers and consumers, in an automated fashion to improve the efficiency, reliability, economics, and sustainability of the production and distribution of electricity. The smart grid represents the full suite of current and proposed responses to the challenges of electricity supply. The smart grid is complicated and by no means is an inexpensive project, since it requires a major infrastructural change .A smarter grid is also a necessity for plugging in the next generation of automotive vehicle including plug in high electrical vehicle. The bulk of smart grid technologies are already used in other applications such as manufacturing and telecommunications and are being adapted for use in grid operations**

Keywords—Objective, Architecture, development ,feature ,technology, research, Renewable Energy Sources

I. INTRODUCTION

In short, the digital technology that allows for two-way communication between the utility and its customers, and the sensing along the transmission lines is what makes the grid smart. Like the Internet, the Smart Grid will consist of controls, computers, automation, and new technologies and equipment working together, but in this case, these technologies will work with the electrical grid to respond digitally to our quickly changing electric demand. The Smart Grid represents an unprecedented opportunity to move the energy industry into a new era of reliability, availability, and efficiency that will contribute to our economic and environmental health. During the transition period, it will be critical to carry out testing, technology improvements, consumer education, development of standards and regulations, and information sharing between projects to ensure that the benefits we envision from the Smart Grid become a reality[1]. A combination of effective legislation and regulation will be needed to secure these developments in a timely way. The Smart Grids Technology Platform has identified ten key challenges that impact on the delivery of the mandated targets for utilization of renewable energy, efficiency and carbon reductions by 2020 and 2050. They are also interlinked with the targets for one common European electricity market, for reducing European dependency on energy imports and for maintaining security of supply with minimum costs. At the beginning of the century, a new concept emerged in how electricity is managed. Under this model, the grid becomes less of a one-way highway and more of an integrated, interactive network. Many smaller power plants are distributed throughout this network, including renewable energy generation. And most importantly, this new grid gains "intelligence" and two-way communications. In Europe, many systems use power line communications as shown in Fig 1, which broadcast over the electric power lines themselves. In the U.S., radio frequency (RF) communications are more common, typically systems that resemble the Wi-Fi networks used for personal computers. And many systems are hybrids, incorporating cellular, satellite, fiber-optic or other forms. Regardless of the specific technologies, the goal is to give every part of the system the ability to talk and to listen.

Fig.1 Two way communication between device's

II. SMART GRID

A. *A Comparison Between Today's Grid and a Smart Grid*

Today's energy grid, the network for delivering power from producers to consumers, is inefficient and unreliable. Congestion, bottlenecks, and blackouts cost energy providers and consumers billions of dollars annually[2]. Additionally, consumers are uninformed when it comes to how and when they use energy and where that energy comes from. Furthermore, most energy generated today comes from a few large fossil fuel-based producers; this makes the grid "dirty" and vulnerable to attacks and natural disasters. The smart grid is highly beneficial than todays grid as shown the comparison

Characteristic	Today's Grid	Smart Grid
Enables active participation by consumers	Consumers are uninformed and non-participative with power system	Informed, involved, and active consumers - demand response and distributed energy resources.
Accommodates all generation and storage options	Dominated by central generation- many obstacles exist for distributed energy resources interconnection	Many distributed energy resources with plug-and-play convenience focus on renewables
Enables new products, services and markets	Limited wholesale markets, not well integrated - limited opportunities for consumers	Mature, well-integrated wholesale markets, growth of new electricity markets for consumers
Provides power quality for the digital economy	Focus on outages - slow response to power quality issues	Power quality is a priority with a variety of quality/price options - rapid resolution of issues
Optimizes assets & operates efficiently	Little integration of operational data with asset management - business process silos	Greatly expanded data acquisition of grid parameters - focus on prevention, minimizing impact to consumers
Anticipates and responds to system disturbances (self-heals)	Responds to prevent further damage- focus is on protecting assets following fault	Automatically detects and responds to problems - focus on prevention, minimizing impact to consumer
Operates resiliently against attack and natural disaster	Vulnerable to malicious acts of terror and natural disasters	Resilient to attack and natural disasters with rapid restoration capabilities

Fig.2 Comparison Between Today's Grid and a Smart Grid

B. Smart grid objectives

The "smart grid" is the application of technologies to all aspects of the energy transmission and delivery system that provide better monitoring, control and efficient use of the system. The ISO's goal is to enable and integrate all applicable smart technologies while operating the grid reliably, securely and efficiently, and facilitate effective, open markets that engage and empower consumers while meeting state environmental and energy policies[3]. To this end, the ISO will research, pilot, implement and integrate smart grid technologies that: Increase grid visibility, efficiency, and reliability .Enable diverse generation including utility-scale renewable resources, demand response, storage and smaller-scale solar PV technologies to fully participate in the wholesale market Provide enhanced physical and cyber security. The expected benefits from smart grid technology deployments include:

Efficiently use the transmission system to defer or displace costly transmission investments ,Enable consumers to react to grid conditions making them active participants in their energy use ,Leverage conventional generation and emerging technologies when possible including distributed energy resources, demand response and energy storage, to address the challenges introduced by variable renewable resources[4]. The research, pilots and implementation efforts to modernize the grid provide the basis for evaluating and understanding new technologies as well as verifying the economics and work force requirements for deploying them. These efforts will require working closely with ISO stakeholders.

III. SMART GRID EVALUATION

The ISO architecture vision is to allow each network service (software designed to do a specific job) to operate individually but share information with other services all through a base system called service oriented architecture (a collection of services that make up a network system). To address issues identified during this road map effort requires building on the ISO's recent Market Redesign and Technology Upgrade implementation and its foundation to accommodate robust and flexible system architecture.

A. Smart grid architecture

As shown in Fig 3, the ISO will develop new systems while existing systems will undergo significant change in the next 10 years to support smart grid implementation efforts. Even systems not directly involved with smart grid support will likely be impacted by the changes, adding to concern about avoiding unintended consequences. One key architectural component is a centrally managed network model. The Enterprise Model Management System (EMMS) the ISO plans to implement will centralize the functions of several current ISO services and significantly reduce the time between network model builds. This model and data management system will reduce the time it takes for new resources to register in the ISO markets, which is a significant improvement over the current process given the larger numbers of resources expected to seek participation under demand response and storage integration programs[5].

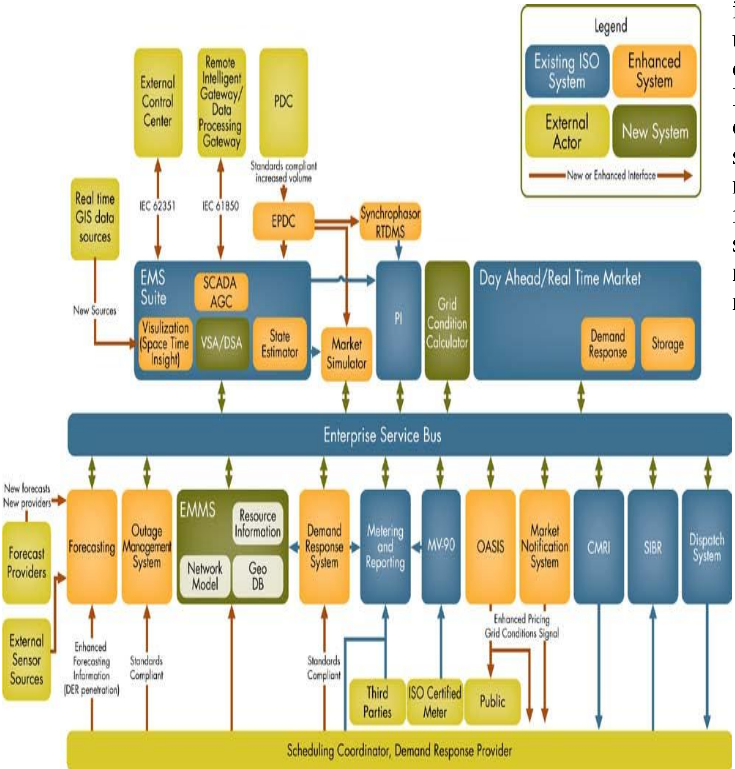

Fig.3 Smart grid ISO architecture

The model and data management system will also enable the ISO to carry out grid, transmission and system event analysis using time-based models that reflect point-in-time grid conditions. This essential feature contributes to the security of a more complex and rapidly changing grid. To support a "price to device concept" that reflects grid conditions, the ISO will explore creating a grid condition indicator that will require a new system capability via the grid condition calculator. The indicator will act as a signal once published for public consumption through a public website and, possibly, a new Internet subscription service that could be directly consumed by end user devices[6]. As mentioned in the advanced application section, the expected increases in wind and solar generation will significantly change the behavioral characteristics of the grid, which in many cases are still unknown.

B. Historical development of smart grid

- The first alternating current power grid system was installed in 1886. At that time, the grid was a centralized unidirectional system of electric power transmission, electricity distribution and demand-driven control.
- In the 20th century local grids grew over time, and were eventually interconnected for economic and reliability reasons. By the 1960s, the electric grids of developed countries had become very large, mature and highly interconnected, with thousands of 'central' generation power stations delivering power to major load centers via high capacity power lines which were then branched and divided to provide power to smaller industrial and domestic users over the entire supply area. The topology of the 1960s grid was a result of the strong economies of scale: large coal-, gas- and oil-fired power stations in the 1 GW (1000 MW) to 3 GW scale are still found to be cost-effective, due to efficiency-boosting features that can be cost effectively added only when the stations become very large.
- Power stations were located strategically to be close to fossil fuel reserves (either the mines or wells themselves, or else close to rail, road or port supply lines). Siting of hydro-electric dams in mountain areas also strongly influenced the structure of the emerging grid. Nuclear power plants were sited for availability of cooling water. Finally,fossils fuel fired power stations were initially very polluting and were sited as far as economically possible from population centres once electricity distribution networks permitted it. By the late 1960s, the electricity grid reached the overwhelming majority of the population of developed countries, with only outlying regional areas remaining 'off-grid'.
- Metering of electricity consumption was necessary on a per-user basis in order to allow appropriate billing according to the (highly variable) level of consumption of different users. Because of limited data collection and processing capability during the period of growth of the grid, fixed-tariff arrangements were commonly put in place, as well as dual-tariff arrangements where night-time power was charged at a lower rate than daytime power. The motivation for dual-tariff arrangements was the lower night-time demand. Dual tariffs made possible the use of low-cost night-time electrical power in applications such as the maintaining of 'heat banks' which served to 'smooth out' the daily demand, and reduce the number of turbines that needed to be turned off overnight, thereby improving the utilization and profitability of the generation and transmission facilities. The metering capabilities of the 1960s grid meant technological limitations on the degree to which price signals could be propagated through the system.
- Towards the end of the 20th century, electricity demand patterns were established: domestic heating and air conditioning led to daily peaks in demand that were met by an array of 'peaking power generators' that would only be turned on for short periods each day. The relatively low utilization of these peaking generators (commonly, gas turbine were used due to their relatively lower capital cost and faster start-up times), together with the necessary redundancy in the electricity grid, resulted in high costs to the electricity companies, which were passed on in the form of increased tariffs. In the 21st century, some developing countries like China, India and Brazil were seen as pioneers of smart grid deployment.

C. Features of the smart grid

The smart grid represents the full suite of current and proposed responses to the challenges of electricity supply. Because of the diverse range of factors there are numerous competing taxonomies and no agreement on a universal definition[7]. Nevertheless, one possible categorization is given here.

- Reliability

The smart grid will make use of technologies that improve fault detection and allow self-heating of the network without the intervention of technicians. This will ensure more reliable supply of electricity, and reduced vulnerability to natural disasters or attack. Although multiple routes are touted as a feature of the smart grid, the old grid also featured multiple routes. Initial power lines in the grid were built using a radial model, later connectivity was guaranteed via multiple routes, referred to as a network structure. However, this created a new problem: if the current flow or related effects across the network exceed the limits of any particular network element, it could fail, and the current would be shunted to other network elements, which eventually may fail also, causing a domino effect. See power outage. A technique to prevent this is load shedding by rolling blackout or voltage

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reduction (brownout).

- *Flexibility in network topology*

Next-generation transmission and distribution infrastructure will be better able to handle possible bidirectional energy flows, allowing for distributed generation such as from photo voltaic panels on building roofs, but also the use of fuel cells, charging to/from the batteries of electric cars, wind turbines, pumped hydroelectric power, and other sources. Classic grids were designed for one-way flow of electricity, but if a local sub-network generates more power than it is consuming, the reverse flow can raise safety and reliability issues. A smart grid aims to manage these situations.

- *Efficiency*

Numerous contributions to overall improvement of the efficiency of energy infrastructure is anticipated from the deployment of smart grid technology, in particular including demand-side management, for example turning off air conditioners during short-term spikes in electricity price. The overall effect is less redundancy in transmission and distribution lines, and greater utilization of generators, leading to lower power prices.

- *Load adjustment/Load balancing*

The total load connected to the power grid can vary significantly over time. Although the total load is the sum of many individual choices of the clients, the overall load is not a stable, slow varying, increment of the load if a popular television program starts and millions of televisions will draw current instantly. Traditionally, to respond to a rapid increase in power consumption, faster than the start-up time of a large generator, some spare generators are put on a dissipative standby mode.

- *Peak curtailment/leveling and time of use pricing*

To reduce demand during the high cost peak usage periods, communications and metering technologies inform smart devices in the home and business when energy demand is high and track how much electricity is used and when it is used. It also gives utility companies the ability to reduce consumption by communicating to devices directly in order to prevent system overloads.

- *Sustainability*

The improved flexibility of the smart grid permits greater penetration of highly variable renewable energy sources such as solar power and wind power, even without the addition of energy storage. Current network infrastructure is not built to allow for many distributed feed-in points, and typically even if some feed-in is allowed at the local (distribution) level, the transmission-level infrastructure cannot accommodate it. Rapid fluctuations in distributed generation, such as due to cloudy or gusty weather, present significant challenges to power engineers who need to ensure stable power levels through varying the output of the more controllable generators such as gas turbines and hydroelectric generators. Smart grid technology is a necessary condition for very large amounts of renewable electricity on the grid for this reason.

- *Market-enabling*

The smart grid allows for systematic communication between suppliers (their energy price) and consumers (their willingness-to-pay), and permits both the suppliers and the consumers to be more flexible and sophisticated in their operational strategies. Only the critical loads will need to pay the peak energy prices, and consumers will be able to be more strategic in when they use energy. Generators with greater flexibility will be able to sell energy strategically for maximum profit, whereas inflexible generators such as base-load steam turbines and wind turbines will receive a varying tariff based on the level of demand and the status of the other generators currently operating. The overall effect is a signal that awards energy efficiency, and energy consumption that is sensitive to the time-varying limitations of the supply.

- *Demand response support*

Demand response support allows generators and loads to interact in an automated fashion in **Renewable Energy Sources** real time, coordinating demand to flatten spikes. Eliminating the fraction of demand that occurs in these spikes eliminates the cost of adding reserve generators, cuts wear and tear and extends the life of equipment, and allows users to cut their energy bills by telling low priority devices to use energy only when it is cheapest. Currently, power grid systems have varying degrees of communication within control systems for their high value assets, such as in generating plants, transmission lines, substations and major energy users. In general information flows one way, from the users and the loads they control back to the utilities. The utilities attempt to meet the demand and succeed or fail to varying degrees (brownout, rolling blackout, uncontrolled blackout). The total amount of power demand by the users can have a very wide probability distribution which requires spare generating plants in standby mode to respond to the rapidly changing power usage.

- *Platform for advanced services*

As with other industries, use of robust two-way communications, advanced sensors, and distributed computing technology will improve the efficiency, reliability and safety of power delivery and use. It also opens up the potential for entirely new services or improvements on existing ones, such as fire monitoring and alarms that can shut off power, make phone calls to emergency services, etc.

D. Technology

The bulk of smart grid technologies are already used in other applications such as manufacturing and telecommunications and are being adapted for use in grid operations. In general, smart grid technology can be grouped into five key areas:

1. Integrated communications

Some communications are up to date, but are non-uniform because they have been developed in an incremental fashion and not fully integrated. In most cases, data is being collected via modem rather than direct network connection. Areas for improvement include: substation automation, demand response, distribution automation, supervisory control and data acquisition (SCADA), energy management systems, wireless mesh networks and other technologies, power-line carrier communications, and fiber-optics. Integrated communications will allow for real-time control, information and data exchange to optimize system reliability, asset utilization, and security.

2. Sensing and measurement

Core duties are evaluating congestion and grid stability, monitoring equipment health, energy theft prevention, and control strategies support. Technologies include: advanced microprocessor meters smart meter and meter reading equipment, wide-area monitoring systems, dynamic line rating (typically based on online readings by Distributed temperature sensing combined with Real time thermal rating (RTTR) systems), electromagnetic signature measurement/analysis, time-of-use and real-time pricing tools, advanced switches and cables, backscatter radio technology, and Digital protective relay[8].

3. Smart meters

A smart grid replaces analog mechanical meters with digital meters that record usage in real time. Smart meters are similar to Advanced Metering Infrastructure meters and provide a communication path extending from generation plants to electrical outlets (Smart socket) and other smart grid-enabled devices. By customer option, such devices can shut down during times of peak demand.

- *Advanced control*

Power System Automation enables rapid diagnosis of and precise solutions to specific grid disruptions or outages. These technologies rely on and contribute to each of the other four key areas. Three technology categories for advanced control methods are: distributed intelligent agents (control systems), analytical tools (software algorithms and high-speed computers), and operational applications (SCADA, substation automation, demand response, etc.). Using artificial intelligent programming techniques, Fijian power grid in China created a wide area protection system that is rapidly able to accurately calculate a control strategy and execute it.

- *Improved interfaces and decision support*

Information systems that reduce complexity so that operators and managers have tools to effectively and efficiently operate a grid with an increasing number of variables. Technologies include visualization techniques that reduce large quantities of data into easily understood visual formats, software systems that provide multiple options when systems operator actions are required, and simulators for operational training and "what-if" analysis.

IV. Research

- *Major programs*

A. IntelliGrid – Created by the Electric Power Research Institute (EPRI), Intelligrid is a vision of the future electric delivery system. The IntelliGrid Consortium is a public/private partnership that integrates and optimizes global research efforts, funds technology R&D, works to integrate technologies, and disseminates technical information. IntelliGrid architecture provides methodology, tools, and recommendations for standards and technologies for utility use in planning, specifying, and procuring IT-based systems, such as advanced metering, distribution automation, and demand response. The architecture also provides a living laboratory for assessing devices, systems, and technology. Several utilities have applied Intelligent architecture including Southern California Edison, Long Island Power Authority, Salt River Project, and TXU Electric Delivery.

B. Modern Grid Innovative (MGI) is a collaborative effort between the U.S. Department of Energy (DOE), the National Energy Technology Laboratory (NETL), utilities, consumers, researchers, and other grid stakeholders to develop a common, national vision to modernize the U.S. electrical grid. MGI supports demonstrations of key systems and technologies that serve as the foundation for an integrated, modern power grid. DOE's Office of Electricity Delivery and Energy Reliability (OE) sponsors the initiative, which builds upon Grid 2030 and the National Electricity Delivery Technologies Road map and is aligned with other programs such as GridWise and GridWorks.

C. Grid 2030 – Grid 2030 is a joint vision statement for the U.S. electrical system developed by the electric utility industry, equipment manufacturers, information technology providers, federal and state government agencies, interest groups, universities, and national laboratories. It covers generation, transmission, distribution, storage, and end-use. The National Electric Delivery Technologies Road map is the implementation document for the Grid 2030 vision. The Road map outlines the key issues and challenges for modernizing the grid and suggests paths that government and industry can take to build America's future electric delivery system.

D. GridWise – A DOE OE program focused on developing information technology to modernize the U.S. electrical grid. Working with the GridWise Alliances, the program invests in communications architecture and standards; simulation and analysis tools; smart technologies; test beds and demonstration projects; and new regulatory, institutional, and market frameworks. The GridWise Alliance is a consortium of public and private electricity sector stakeholders, providing a forum for idea exchanges, cooperative efforts, and meetings with policy makers at federal and state levels.

E. GridWise Architecture Council(GWAC) was formed by the U.S Department of Energy to promote and enable interoperability among the many entities that interact with the nation's electric power system. The GWAC members are a balanced and respected team representing the many constituencies of the electricity supply chain and users. The GWAC provides industry guidance and tools to articulate the goal of interoperability across the electric system, identify the concepts and architectures needed to make interoperability possible, and develop actionable steps to facilitate the inter operation of the systems, devices, and institutions that encompass the nation's electric system. The GridWise Architecture Council Interoperability Context Setting Framework,V 1.1 defines necessary guidelines and principles[9].

GridWorks – A DOE OE program focused on improving the reliability of the electric system through modernizing key grid components such as cables and conductors, substations and protective systems, and power electronics. The program's focus includes coordinating efforts on high temperature superconducting systems, transmission reliability technologies, electric distribution technologies, energy storage devices, and GridWise systems.

V. **Distributed Renewable Energy Sources (RES)**

The integration of fluctuating Renewable Energy Sources (RES) and Distributed Energy Resources (DER) into today's distribution networks can result in various challenges for network planning and operation. On one hand changing power flows due to large shares of distributed generation in the low and medium voltage networks will affect the voltages, which can result in voltages violating the operational steady-state maximum and minimum voltage limits. On the other hand the capacity of DER generation highly exceeds the load already today in some distribution networks, e.g. in Southern Germany. The ratings of the network components are not designed for these high power flows feeding back into the overlaying network[10][11]. Thus overloading of cables, overhead lines and distribution transformers can be a serious problem resulting in large investments, which are necessary to strengthen the networks and to ensure security of supply.

V .CONCLUSION

Smart grid programs are typically evaluated on the basis of how they affect peak electricity demand, without regard to the source of the power. The greater the level of renewable generation the Smart Grid can reliably and efficiently accommodate, the larger the environmental benefits will be. The implementation of Smart Grid technology will be an exciting time for the energy industry and consumers of electricity. The ability to manage one's own consumption based on pricing and need will help the reliability of the network by easing peak demands and improving energy efficiency.

Efficiency improvement of alternate energy sources at a system level, which in essence is a nugget of the smart grid system, can only be realized through efficiency improvements in power electronics. Demand response initiatives should be through right balance of pricing and incentives. pace of challenges to the existing grid continues unabated, with increased renewable linking onto the grid as utilities meet RPS requirements and existing infrastructure continuing to age. A Smart Grid can be a mechanism for achieving the worldwide goals in the areas of energy security, climate change, grid reliability, economic growth, and national competitiveness.

The Future Renewable Electric Energy Delivery and Management (FREEDM) System Residential users control their energy needs with small and modular distributed renewable resources (DRERs) through a standardized plug-and-play interface. The objective of this report was to compile various smart grid concepts, architectures, and details of associated technologies implemented worldwide. Energy demand is exponentially increasing worldwide and energy saving has become a dire need of the times. However, integration of RES into existing power network in future may bring many technical challenges, system reliability and security. We need an intelligent system that can receive power of all qualities from all sources, both from centralized and DG and deliver reliable supplies on demand to consumers of all kinds. The smart grid will be a user-centered, market-based, interactive, reliable, flexible and sustainable electrical network system.

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