ABSTRACT

The Smart Grid is the latest direction for the future power system development. Many electric utilities are investigating and implementing a Smart Grid. Smart Grid is expected to be the new industry platform. This paper presents the background, meaning, concept as well as the structure of Smart Grid. Typical diagram of Smart Grid is illustrated. The paper analyses the characteristics and direction of smart grid development, and point out that the development of smart grid requires the development of many smart grid technologies and the building of grid structure, and it also describes the realization of the self-healing function as well as distributed power generation technology. This paper describes Grid's vision for Smart Grid in India.

KEYWORDS: Smart grid, renewable energy sources, challenges and solution of smart grid, reduce green house gas emission.

1. BACKGROUND

Power generation companies generate power from conventional sources (coal, oil, natural gas) and renewable sources (hydroelectric, solar, wind). Usually, the power is generated far away from the end user. Therefore, the power needs to be transported from the generation site to the end user. Transmission companies fill this need with their high voltage transmission lines. The voltage is “stepped up” by a transformer, and then it is transported rapidly on high voltage lines. At higher voltages less power is lost to inefficiencies and travels faster to the end user. Lastly, power needs to be distributed to the end users. The high voltage power is “stepped down” by several transformers, transferred to low voltage power lines to your home or office and then consumed. Distribution companies and public utilities control these last steps and also deal with customer service and new connections to the grid [17].

2. INTRODUCTION

A smart grid delivers electricity from suppliers to consumer using two way digital technologies, advanced sensors, automated metering, and specialized computer systems to enhance reliability performance, enhance customer awareness and choice, and encourage greater efficiency decisions of the customer and of the utility provider [17].

To control appliances at consumer home to save energy, reduce cost and increase reliability and transparency. Such a modernised electricity network is being promoted by many governments as way of addressing energy independence, global warming and emergency resilience issues. Smart meter may be part of smart grid but alone do not constitutes a smart grid [17].

A smart grid includes intelligent monitoring system that keeps track of all electricity flowing in the system. It also incorporate the use of superconductive transmission line for less power loss, as well as the capability of integrating alternative source of electricity such as solar and wind. When power is least expensive a smart grid could turn on selected home appliances such as washing machine or factory processes that can run a arbitrary hours. At peek time it could turn off selected appliances to reduce demand [17].

As shown in Fig.1 [4], a Smart Grid is basically overlaying the physical power system with an information system which links a variety of equipments and assets together with sensors to form a customer service platform. It allows the utility and consumers to constantly monitor and adjust electricity use [4].

3. COMPARISON BETWEEN EXISTING POWER GRID AND SMART GRID

Compared with the traditional power grid, smart grid in all aspects of power system has obvious advantages and characteristics. Table 1 provides the comparison between the current grid and smart grid [18].

4. COMPONENTS OF SMART GRID

4.1. Demand Management

Demand management works to reduce electricity consumption in homes, offices, and factories by continually monitoring electricity consumption and actively managing how appliances consume energy [19]. It involves,

4.1.1 Demand response
During periods of peak energy use, utility companies send electronic alerts asking consumers to reduce their energy consumption by turning off non-essential appliances.
To remedy this situation, utility companies are now replacing traditional mechanical electric meters with smart meters. These new devices allow utility companies to monitor consumer usage frequently and, more important, give customers the ability to choose variable-rate pricing based on the time of day [1][20].

### 4.2 Distributed Electricity Generation

#### 4.2.1 Renewable energy using micro generation devices

Already, some homes and offices find it cost-effective to produce some or all of their own electricity using micro generation devices small-scale energy-generation equipment designed for use in homes and offices. When fully developed, a Smart Grid will allow owners of micro generation devices and other energy-generation equipment to sell energy back to utility companies for a profit more easily. [20][1]

#### 4.2.2 Storage and PHEVs

With the development of PHEVs and electric cars, new opportunities will become available. For example, car batteries can be used to store energy when it is inexpensive and sell it back to the grid when prices are higher. For drivers, their vehicles would become a viable means to arbitrage the cost of power, while utility companies could use fleets of PHEVs to supply power to the grid to respond to peaks in electricity demand.[20][2]

#### 4.3 Transmission and Distribution Grid Management

Monitoring has focused only on high-voltage transmission grids. Increasing overall grid reliability and utilization, however, will also require enhanced monitoring of medium- and low-voltage distribution grids.

##### 4.3.1 Grid monitoring and control

Expensive power outages can be avoided if proper action is taken immediately to isolate the cause of the outage. Utility companies are installing sensors to monitor and control the electrical grid in near-real time (seconds to milliseconds) to detect faults in time to respond. These monitoring and control systems are being extended from the point of transmission down to the distribution grid. Grid performance information is integrated into utility companies’ supervisory control and data acquisition (SCADA) systems to provide automatic, near-real-time electronic control of the grid. [19][2]

### 5. GRID STABILITY

The high variability of PV production causes grid stability issues. The voltage and current will vary with insulation, producing spikes and dips of duration as small as a few milliseconds. Power quality issues cost American businesses billions of dollars each year. Bi-directional current flow is the biggest hardware problem. Current power lines and transformers cannot handle current flowing backwards through the system as would occur if houses send power back into the network. These problems are compounded by the lack of grid monitoring equipment. With these variability problems, utilities would need to know about power flow at all points of the grid to have the control needed. Sensors are needed at the substation, transformer, and household levels.

### 6. TECHNICAL CHALLENGES AND SOLUTION

If the grid remains a network, the network must support bi-directional current flow at a significant level [17]. There needs to be a power source when RES resources are unable to generate power (i.e. at night or due to weather) [17]. There is currently no satisfactory model for sunlight, wind or cloud cover that could be used to predict renewable energy production [17]. In order to manage the significant number of generation sources, and distribution between them, the grid needs improved monitoring and communications infrastructure [17]. The quality of power (i.e. voltage and frequency) delivered to consumers must be consistent [17]. Utilities are unable to strategically and precisely direct power to meet individual users’ needs. [17].

Integrating the solution methods (i.e. hitting two birds with one stone) would be ideal. Not all of these problems can be solved by a single solution, but they can all be captured by three main solutions: [17]

1. Introducing a significant amount of energy storage both centralized and distributed [17].
2. Incorporating new hardware including improved transformers and inverters.
3. Installing a ‘smart grid’ infrastructure and operating procedure [17].

In order to interface RES and storage technologies with the grid, though, the incompatibility between alternating and direct current needs to be resolved. Commercially available inverters solve this issue conveniently. This allows the DC power generated by solar panels to interface with the AC power needed for homes and to transmit on the grid. Installing inverters at each household has the additional benefit
of improving the quality of power that is transmitted to the grid [17].

As renewable energy penetration increases, however, more and more individual users’ generated energy will be transmitted back to the grid. This reverse power flow would cause traditional grid components (especially transformers and voltage regulators) to fail. Therefore, bi-directional transformers and voltage regulators would need to be installed throughout the grid, at both the distribution and substation level. Since the majority of grid components need to be replaced to install a smart grid [17].

The key to integrating the previously mentioned technological solutions is employing “smart grid” technology. A smart grid is an upgrade of the current transmission and distribution network that employs a network of advanced sensors connected by two-way communications and controlled by computational centers distributed geographically. The technology involved in implementing a smart grid allows more efficient, reliable, and safe power delivery and use. In order to realize these benefits, however, the infrastructure needs to be put in place. This involves outfitting each customer with “smart meters” that provide information to utilities in real time. Additionally, sensors would need to be installed (monitoring voltage and power quality) at many intermediate points within the grid. Also, computation and control centers would need to be constructed and the models needed to run them would need to be developed and implemented [17].

6.1 The Micro-Network

One step away from distributed power with autonomous power producers is the idea of a Micro-Network. A Micro-Network is a neighborhood size group of individual power producer-consumers who are connected with each other and share communal power and centralized storage. This method is preferable because of the increased reliability and cost effectiveness of the centralized storage. In this solution, there is almost no individual residential or commercial energy storage, instead, excess power generated is passed on to the Micro-Network either to be used by others on the network or stored at the centralized storage facility. Bi-directional power flow is a key component of the Micro-Network; this problem will be addressed either by redundant transformers (one for each direction) or improvements in transformer technologies such as solid state transformers [17].

In addition to the government mandates and incentives toward achieving this solution is upgrading the current electric transmission and consumption hardware to include sensors, a communication infrastructure, and controls software. These improvements will allow for the intelligent distribution and consumption of electricity and will provide data that will be necessary for the final implementation of the Micro-Networks [17].

The power within the Micro-Networks will be bi-directional and shared within the group, or shunt to the main power grid. The electric companies will lose power generation revenue, but can create new sources of revenue installing the smart grid equipment, the bi-directional equipment, and by maintaining and managing the bi-directional equipment, and by connecting Micro-Networks. Fig 2 explains the Architecture of General Network connecting Micro-Network.

Fig 2. Architecture of General Network connecting Micro-network

The various levels and scales of storage combined with completely distributed generation will require bi-directional power components managed by an intricate Smart Grid that will control the flow of power as demand and supply vary regionally and with time of day.

At 50% generation, most of the smaller power consumers who demand less reliability will rely solely on RES, while the larger and more vital power consumers will stay primarily on traditional power. As the role of RES continues to grow, the traditional power sources will slowly be replaced by large power storage units such as pump hydroelectric, which will continue to feed the vital energy consumers. Ultimately the Micro Networks will be self sufficient [17].

7. REDUCE GREENHOUSE GAS EMISSIONS

A Smart Grid that incorporates demand management, distributed electricity generation, and grid management allows for a wide array of more efficient, “greener” systems to generate and consume electricity. Worldwide demand for electric energy is expected to rise 82 percent by 2030. Unless revolutionary new fuels are developed, this demand will be met primarily by building new coal, nuclear, and natural gas electricity-generation plants. Not surprisingly, world CO2 emissions are estimated to rise by 59 percent by 2030 as a result. The Smart Grid can help offset the increase in CO2 emissions by slowing the growth in demand for electricity [17].

DISCUSSION AND CONCLUSION

Smart Grid is a hot spot in today's electric power system, also regarded as one of the vanes in 21st century for the major scientific and technological innovation and development in power system.[4]

There are several points to progress toward the smart grid. Operational Technology and Information Technology departments should become closer. Security has to be considered from the beginning of the project. Data communications is often the largest missing piece. The project needs to be done in well defined phases.

This paper describes the solution with higher strength and minimal costs and recommends that the government, public, and utilities work to implement Solution of an Interconnected Micro-Network. Also suggestions in this paper will help the Smart Grid become a reality that will ensure we have enough power to meet demand, while at the same time reducing greenhouse gases that cause global warming.
A smart grid will allow consumer to receive valuable and understandable information. This enables us to make intelligent and informed choices about how we use energy, so that the consumer cost and out of pocket expenses that could arise with the implementation of the SMART GRID will be minimized [19].

A smart grid will allow consumer to receive valuable and understandable information that enables us to make intelligent and informed choices about how we use energy, all while minimizing the consumer cost and out of pocket expenses that could arise with the implementation of the SMART GRID[19].

REFERENCES