AN OVERVIEW OF SMART GRID TECHNOLOGY IN INDIAN POWER SECTOR

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Abstract—

Smart grids are the future of Indian power sector and would go a long way in reducing environmental impact and tackling the major challenges faced like technical and commercial losses, chronic supply-demand gap and frequent blackouts. Transforming the existing electric infrastructure through a smart grid is the way forward to ensure efficient and reliable power supply, and achieve sustainable development. The Government of India has identified and initiated a number of remarkable steps towards a more reliable, resilient, cost-effective and interactive power grid. This paper aims at providing a detailed view of the background and current status of the major smart grid initiatives and projects in India, along with a few suggestions for the successful way ahead.

Keywords—advanced metering infrastructure; distributed energy resources; dynamic pricing; electric vehicles; peak load management; personal power plants; smart home energy management; street light automation; smart grid

I. INDIAN POWER SECTOR-CURRENT SCENARIO

India is world's sixth largest energy consumer, accounting for almost 4 % of the total energy consumption in the world. The country has been increasingly adding to its capacity over the last few years, with total installed capacity growing to 243GW during the year 2014 [2], of which only 12% comes from renewable energy sources. Coal and gas are the most popular sources with a share of 58% and 9% respectively. The dependence on imported oil is currently about 75%, which is expected to increase to 80% by 2016-17. As far as gas is concerned, the import rate is currently 19%, which is expected to increase to 28% by 2016-17. Similarly, coal import is expected to rise from about 90 million tons at present to over 200 million tons in 2016-17. Due to the increasing coal and gas supply storage, average plant load factor (PLF) for thermal capacity in India has considerably declined from 70% in 2012-2013 to 65.5% in 2013-14 [2]

India's being one of the fastest growing economies with its GDP growth projected over 8%, the installed capacity requirement of the country shall be around 685GW by the year 2030 [4]. According to the estimates of the Planning Commission, during twelfth five year plan period (2012-13 to 2016-17) for a GDP growth of 9% per year, energy supply has to grow at 6.5% per year. During the year 2013-14, the peak demand met was approximately 130GW with a shortage of 4.3% where as the total energy availability was 877 Giga units with a shortage of 4.2% [2]. In order to meet the increasing requirement of electricity, massive addition to the installed generating capacity in the country is required. While planning the capacity addition program, the overall objective of sustainable development has to be kept in mind. It is very obvious that the far-reaching goals of the Indian power system can be attained by smart grids which can help in improving the efficiency and optimize performance within the sector.

II. DRIVERS FOR SMARTGRID IN INDIA

The current scenario of the Indian power sector as depicted above calls for a complete switch into the next generation through the adoption of 'smarter' technologies into the grid. Smart Grid as defined in [5] refers to a modernised electrical system in which new and more sustainable models of energy production , distribution and usage will be made possible by incorporating pervasive communication and monitoring capabilities; and more distributed and autonomous control and management functionalities.

The drivers towards smart grid for the various stakeholders are as below:

A. Service Provider

The main driver towards smart grid for utilities is the reduction in transmission and distribution losses and thereby improving the collection efficiency. Currently the transmission and distribution losses is around 27% which amounts to 20 billion dollar per year revenue losses to the utility. Enabling multiple options from direct load control to consumer pricing incentives by peak load management, reduction in power purchase cost, better asset management, increased grid visibility and resiliency, self-healing property of the grid and integration of distributed energy sources are the other drivers for utilities.

B. Consumers

For consumers, the main driver is the expanded access to electricity. Currently, 20% of the rural households in india do not have access to electric power. Through better integration of renewable sources, solar rooftops and microgrids, government is planning to achieve energy independence and 'power to all' by 2020. Improved reliability and quality of power, increased choices, 'prosumer'(producer cum consumer) enablement, and options to monetary savings by shifting loads from peak periods to off-peak periods etc are the other factors that lead consumers to support smartgrid technologies as well.

C. Government and Regulators

Satisfied customers, financially sound utilities, tariff neutral system upgrade and modernization, reduction in emission intensity etc are the main drivers for government and regulators.

III. SMARTGRID INITIATIVES IN INDIA

India Smart Grid Forum (ISGF) and India Smart Grid Task Force(ISGTF) were two major measures taken by the Government of India in May, 2010 to accelerate implementation of smart grids in India.

ISGTF is an inter- ministerial group which will serve as Government's focal point for activities related to smart grid [2]. The main functions of ISGTF are to ensure awareness, coordination of diverse activities related to smart grid technologies, practices and services for development of smart grid, collaborate on interoperability framework, review and validate recommendations from ISGF etc.

ISGF is a non-profit voluntary consortium of public and private stakeholders with the prime objective of accelerating development of smart grid technologies in the Indian power sector [2]. The goal of the forum is to help the Indian power sector to deploy smart grid technologies in an efficient, cost-effective, innovative and scalable manner by bringing together all the key stakeholders and enabling technologies.

ISGTF under the aegis of Ministry of Power has started implementation of 14 pilot projects across the country. The projects belong to the distribution utilities of the following states: Karnataka, Andhra Pradesh, Assam, Gujarat, Maharashtra, Haryana, Tripura, Himachal Pradesh, Puducherry Electricity Department, Rajasthan, Chattisgarh, Punjab and Kerala. The main objective of the implementation of the pilot projects is to determine the selection of appropriate technologies and communication systems for different regions in the country and build policy and regulatory recommendations accordingly.

IV. SMARTGRID TECHNOLOGIES AT PUDUCHERRY

The Puducherry smart grid pilot is India's first smart grid project developed jointly by The Electricity Department of Puducherry and the Power Grid Corporation of India Ltd (PGCIL), The project is being implemented with following objectives: indigenization of technology, common information sharing platform, demonstration of effectiveness of each functionality, evolving policy advocacy for successful implementation and evolving commercial mechanism. The major smart grid technological attributes that has been implemented at Puducherry are explained below along with the current status.

A. Advanced Metering Infrastructure(AMI)

AMI is one among the few main smartgrid attributes implemented at Puduchery. AMI (Advanced Metering Infrastructure) describes the total infrastructure from smart meter to two way-communication network to the control center and all the applications that enable the collection and transfer or measured data. AMI is the backbone of smart grid and makes two-way communications between the customers and the utility possible. These systems include smart meters, communications, energy displays and controllers, Meter Data Acquisition System (MDAS), Meter Data Management (MDM) software and the utility business information systems. Smart meters are advanced meter devices which collect information about energy and other relevant data at various intervals and transmit the data over the communication networks to utility, as well as receive information like pricing and reliability signals from utility and convey it to the consumer. MDAS is the application at the control centre and the Data Concentrator Units(DCUs) are used to collect data from meters and send it to the MDM system. MDM system is the system which receives and analyzes the metering information [6].

The main features of AMI in Puduuchery project are recording of energy consumption data for consumer and utility (kWh, kVar, voltage, power factor, maximum demand etc.), automatically sending the consumption data to the utility at pre-defined intervals, time-based pricing signal for demand response, bi-directional communication ability, net metering to facilitate integration of distributed generation, remote connection and disconnection of consumer supply, reporting tampering and theft in real time to the utility, communications with other intelligent devices in the home. Currently more than 1600 numbers of smartmeters and almost 29 DCUs have been installed in puducherry covering 9 DTs [5]. Meters of different communication technologies (radio frequency 2.4 GHz, radio frequency 865 MHz, power line communication, broad band power line communication, general packet radio service) have been successfully integrated at the control centre [5].

B. Peak Load Management (PLM)

PLM is one of the smart grid technology initiatives through which utility can reduce the peak demand. Demand side integration(DSI) is a set of measures to use loads and local generation to manage and improve the quality and reliability of power supply. DSI is consists of Demand Side Management(DSM) and Demand Response(DR) [6].

Demand Side Management includes utility side activities like direct load control where individual consumers and their loads are controlled directly from the utility. In demand response, the consumer manages demand in response to some pricing or reliability signals or incentives from the utility. Dynamic or time of use pricing of electricity and other incentives are communicated to the consumer through the smart metres or short message services(SMS) and the consumer responds to it accordingly by reduction in consumption. Consumer is provided with in-home display device which displays the consumption, tariff rates and other related information.

A virtual DR program with associated dashboards and actual loads is placed in Puducherry smart grid control centre(SGCC) [5].

C. Outage Management System(OMS)

OMS manages unscheduled and scheduled outages of distribution infrastructure. It collects and coordinates information about outages and reports them to the operator who then takes corrective actions through crew management and remote controls. It would improve not only the reliability of power supply but also the sale of power through same infrastructure may be increased which is beneficial to the consumers as well as utility.

The two main features of OMS in Puducherry are distribution transformer monitoring units (DTMU) and fault passage indicators (FPIs). A DTMU increases the reliability of distribution network, by monitoring critical information such as oil temperature, oil level, winding temperature, total harmonic distortion, load unbalance and actual loading of the transformer. Currently, 8 numbers of DTMUs have been installed in Puducherry smartgrid project [5].

Fault Passage Indicators (FPIs) are a cost effective solution to increase grid reliability. They are devices that are mounted on the lines and when a fault is detected, alarms are operated for remote indication and an integral LED is illuminated. FPIs coupled with effective communication can help in faster fault location and lead to faster restoration of supply. Currently 21 numbers of FPIs (communicable/ non-communicable) have been installed at Puducherry sending alerts to SGCC as well as mobile phones of maintenance crew [5].

D. Power Quality Management(PQM)

The two key factors that affect power quality are harmonics and voltage deviation. PQM address events like voltage flickering (sags/swells), unbalanced phases voltages and harmonic distorted/contaminated supply etc. This will facilitate efficient and reliable operation of the power system, reduce losses, improve customer satisfaction and reduced equipment failures. PQM shall include voltage / var control, load balancing, harmonics controller etc.

The smartgrid project at Puducherry incorporates automatic power factor correction(APFC) and active filters as a part of power quality management. Automatic power factor correction systems are designed to automatically turn power factor correction capacitors on or off to maintain a desired target power factor under varying load conditions on the low voltage distribution systems. The capacitor bank is divided into steps because the load may vary daily, weekly and seasonally. The APFC at puducherry has built in capacitor bank controller and can provide a total Var compensation of 140Mvar in steps of 50, 50, 20, 10 and 10 [5].

Active filters use power electronic converters to compensate for current and/or voltage harmonics originated by non-linear loads. There are basically two types of active filters: the shunt type and the series type. Smartgrid project at Puducherry has insulated gate bipolar transistor (IGBT) based active filter of total Var compensation rating of 150kVar installed [5].

E. Renewable integration with net metering/Micro grid

A Microgrid is an integrated energy and communication system consisting of interconnected loads and distributed energy resources (DER) which can operate in island or grid-connected mode. DER systems are small-scale power generation technologies (typically in the range of 1 kW to 10,000 kW) used to provide an alternative the traditional electric power system. DER technologies primarily consists of microturbines, photovoltaic systems, wind etc.

Net metering is a service to an electric consumer under which electric energy generated by that consumer from a renewable energy source of his own and delivered to the local distribution facilities is used to offset electric energy consumed by the same consumer from the grid during the particular billing period. Net metering is a policy aimed at encouraging private investment in renewable energy. Smart meters with net-metering were installed for three roof top solar consumers, in a first of its kind initiative in Puducherry. For one case the total energy imported from the grid for a day observed was 557 kWh and total export to the grid through roof top solar generation was 633 kWh, resulting in zero net energy usage. Also, the solar performance with net metering system was found to be excellent with the solar power output much greater than the energy consumption when compared for the month of November 2013[5].

F. Smart Home Energy Management System(HEMS)

Smart home energy management systems use advanced technologies to make the electricity consumption at home more rational and prudent, resulting in energy and money savings. HEMS helps in reducing energy consumption by using weather, sensor, and other types of information to identify unnecessary energy use and controlling the smart home appliances. HEMSs also work actively to make the best use of electric power by, for example, operating few appliances during times when solar panels are generating excess power. It provides proper picture of electric energy consumption to give the consumer a way to view their own usage on a display.

A sample of energy efficient smart home was established at Puducherry near interim SGCC to demonstrate the smart home functionalities in a smartgrid network. It was demonstrated how energy can be saved by using energy efficient home appliances and building materials. It was also demonstrated how home appliances can be controlled remotely by consumer [6].

G. Street light automation

Street lighting is a major consumer of electricity. All outdoor lighting is estimated to comprise 19% of worldwide energy consumption today. Street light automation is automatic control of the street lights mostly through a microcontroller based system. The main advantages of street light automation system are substantial energy savings (up to 35%) by optimizing burning times and dimming at off-peak traffic hours, substantial maintenance cost savings by detecting burned lamps, less load on transformers by lamps dimming and optimizing in peak consumption periods etc.

Street light automation in Puducherry incorporates the concept of automatic on-off and intensity control of the street lights depending on the luminance and traffic conditions. Smart street lighting system covering 126 lamps have been implemented so far and overall energy saving of about 57% has been attained [5].

H. Energy Storage & Electric Vehicle with solar charging station

In recent years the Indian government has implemented a number of initiatives to advance the use of electric vehicles(EVs). But the increasing use of EVs pose new challenges to electric grids because of the significant increase in the energy demand. Thus, considerable work has to be done on establishing control strategies to distribute spatially EV charging in order to avoid peak loads and to optimally utilize grid capacity . The battery powered vehicles can be used to shave off the peak demand for electricity by supplying energy to the grid from their batteries during peak use periods during the day while charging mostly at night, when the demand is very less.

Also when the EVs are plugged into the electric grid their batteries can be used as backup energy storage systems. For instance, EVs can supply back part of their stored electric power to stabilize the electricity produced by intermittent renewable energy sources. This technology is called Vehicle to Grid (V2G) and can help a great deal in reducing the need for new power plants.

In Puducherry, in the past Plug-in electric vehicle(PEVs) which has rechargeable batteries had been deployed but has been discontinued due to lack of maintenance support. It is expected that they will be introduced later with adequate solar based charging infrastructures at proper locations such as parking lots, markets etc. with remotely monitored pre-paid meters using AMI.

V. BENEFITS OF SMART GRID AT PUDUCHERRY

The smart grid pilot project at Puducherry has delivered a large number of benefits as listed below:

A. Service Provider

Reduction of transmission and distribution losses:

a. *Improved billing and collection efficiency*
b. *Considerable ncrease in revenue*

Better load management:

a. *Optimization of utilization of assets*
b. *Reduction in blackouts and avoidance of purchase of expensive peak power.*

Improved quality of supply

a. *Reduction in outage time and frequency*
b. *Improvement in voltage profile*
c. *Faster identification of fault*

B. Consumer:

a. *More reliable and continuous supply of power*
b. *Reduction in electric bills by shifting loads from peak hours to off-peak hours*

c. *Avoidance of investment in power backup solutions like inverters*
d. *New role as producers of energy from renewable sources with facility to feed excess power into the grid – zero net energy homes*

VI. WAY AHEAD –SUGGESTIONS

A. *Introduction of Smarter Tariff Systems*

The basic idea behind variable tariff system is to let the consumers who contribute to the peak pay for it. A full scale deployment of variable or dynamic tariff system is critical in the current scenario of Indian power sector where we still face shortage in peak load as well as overall supply. Currently, there is only limited application of ToU (Time Of Use) variable tariff system, only to voluntary and bulk consumers, and with a differential too low to be attractive. A way to move forward would be increasing the differential and application of ToU to a larger section of consumers.

Adoption of dynamic pricing programs such as RTP(real time pricing), VPP(variable peak pricing), CPP(critical peak pricing) etc where rate schedules are not predetermined and static is also advisable. In RTP, pricing rates generally apply to usage on an hourly basis. VPP is a hybrid of ToU and RTP where the different periods for pricing are defined in advance but the price established for the on-peak period varies by utility and market conditions. Utilities may call critical events during a specified time period when they expect high wholesale market prices or grid emergency conditions, the price for electricity during these time periods is substantially raised. This is called CPP.

B. '*Personal Power Plants'*

Personal power plants is a great solution to the issue of rural electrification in India. This idea has already been successfully implemented in a city near Denver in United States. The city will consume no more energy than it generates in a given year and is called a net zero energy district. Extensive deployment of advanced energy technologies including combined-cycle gas turbines, rooftop solar photovoltaics, community solar gardens, wind turbines, thermal and electricity storage and energy-efficient schemes made it possible [10]. The key to these projects is to reduce the energy consumption by almost 60%, and then offset the remaining 40% through renewable energy sources.

C. *Mandatory Demand Response programs for larger sections of consumers*

Currently the demand response schemes are being implemented in a very small scale and only to the voluntary customers. A big and critical step would be making them mandatory that too to a larger section of customers thereby improving the peak load management. Considering the large diversity in the consumers to be served in India, it is necessary to identify the appropriate consumers to be roped in for demand response to ensure the success of the program.

D. *Creating awareness among 'prosumers'*

From a customer's standpoint, participating in a demand response event can be burdensome, particularly because it might mean shifting of their requirements for energy or curbing heating and cooling systems on days of extreme temperatures. Utilities must find appropriate incentives to motivate customers. Creating consumer awareness and maintaining transparency with them must be a priority to win their confidence and ensure acceptance of the demand response program. Without active participation of the 'prosumers', smart grid simply fails.

E. *Improved financing and accounting*

It would be better to use cost benefit analysis (CBA) for proving business cases of smart grids , instead of return on investment (ROI). If a Smart Grid helps in putting an end to load-shedding, the utility may not benefit financially, but the consumer gets savings on back-up power. This can be captured by CBA, whereas ROI cannot.

Customers can pay for the smart meters whereas the utility could cover shared infrastructure, data center, analytics and others. This shall be similar to the way in telecom departments where the cost of the last hop optical fiber are taken by the household, in exchange for a network it can simply plug in to. Development of low cost indigenous smart meters shall also be a big step.

VII. CONCLUSION

The evolution of smart grid is still in its initial stage. The entire power society is now understanding, learning and developing smart power grid system and it is no longer a proposal for the future. It is the best and the most viable answer to all the major challenges being faced by Indian power sector today which includes technical and commercial losses, chronic supply-demand gap, and the need for a more advanced electricity supply solution to satisfy its far-reaching goals. The government of India has initiated many remarkable steps in this regard and the fourteen pilot projects shall help in creating a basic outline for the Indian smart grid. The outcome and learning from implementation of these pilot projects shall be used in the implementation of the large scale smart grid projects in larger regions in the future

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