Smart Grid Development in India – A Case Study

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***Abstract*—Consistent high growth of Indian economy has resulted in a surging demand for energy. Since, independence Indian power system has grown from 1362 MW to 250GW. In the past decade, installation of renewable sources of energy for electricity has grown at an annual rate of 25%, which has reached 29,500 MW as on March 2014. Despite this, presently 400 million people in the country have no access to electricity and hundreds of millions get electricity for only a few hours. Distribution system is suffering from frequent and long duration outages. To supplement capacity addition as well as electrification of remote areas, development of micro-grid also needs attention. Standalone/decentralized micro grid can provide basic energy access to all.**

Presently, high AT&C losses of utilities are resulting into poor financial health of distribution utilities across the country. To address these issues and bring efficiency, seamless integration of emerging technologies in the field of monitoring, automation, control, communication and IT systems with active participation of all stakeholders are inevitable. It is expected that the far-reaching goals of modern Indian power system can be achieved by deployment of smart grids which can help to improve efficiency of Indian power sector. In this direction, several initiatives have been taken to implement smart grid in entire supply value chain - generation, transmission distribution and consumer participation in power sector. This paper presents initiatives taken by Power Grid Corporation of India Ltd. (POWERGRID) to implement Smart Grid in Indian Power System as a case study on Puducherry Smart Grid Pilot Project.

Keywords— AMI; Puducherry; Renewable; Smartgrid; Rooftop; Smart meter; Solar; Wind; ditribution;

I. INTRODUCTION

The landscape of entire value chain of power system - generation, transmission and distribution, has changed significantly throughout the world, over the past decade. There is a paradigm shift in the way with which the power sector is being viewed. The penetration of renewable generation in the installed capacity has increased to 12% by March 2014. The introduction of competition and market has necessitated focusing on aspects like curbing AT&C losses, bringing efficiency in entire supply chain, use of alternate/renewable sources, demand side management etc. In the new environment the consumers' aspirations from the power sector is changing. Unlike the earlier days, mere availability of power no longer satisfies the consumers' demand, the consumer today is looking for digital grade power supply which is secure, reliable and best of quality at affordable price. Commensurate with industry requirement and consumer aspirations, it has become necessary that the power engineering community should gear up to meet the challenges.

978-1-4799-5141-3/14/$31.00 ©2014 IEEE

The emergence of IT and intelligent devices has offered immense opportunity for its synergic use to mitigate above challenges. Today, two-way communication between devices and traffic of terabytes of data over wired/wireless networks is a reality. The integration of communication, computational and advances in power devices can be harnessed to develop Smart Grid; a grid which is smart enough to communicate with its users, managers and can take self-healing measures in case of contingencies to enable utilization of facilities to the extent possible.

II. POWER SCENARIO IN INDIA

A. *Present Power Scenario and Future Projection*

India is the fourth largest energy consumer in the world. The fast paced growth of Indian economy has resulted in a

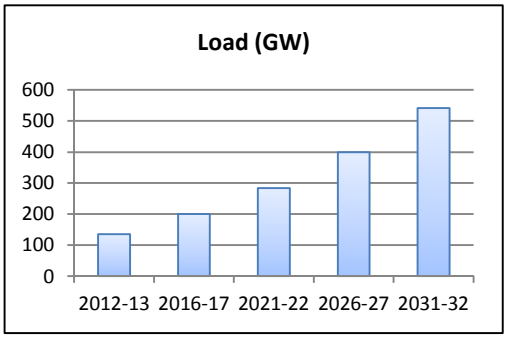

Fig 1: Projected Electricity Demand (As per 18th EPS)

surging demand for energy. Projected electricity demand growth in India is shown in Fig-1.[1]

Since independence, India has seen a phenomenal development in power sector, despite that about 400 million people in India have no access to electricity and hundreds of millions get electricity for only a few hours. To maintain the pace of economic development, provide access of electricity to all along with meeting environmental concerns, India needs to explore non-conventional sources of energy for long term energy security and sustainability. Unlike conventional generation renewables are non-dispatchable i.e. there are uncertainties and variability associated with large scale wind / solar generation. Smart Grid development in India is expected to facilitate in integration of large scale renewable generation through enhanced monitoring of power system and greater consumer participation as well as address the various issues associated with the distribution sector.

B. Renewable Development in India

In line with international development, portfolio of installed generation capacity is also changing in India. Out of total installed capacity about 12% i.e. 29.5 GW is through renewable (RE) generation. In energy terms, RE energy penetration is about 6%. [2]

In this direction, Ministry of New and Renewable Energy Sources (MNRE) projected that RE capacities at the end of the 12th & 13th Plan would be around 55 GW and 98 GW respectively. The renewable generation growth trend in India is shown in Fig 2.

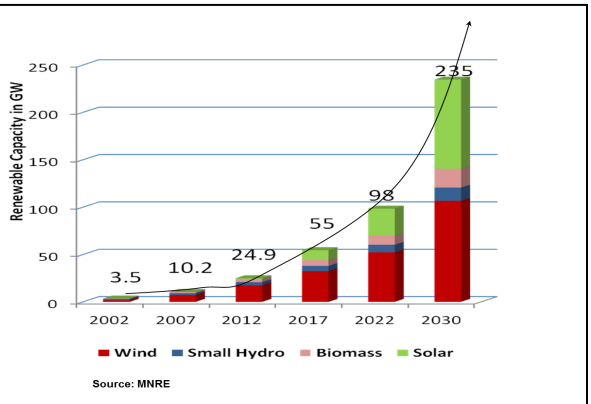

Fig 2: Renewable Generation Growth Trend

Major contribution in renewable capacity addition is envisaged through wind, solar and small hydro sources. Renewable Generations are not uniformly distributed across the country. In India, it is mainly concentrated in Gujarat, Rajasthan, Maharashtra, Himachal Pradesh, Jammu & Kashmir, Andhra Pradesh, Karnataka, Tamil Nadu etc.[3]

India's long coastline of 7,600 km gives it a high offshore wind power potential. Center for wind energy technology (C-WET) has assessed India's wind power potential as 1,02,778 MW at 80 meters height considering 2% land availability.[4] According to C-WET, Gujarat has highest wind potential in the country followed by three southern states, Andhra Pradesh, Tamil Nadu and Karnataka. Offshore Potential of renewable generation is also being explored.

A comprehensive master plan for grid integration of large scale renewable capacity addition in twelfth Five Year plan across India has been formulated in the "Green Energy Corridors" report. [3] The master plan covers intra-state & inter-state transmission systems and mitigating measures for grid interconnection of variable & intermittent renewable energy like flexible generation, renewable forecasting, setting up of Renewable Energy Management Center (REMC), energy storage facility etc. It also covers perspective plan for large scale renewable generation by 2030 and 2050.

India receives nearly 3,000 hours of sunshine every year with a solar generation potential of about 20-30 MW/ km^2. The country's installed solar power generation capacity has grown exponentially in the recent past, from mere 2.12 MW in 2007-08 to 2208 MW in Jan 2014. Four major deserts i.e. Thar, Rann of Kutch, Ladakh & Lahul Spiti in India have significant renewable (Solar) potential. A report titled "Desert Power in India: 2050" describes integrated plan for renewable development in Deserts of India. [5]

C. Status of Distribution Sector in India

Distribution sector in the Indian power system suffers from operational inefficiencies (high AT&C losses, frequent and long outages etc.). The average AT&C loss for utilities selling directly to consumers is 27% in 2012-11.[6] Other aspects like reliability in supply, power quality etc. are causes of concern. Good health of the distribution sector is the key for the success of entire power sector. Consumers are mostly passive, i.e. they are least informed about their consumption pattern and rarely participate in energy management.

III. SMART GRID DRIVERS

Unlike conventional energy sources, renewable generations are highly intermittent and variable type. Large Scale Integration of renewable generation requires special balancing mechanism to deal with the uncertainty and variability to maintain grid stability & security. To supplement capacity addition as well as electrification of remote areas, development of micro-grid also needs attention. Successful integration of such large scale RE integration would require active participation of all players i.e. from government agencies to NGO's, from manufactures to R&D institutions, from financial institution to developers and of course a new breed of energy entrepreneurs.

To address these issues and bring efficiency, seamless integration of emerging technologies in the field of monitoring, automation, control, communication and IT systems with active participation of all stakeholders are inevitable. In this direction, smart grid which integrates 21st century technology with the 20th century electrical grid has potential to revolutionise electricity delivery system and provide access to electricity for all. It offers hundreds of

millions of populations the possibility of accessible, reliable power - a fundamental requirement of inclusive growth. Every global driver for smart grids applies to India, but it has additional drivers, which are as given below:

For Utilities:

- Reduction of T&D losses in all utilities as well as improved collection efficiency
- Peak load management – multiple options from direct load control to consumer pricing incentives
- Reduction in power purchase cost
- Better asset management
- Increased grid visibility
- Self-healing grid
- Renewable integration

For Customers:

- Expand access to electricity – "Power for All"
- Improve reliability of supply to all customers – less or no power cuts, lesser of no more DG sets and inverters
- Improve quality of supply
- User friendly and transparent interface with utilities
- Increased choices for consumers, including green power
- "Prosumer" (producer and consumer) enablement
- Options to save money by shifting loads from peak periods to off-peak periods

For Government & Regulators:

- Satisfied customers
- Financially sound utilities
- System upgrade and modernization
- Reduction in emission intensity

IV. SMART GRID DEVELOPMENT IN INDIA

It is evident that the far-reaching goals of the modern Indian power system can be achieved by development of smart grids which can help to improve efficiency of Indian power sector. Smart Grid Vision for India is: "*Transform the Indian power sector into a secure, adaptive, sustainable and digitally enabled ecosystem that provides reliable and quality energy for all with active participation of stakeholders*." [7] It is aligned to the Government's overreaching policy of "Access, Availability and Affordability of Quality Power for all". Indian Smart Grid Task Force (ISGTF) under MoP, GoI has shortlisted fourteen (14) Smart Grid Pilot Projects spread across the country for demonstration of technology. Govt. of India will finance 50% of the cost of the project as grant and balance cost has to be borne by respective state utilities.

V. POWERGRID INITIATIVE ON SMART GRID

POWERGRID has taken initiative in deployment of smart grid technology in all facets of electricity supply value chain. In "Distribution" sector a pilot smart grid is being developed at Puducherry through open collaboration with manufacturer, academicians, solution providers & consultants. Similarly, Synchrophasor pilot projects have been undertaken in "Transmission" for real time dynamic state measurement of system in all the five regions across India. Based on the experience of synchrophasor pilot project large scale deployments of PMUs are being undertaken in the form of "Unified Real Time Dynamic State Measurement" (URTDSM) scheme. For large scale integration of upcoming renewable capacity in Indian grid, a comprehensive report titled "Green Energy Corridors" has been developed by POWERGRID. It comprises transmission system strengthening, Control Infrastructure, Energy Storage & REMC establishment.

A case study of Smart Grid pilot Project implemented at Puducherry is being presented in this paper.

A. Puducherry Smart Grid Pilot Project

POWERGRID has taken a pioneering initiative to develop Smart Grid Pilot Project at Puducherry through open collaboration jointly with Electricity Department, Govt. of Puducherry for demonstration of technology efficacy, provide input for standardization and interoperability framework of various technologies, policy advocacy and regulatory framework for tariff design & net metering, electric vehicle deployment with charging through renewables etc. [9]

Under this project various Smart Grid attributes have already been implemented and are being scaled up in a progressive manner. Presently, more than 1600 smart meters at consumer premises along with Data Concentrator Units (DCU) & Meter Data Management System (MDMS) have been integrated at one common platform at Smart Grid Control Centre at Puducherry.

Real time monitoring of energy consumption pattern, various alarms associated with it, etc. have been made possible with AMI system installed at Puducherry.

Meters with various communication technologies have been deployed including narrow band & broad band PLC, RF-2.4GHz, RF-865 MHz & GPRS. Smart Grid Control Centre at Puducherry is the first of its kind in the country has been established under this project. Real time Distribution Transformer (DT) wise energy audit is also possible, an example of monthly audit of a given DT is shown at Fig 3. [9]

To bring down outage duration and ensure reliable supply to consumers, Outage Management System (OMS) having Distribution Transformer Monitoring Unit (DTMU) and Fault Passage Indicators (FPI) have also been installed integrated with Smart Grid Control Center. DTMU monitors various parameters of distribution transformers (DT) like oil

level, oil temperature, load current, voltage, harmonics, palm temperature etc. on real time. Daily average Loading and temperature profile monitored through a DTMU installed at Puducherry is shown in Fig 4 & Fig 5. FPI facilitates in quick detection and identification of faulty network.

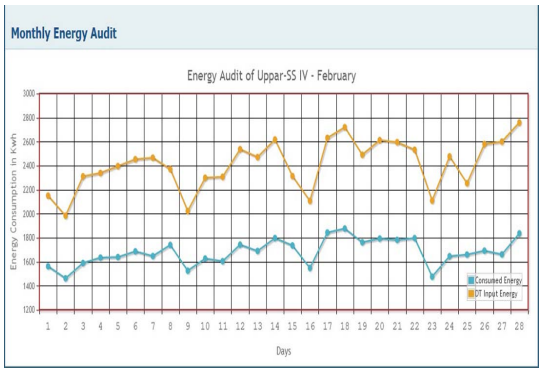

Fig 3: Real Time DT wise Energy Audit

Outage information is being sent to control center through GPRS communication at regular interval.

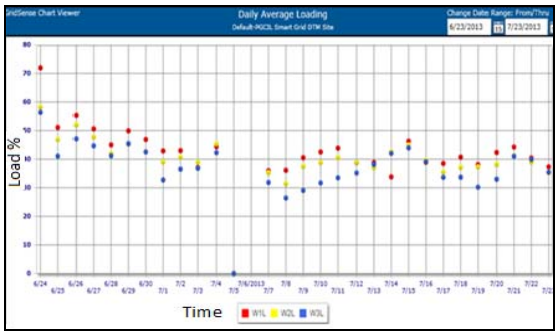

Fig 4: Daily Average Loading of a DT

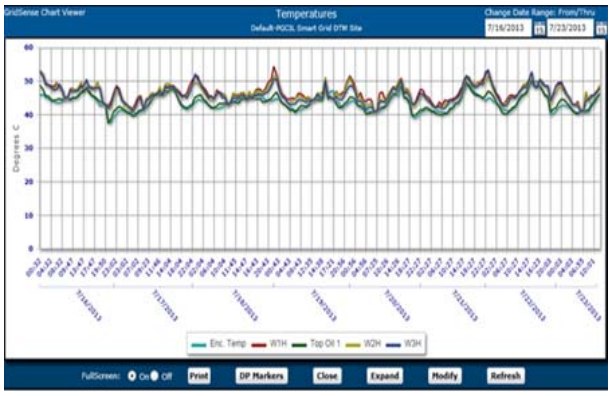

Fig 5: DT Temperature Monitoring through DTMU

In order to ensure quality supply to consumers 140 kVAR Automatic Power Factor Corrector (APFC) in steps of (50+50+20+10+10) as part of Power Quality Management (PQM) has been integrated. Performance of this APFC is shown in Fig-6.

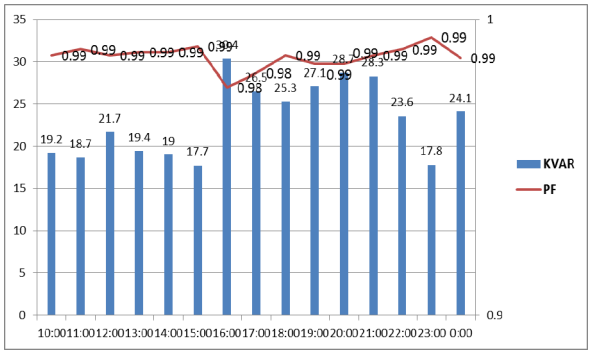

Fig 6: APFC Performance

In addition IGBT based 150 kVAR active filters for harmonic suppression; reactive power compensation and smooth voltage control have also been deployed.

A demonstration model of demand response has also been set up at Puducherry. It would facilitate customer to receive utility signals and to respond for demand management. In addition, efficient street light automation system has been implemented for 126 nos. of street light which has resulted into reduction of energy consumptions for street lighting by about 57%.

Renewable integration is one of the major thrust areas of Smart Grid implementation. With rooftop solar generation, every consumer has become a "Prosumer" (a term commonly used for energy producer and consumer). For integration of distributed generation in the form of roof top solar & integration into grid, net metering has been implemented in the premises of two different types of consumers' i.e. residential consumer and academic Institute in the Puducherry Project area. Besides getting clean and reliable supply of power, these consumers with rooftop solar are saving significantly on monthly electricity bill. Typical monthly energy consumption and Solar energy generation in the premises of these consumers with rooftop solar is shown in Table 1 and typical daily electricity demand vs. Solar Generation of a consumer having rooftop solar generation is shown in Fig-7.

Table 1: Typical Energy Exchange scenario having Rooftop solar

Energy Exchange (kWh)	Case-1 (Residential Consumer) 3 kWp	Case-2 (Educational Institute) 3 kWp	Case-3 (Residential Consumer) 2.4 kWp
Total Import from Grid	557.03	1720.89	1611.14
Total Export to Grid	633.65	358.88	302.07
Net Energy Exchange with Grid	-76.62	1362.02	1309.07

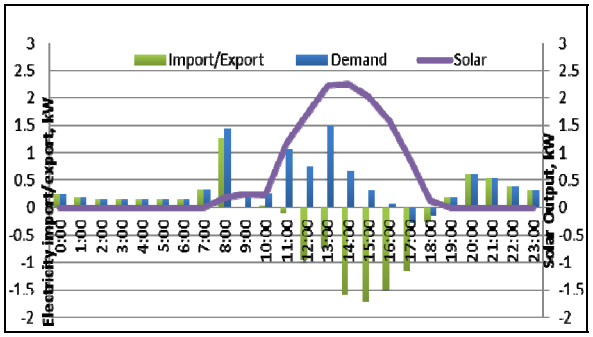

Fig 7: Demand Vs Consumption of a Consumer with Rooftop solar

Environmental friendly Electric vehicle having charging facility through Solar PV has been deployed at Puducherry under this pilot project.

To facilitate in consumer participation, Smart Home Energy Management system has been demonstrated at Puducherry. Functionality like Smart security, Micro grid controllers etc. have also been demonstrated under this project.

PED, the electricity utility in the project area has been immensely benefited from the success of Smart Grid Pilot. Some of the tangible benefits reported by PED on implementation of initial phase of Smart Grid pilot Project in their area are as summarized below:

1. Improved metering and collection efficiency: Metering efficiency increased by 14 % in the project area. This resulted in corresponding increase in billing efficiency.
2. Improved Billing Cycle: Remote meter reading through AMI has enabled simultaneous collection of meter reading for a large consumer base. Therefore, now working on modification of billing cycle that would improve collection and cash flows.
3. AMI has facilitated utility in detection of abnormal consumer behavior in real time. Examples of few such cases are explained below:
   - In one of the case utility observed very high consumption by a consumer. On investigation it was found that there was additional lighting and other loads during a family function.
   - Detecting meter tampering in real time: On investigation it was observed that consumer was trying to bypass the meter for using welding machine.
   - Several cases of consumer shifting the meter within his premises due to some construction work were detected. Consumers were advised to inform the utility for carrying out such activities.
   - In another case damaged wiring at consumer premises was also detected. Consumer was advised to rectify the wiring.
   - Case of meter recording more than actual consumption due to faulty meter was reported. Faulty meters were replaced.
   - Cases of bypassing meter were also reported.
4. AMI also helped utility in detecting unbalance in power supply as shown in Fig-8, thereby reducing the overall efficiency of system. Facilitated utility in planning mitigating measures.

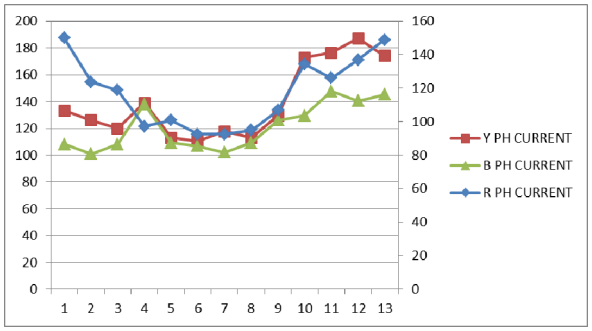

Fig 8: Unbalance in 3 phase supply

5. AMI also helped utility in detecting variation in voltage at consumer end as shown in Fig 9.

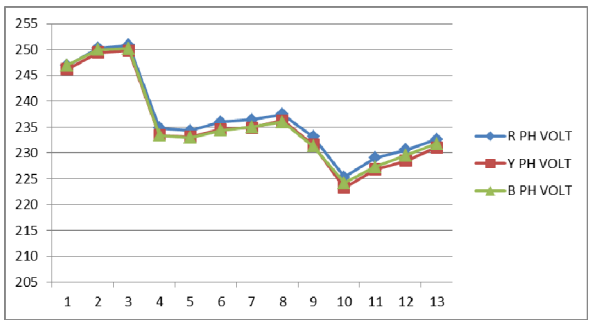

Fig 9: Voltage at Consumer End

This pilot would help in Indigenization of technology and evolve a suitable commercial mechanism. The project also aims at preparing groundwork for policy advocacy, regulations, standards, and evolution of a commercial mechanism among other things.

VI. Conclusion

For power sector to continue on the path of economic growth, deployment and adoption of latest technologies, introduction of more intelligence into the grid in the form of Smart Grid are inevitable.

This Puducherry Smart Grid Pilot Project has not only been found to be very useful in understanding the evolving Smart Grid technology but also act as a proof of concept in India. Experts from distribution utilities across the country, regulators and policy makers, etc. are regularly witnessing various smart grid attributes like, AMI, OMS, PLM, net metering, smart street lighting, demand response etc.

implemented under Puducherry Smart Grid Pilot Project. Various functionalities implemented under this smart grid project can serve as a reference for other utilities planning to implement it in their system.

The smart grid shall bring efficiency and sustainability in power sector, meeting the growing electricity demand with reliability, resilience, stability and best of the quality while reducing the electricity bill of a consumer. It also enables consumer participation in energy management.

ACKNOWLEDGMENT

Authors are thankful to the management of POWERGRID for granting permission for presentation of this paper. Views expressed in the paper are of the authors only and need not necessarily be that of the organization to which they belong.

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