

A Review on Development of Smart Grid Technology in India and its Future Perspectives

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Abstract-- India is truculent to meet the electric power demands of a fast expanding economy. Restructuring of the power industry has only increased several challenges for the power system engineers. The proposed vision of introducing viable Smart Grid (SG) at various levels in the Indian power systems has recommended that an advanced automation mechanism needs to be adapted. Smart Grids are introduced to make the grid operation smarter and intelligent. Smart grid operations, upon appropriate deployment can open up new avenues and opportunities with significant financial implications. This paper presents various Smart grid initiatives and implications in the context of power market evolution in India. Various examples of existing structures of automation in India are employed to underscore some of the views presented in this paper. It also reviews the progress made in Smart grid technology research and development since its inception. Attempts are made to highlight the current and future issues involved for the development of Smart Grid technology for future demands in Indian perspective.

Index Terms-- Smart Grid; Indian Electricity Act 2003; Availability Based Tariff (ABT); Demand Side Management (DSM); Renewable Energy; Rural Electrification (RE); Micro Grid.

I. INTRODUCTION

THE economic growth of developing countries like India depends heavily on reliability and eminence of its electric power supply. Indian economy is anticipated to grow at 8 to 9% in 2010- 2011 fiscal year, which in the impending years is set to reach double digit growth (10%+) [1]. But India suffers from serious power shortage which is likely to worsen over the next few decades. India has a power sector characterized by deficient generation and high distribution losses. In addition to that, abhorrent geological and environmental factors have encouraged carbon footprints since its grass roots level of CO₂ emissions, greenhouse effect and the adverse effect of globalization in the country [2]. This may cause instability in the power system and problems like brownout and blackout might arise. In order to prevent the occurrence of instability, it is essential to upgrade the prevailing power systems.

One of such incipient technology, Smart Grid (SG) plays a very vital role in achieving the key technical benefits like power loss reduction; refining quality of supply, peak reduction, economic load dispatch etc. Smart Grid technology has been a high priority topic of research and development in many developing as well as developed countries. This technology also has a dynamic role in remodelling the energy scenario of the global market. Factors like policies, regulation, efficiency of market, costs and benefits and services normalizes the marketing strategy of the Smart Grid technology. Other concerns like secure communication, standard protocol, advance database management and efficient architecture with ethical data exchange add to its essentials [3]. Such technology has a potential to proliferate other technologies like Flexible AC Transmission System (FACTS) and Wide Area Monitoring (WAM) to redefine the capability of power system engineering and unite the necessity of the rural, suburban and urban regions across the globe under single roof [4]. In addition, the technology employs the reduction of carbon footprints and foot-dragging the greenhouse gas emission. This paper designates about the Smart Grid initiatives along with various examples of existing structures of automation in India. It also reviews the encroachment made in Smart Grid technology in R&D, initiated by various public and private sector organizations supported by prominent institutions across the globe. Limelight on the current and future issues involved for the development of Smart Grid technology for future demands has also been debated.

The organization of the paper is as follows: In section II, an overview of the Indian Power market along with its current strategy of power system is presented. Section III describes the vision of India on Smart Grid (SG) technology along with section IV debriefing about the prevailing units and its future enactments. Section V reveals some of the required focus areas and advent of enhanced smart grid technologies. Section VI is dedicated to general conclusion followed by references.

II. OVERVIEW OF INDIA POWER MARKET AND ITS STRATEGY

The re-evaluation of the Indian Electricity Supply Act, 1948 and Indian Electricity Act, 1910, has led the Electricity Act 2003 which has facilitated government and many non-government organizations to participate and to alleviate the electricity demand. The act redefines the power market economy, protection of consumer's interest and provision of

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power to urban, sub-urban and rural regions across the country. The act recommends the provision for national policy, Rural Electrification (RE), open access in transmission, phased open access in distribution, mandatory state electricity regularity commission (SERCs), license free generation and distribution, power trading, mandatory metering, and stringent penalties for theft of electricity [3]. In addition to these guidelines, a concept called as Availability Based Tariff (ABT) has also been implemented to bring effective day ahead scheduling and frequency sensitive charges for the deviation from the schedule for efficient real-time balancing and grid discipline. Exclusive terms like fixed cost and variable cost, and unscheduled interchange (UI) mechanism in ABT acts as a balancing market in which real-time price of the electricity is determined by the availability and its capacity to deliver GWs on day-to-day basis, on scheduled energy production and system frequency [5-7].

Indian power system has an installed capacity of around 164 GW and meets a peak demand of 103 GW. According to the current five year plan (2007-2012) by the year 2012, the installed capacity is estimated to be over 220 GW and the peak demand is expected to be around 157 GW and is projected to reach about 800 GW by next two decades [8-9]. However certain complexities are envisaged in integrating IPPs into grid such as, demarcation, scheduling, settlement and gaming [10]. But these issues are being addressed by proper technical and regulatory initiatives. In addition to that, the transmission sector has progressed in a very subsequent rate, currently at installed capacity of 325,000 MVA at 765, 400, 220kV voltage levels with 242,400 circuit kilometers (ckt-km) of HVAC and HVDC transmission network, including 765kV transmission system of 3810 ckt-km [8], [11]. On distribution sector, the Ministry of Power has also maneuvered to leverage the digital technology to transform and reshape the power sector in India to make an open and flexible architecture so as to meet the core challenges and burning issues, and get the highest return on investment for the technology [8].

The Electricity Act 2003, created a liberal and competitive environment, facilitating investments by removal of energy barriers, redefining the role of system operation of the national grids. New transmission pricing, loss allocation schemes, introduction of ULDC scheme and Short Term Open Access (STOA) schemes have been introduced based on distance and direction so that power could be traded from any utility to any utility across the nation on a non-discriminatory basis [12]. Currently, Indian transmission grid is operated by a pyramid of 1 NLDC, 5 RLDCs and 31 SLDCs, monitoring round the clock with SCADA system enabled with fish as well as bird eye view, along with advance wideband speech and data communication infrastructure. In addition, other key features like smart energy metering, CIM, Component Interface Specification (CIS), synchrophasor technology, Wide Area Monitoring (WAM) system using phasor measurements, enhanced visualization and self-healing functions are being exclusively employed [11].

III. VISION OF INDIA ON SMART GRID (SG) TECHNOLOGY

Due to the consequence of cutting edge technology, buzzwords like energy conservation and emission reduction, green energy, sustainable development, safety factor, reduction of T&D losses, optimal utilization of assets, have turn out to be the core of discussion. As India is struggling to meet its electricity demands, both in terms of Energy and Peak Load, Smart Grids can help better manage the shortage of power and optimize the power grid status in the country. A “Smart Grid” is a perception of remodeling the scenario of the nation’s electric power grid, by the convergence of information and operational technology applied to electrical grid, allowing sustainable option to the customers and upgraded security, reliability and efficiency to utilities [14]. The elite vision of Smart Grid (SG) Technology allows energy to be generated, transmitted, distributed and utilized more effectively and efficiently.

Demand Side Management (DSM) is an essential practice for optimized and effective use of electricity, particularly in the developing countries like India where the demand is in excess of the available generation. Such kind of non-technical losses can be overcome by electricity grid intelligence [15], which focuses on advanced control and communication protocols integrated with the utility providing a complete package for the requirement of “Smart Grid”.

With the introduction of the Indian Electricity Act 2003, the APDRP was transformed to restructured APDRP (R-APDRP) which has improvised the operation and control [7], [15], and has attempted a seamless integration of generation (including distributed energy resources (DER), transmission and distributed system through usage of intervening information technology (IT) that uses high speed computers and advance communication network, and employing open standard with vendor-neutrality is deemed a cornerstone for embracing the up-and-coming conceptualization of Smart Grid for India scenario.

A vivid study of the power scenario has been illustrated each classified rendering to the timeline in brief. Introducing with the power strategy management in the past, the whole system was monitored and controlled using telephonic medium which was purely a blue-collar job. The system was solely dependent on a single generation unit or the interconnected substations. On further progress in science and technology, the system is monitored round the clock using advance data communication protocols. As well the substation has the islanding facility with immediate power backups to maintain the grid stable.

India as a developing country, the scenario of the power system changes in exponential basis. Moreover the system is expected to be more reliable and flexible with its advancement in data communication and data analysis facility. Fig. 1 illustrates about the advancement and its immediate results during its implementation in future. The conclusive approach for the Indian Smart Grid would be visualized accordingly, with latest technological advancement and extensive features as shown in Fig. 2 [16].

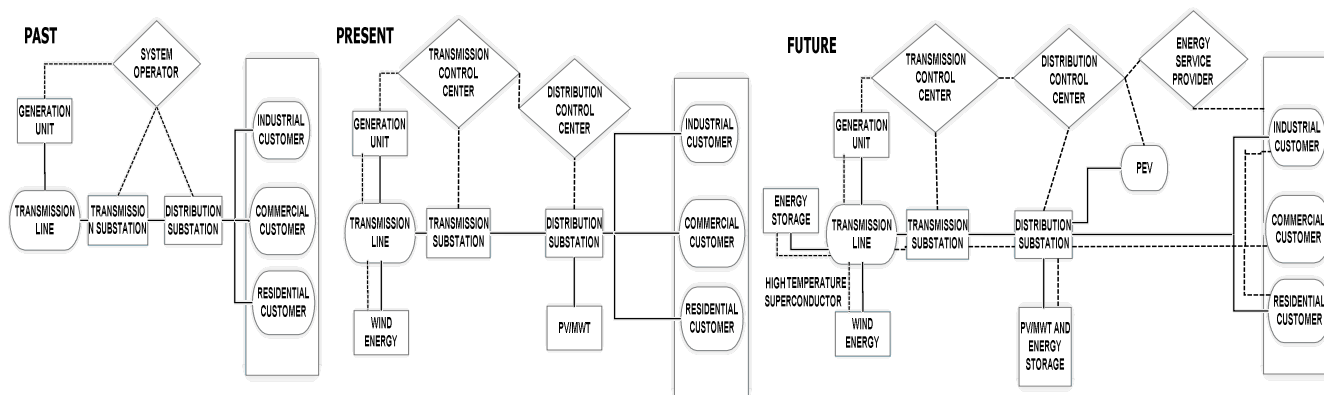


Fig. 1. Smarter electricity systems

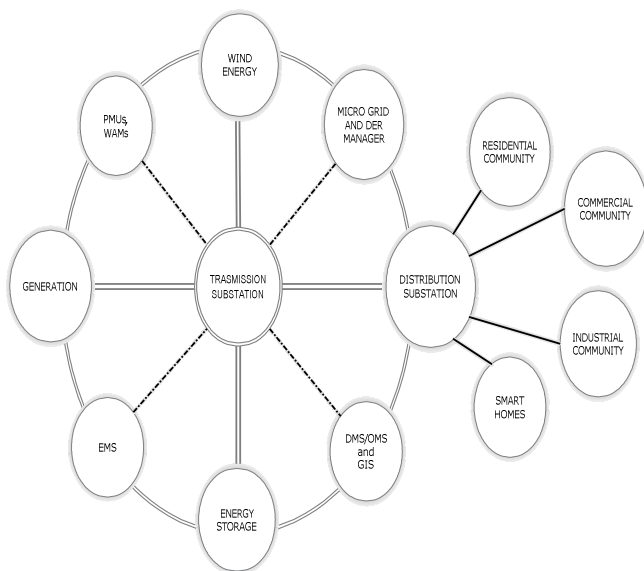


Fig. 2. Hierarchy of Indian Smart Grid

IV. SMART GRID INITIATIVES IN INDIA

As it has been acknowledged earlier that, Smart Grid Technology has a widespread overview of transforming the Indian power grid from technology based standard to performance based standard. The Ministry of Power (MoP) participated in the SMART 2020 event with “The Climate Group” [17] and “The Global e-Sustainability Initiative (GeSI)” in October 2008 which aimed to highlight the reports relevant to key stakeholders in India [7]. Unfortunately, the possible “way forward” has not yet been drilled out and is still a question mark for the Government. But to facilitate demand side management distribution networks has been fully-augmented and upgraded for IT enabling, which has enhanced the grid network with amended customer service.

Table-1 provides a brief analysis of some of the initiative which has been taken under the supervision of many government and private bodies and allies [18-23].

In the view of multitude that could be accrued, it is suggested that there should be ample Government regulatory support and policy initiatives to move towards Smart Grids. India is in its nascent stage of implementing various other controls and monitoring technology, one of such is ADA [24].

Further researches are being carried out in some of the elite institutes in the country in collaboration with some of the various multinational companies and power sectors across the nation.

V. ENHANCED SMART GRID TECHNOLOGY

Due to advent of advance information and communication technology (ICT) and proliferation of green energy, it's liable that Smart Grid technology transforms to more superior and advanced form. Some the newly innovated prospects like renewable energy integration, rural electrification and micro grid are to be featured in it [25].

A. Renewable Energy Integration

Present-day environmental awareness, resulting from coal fired power station, has fortified interest in the development of the modern smart grid technology and its integration with green and sustainable energy. Table-2 provides a brief analysis of the renewable energy development in India which has been planned according to Five year Plans by the Indian Government and the Ministry of New and Renewable Energy (MNRE) [26].

TABLE-2: INSTALLED CAPACITY OF RENEWABLE ENERGY IN INDIA ACCORDING TO FIVE YEAR PLAN

RENEWABLE ENERGY RESOURCES	2007-2012 (in GW)	THROUGH 2012 (in GW)	THROUGH 2022 (in GW)
Wind	10.5	17	40
Hydro	1.4	3.5	6.5
Biomass	2.1	3	7.5
Solar	1	1.5	20
TOTAL	15	25	74

TABLE-1: SMART GRID INITIATIVES IN INDIA BY VARIOUS ORGANIZATIONS

SMART GRID INITIATIVES IN INDIA	REGION/LOCATION OF IMPLEMENTATION	FACILITIES	CONSORTIUMS & JOINT VENTURES
POWER GRID CORPORATION OF INDIA LIMITED (PGCIL)	NORTHERN REGION (NR-I and NR-II)	PMUs with GPS system, PDC at NRLDC, smart load control, on-line condition monitoring, data communication using fibre link	M/s SEL group
	WESTERN REGION (WR-I and WR-II)	Intelligent monitoring and control of the interconnected electric power grid using Wide Area Monitoring (WAM)	TCS, IIT Mumbai, Tata Power Project funded by CSIR under NMITLI
CROMPTON GREAVES LIMITED (CGL)	NA	Integrated SCADA solution, Smart bay control, Smart protection IEDs, Smart Metering solution, Smart load break switches etc.	Govt. of India
NORTH DELHI POWER LIMITED (NDPL)	NORTH AND WEST DELHI	SCADA controlled grid station, automatic meter infrastructure, GSM based street lightning, GIS platform with fault management system	Tata Power, GE SmartGrid Technologies and Govt. of Delhi
	NORTH AND WEST DELHI	Development of SGMM, hi-tech automation control and monitoring, integration of grids, improvise market strategy	IBM, IUN Coalition
BANGALORE ELECTRICITY SUPPLY COMPANY (BESCO)	8 DISTRICTS OF KARNATAKA	T&D Loss reduction, ensuring reliable and quality power with least interruption, quick turnaround, intelligent grid monitoring	KPTCL

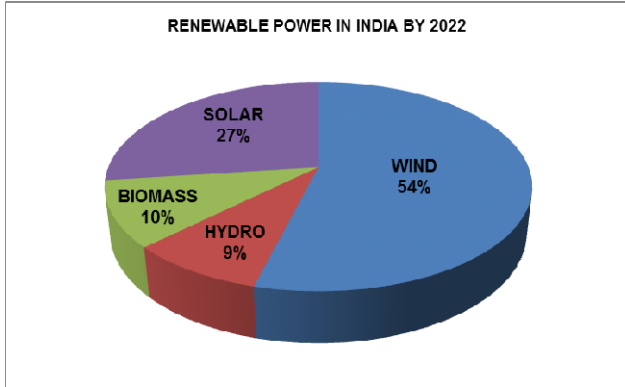


Fig.3. Renewable Power in India by 2022 (by end of Thirteenth Five Year Plan)

With the perception of renewable energy, the energy converges to; reduction in carbon footprints, cleaner environment, plug-in EV, decentralized power which increases the quality of living standard and enhances the power system quality along with the stability of the grid network. But in contrary to that the power quality also bids some of the potential challenges such as; voltage regulation, power system transient and harmonics, reactive power compensation, grid synchronization, energy storage, load management and poor switching action etc., [27]. These problems are mainly visualized for major renewable energy sources like wind and

solar energy. Other energy sources like biomass, hydro and geothermal sources have no such significant problem on integration of grid.

Integration of renewables with the Smart Grids makes the system more reliable and flexible in economic load dispatch, not only in a specified location but in a wide area, even between the nations. Nordic countries have practised such grid integration among its neighbouring nations and still future implementations are being focused on [28]. However, forecasting approaches, design algorithm and other models are being developed by many research analysis teams and are to be established in many regions across the nationwide. Fig. 4 below represents a brief analysis of solicitation of renewables in smart grid technology in its whole network of power system engineering.

The volatility of fossil fuels has opened the ground for new and renewable energy sources. With the inherent unpredictability, the wind and the photo voltaic cell should be supported by upcoming technologies like Micro Grid and ICT [27]. Such emerging technologies will play a major role in sustainable standard of living with economical insolvency. Large scale implementation of the renewables need to have motivating government policies and well established standards. Proper financial support is the governing factor for a generation deficient and developing country like India.

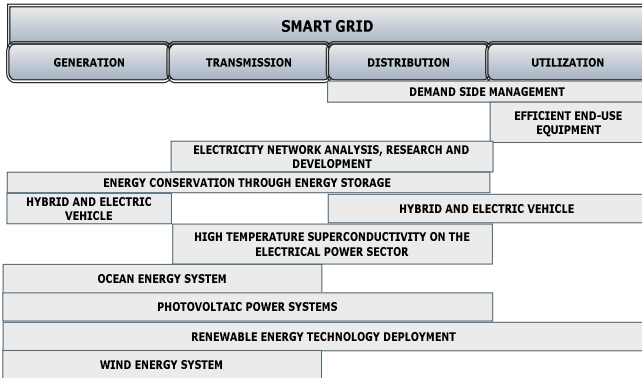


Fig.4. Renewable energy sources in Smart Grid Technology

B. Rural Electrification

Technologies are advancing day-by-day, Smart distribution technologies allowing for increased levels of distributed generation have a high potential to address rural electrification needs and minimize the erection costs, transmission losses and maintenance costs associated with large transmission grids. Rural Electrification Corporation Limited (REC) is a leading public infrastructure finance company in India's power sector which finances and promotes rural electrification projects across the nation, operating through a network of 13 Project offices and 5 Zonal offices. Along with the government of India has launched various programs and schemes for the successful promotion and implementation of rural electrification. One such major scheme is *Rajiv Gandhi Gramen Viduytkaran Yojana (RGGVY)*. Other schemes like, *Pradhan Mantri Garmodaya Yojana (PMGY)*, *Three phase feeders-single phasing and Smart metering*, *Kutir Jyoti Program (KJP)*, *Accelerated Rural Electrification Program (AREP)*, *Rural Electricity Supply Technology Mission (REST)*, *Accelerated Electrification of one hundred villages and 10 million households*, *Remote Village Renewable Energy Programme (RVREP)* and *Grid-connected Village Renewable Programme (GVREP)* [5], [29-30]. Some of them have got a remarkable success but some of them got trapped in for their own interest due to various non-technical issues [31], [32]. Some of the key features of such projects are; to achieve 100% electrification of all villages and habitation in India, provide electricity access to all households, free-of-cost electricity to

BPL households, DG system, smart based metering, promote fund, finance and facilitate alternative approaches in rural electrification, single light solar lightning system for remote villages and its hamlets.

The present rural electrification scenario in the nation is still uncertain, and is yet to be put on more exploration and verified by the Ministry of Power (MoP) and Ministry of New and Renewable Energy (MNRE). Over 500,000 thousand of India's 600,000 thousand villages are deemed to be electrified [33]. As in such case, the Indian Government and Indian businesses sector would need to invest on more such projects and schemes, for low-footprint technologies, renewable sources of energy, smart metering and resource efficient infrastructure.

C. Micro Grid

The renewable resources in absolutely stand-alone mode do not perform reasonable due to reliability issues subjected to asymmetrical behaviour and disturbance in weather conditions. As in such cases, the generators are supported by another generating technology and/or storage devices consist of two or more distributed generation system like; wind-PV, wind-diesel etc., to supply a common load. Such a technology is called Hybrid energy [34]. Hybrid connection of different resources and/or storage devices improves the reliability of the system, as well as is technically and economically sustainable a more ethical approach is to congregate all such technology into Micro Grid. There are some similarities between Smart Grid and Micro Grids or smart Micro Grids. But, the scale, the type of decision makers involved and the impending rate of growth are different for both. Smart Grid are realized at the utility and national grid level, concerning large transmission and distribution lines, while the smart Micro Grid integrates various DG technologies into electricity distribution networks and have faster implementation [25], [34]. Smart Micro Grid are to create perfect power system with smart technology, redundancy, distributed generation and storage, cogeneration or combines heat and power, improve voltage profile, cost reduction, reduction in carbon credits, smart regulation of appliances and load etc.. The Fig. 5 gives an overview of Smart Micro grid architecture with several different AEDGs split DC and AC buses with centralized and de-centralized controlsystem.

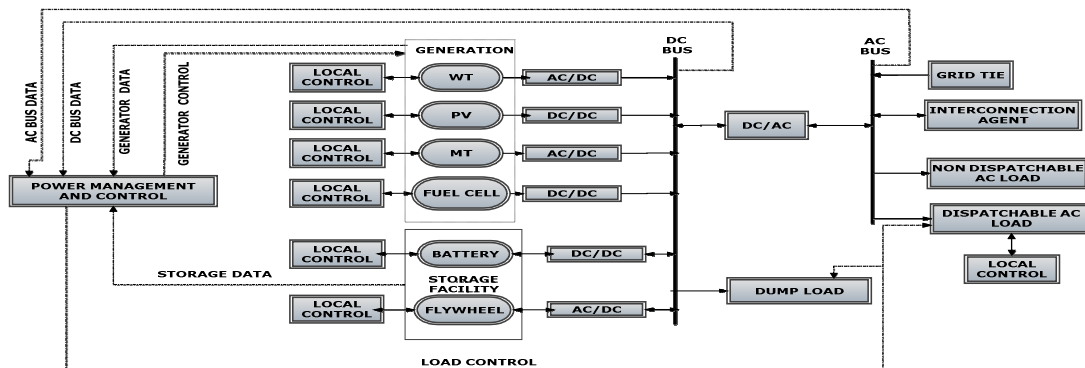


Fig.5. Smart Micro Grid Architecture

CONCLUSIONS

The paper presents a discussion on Indian Power Strategy along with its pitfalls in various technical and non-technical themes, with an organized approach to evolve the conceptualization of Smart Grid. An overview of Indian Power Market along with brief analysis about the power system units is described. Power market in India is generally characterized by the poor demand side management and response for lack of proper infrastructure and awareness. Smart Grid Technology can intuitively overcome these issues. In addition to that, it can acknowledge reduction in line losses to overcome prevailing power shortages, improve the reliability of supply, power quality improvement and its management, safeguarding revenues, preventing theft etc.. Model architecture as well as India's Smart Grid initiatives taken by the government and many private bodies, are presented in the paper. Further, various prospects of sustainable energy and off-grid solutions, Rural Electrification (RE) and evolution of Micro Grid along with various policies and regulatory affairs of India is also presented here. In this connection, the paper should act as advocate to bring forth the significance and fortification of Smart Grid philosophy and implanting it on the basis of proposed ideology in Indian subcontinent.

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