Development of Smart Grid Technology in India: An Overview

Md. Imran[1] Prof. Alka Thakur[2]
[1,2]Department of Electrical Engineering
[1,2]School of Engineering, SSSUTMS, Sehore, India

Abstract— India is lagging behind in meeting the electricity needs of a rapidly growing economy. Power system engineers face more challenges now than ever as a result of the restructuring of the energy industry. The proposed vision is to adopt advanced automation mechanisms to implement a functional Smart Grid (SG) at various levels in the Indian power system. Smart grids are introduced to improve grid operations. Smart grid operations when properly implemented have the potential to create new avenues and opportunities with major economic implications. This article discusses several smart grid initiatives and their implications in the context of India's evolving electricity market. Some existing Indian automation frameworks are used as examples to support some of the ideas of this study. Furthermore, it examines the development and study of smart grid technology since its inception. The development of smart grid technology for future needs from an Indian perspective is being done with an effort to highlight current and future challenges.

Keywords: Smart Grid; Availability Based Tariff (ABT); Demand Side Management (DSM); Renewable Energy; Rural Electrification (RE); Micro Grid

I. INTRODUCTION

The stability and excellence of a country's electric power supply are crucial for economic development, especially in developing nations like India. The Indian economy is projected to expand by 8 to 9% in the 2010–2011 fiscal year and is expected to approach double-digit growth (10%+) in the following years [1]. However, India has a severe electricity constraint that is only going to get worse over the next few decades. The power industry in India is characterized by low generation and large distribution losses. Additionally, deplorable geological and environmental elements have promoted carbon footprints since the country's CO2 emissions started at a low level and the greenhouse effect and negative effects of globalization began to take hold [2]. This could lead to power system instability and issues like brownouts and blackouts.

One such emerging technology, Smart Grid (SG), is crucial in attaining important technical benefits including reducing power loss, improving supply quality, reducing peak demand, and economically dispatching loads, among others. Many industrialized and emerging nations have made research and development into smart grid technologies a key priority. This technology also plays a vital part in changing the worldwide market's energy landscape. The marketing strategy for the Smart Grid technology is standardized by elements such as laws, rules, market effectiveness, costs, benefits, and services. Additional considerations include secure communication, standardized protocol, sophisticated database administration, and effective architecture with ethical data exchange [3]. Such technology may influence other technologies, such as flexible AC transmission (FACTS) Using Wide Area Monitoring (WAM) to bring together the needs of rural, suburban, and urban regions worldwide under one roof and redefine the power system engineering competence [4]. Additionally, the technology employs the lowering of greenhouse gas emissions and the reduction of carbon footprints. This paper describes the Smart Grid initiatives and different illustrations of Indian automation mechanisms that are already in place. It also examines the advancement of Smart Grid technology in research and development, driven by several governmental and private sector organizations with the backing of eminent institutions across the world. It has also been discussed how to shed light on the current and upcoming problems connected with the development of Smart Grid technology for future demands.

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 debriefs about the prevailing units and its future enactments. Section V reveals some of the required focus areas and the advent of enhanced smart grid technologies. Section VI is dedicated to a general conclusion followed by references.

II. OVERVIEW OF INDIA POWER MARKET AND ITS STRATEGY

Amendments to the Indian Electricity Act of 1948 and the Indian Electricity Act of 1910 resulted in the Electricity Act of 2003 allowing the government and many non-governmental organizations to participate and compete in electricity. The law of energy markets in urban suburbs and villages across the country. The law provides a mechanism for public access to rural electricity supplies to the national plan (RE) supplies [3]. In addition to these methods, a concept called Availability-Based Tariff (ABT) has also been developed as an effective advanced system and frequency-sensitive charging for schedule deviations for effective real-time comparison and network training. Exclusive terms such as fixed variable cost and the ABT trading mechanism (UI) in ABT balance the trade where the real-time price of electricity is determined by the availability and ability to supply GW during the day programmed around the generation and generation of power. with the frequency system [5-7]. The installed capacity of the Indian power system is about 164 GW and meets the peak demand of 103 GW. According to the current five-year plan (2007-2012) the installed capacity is estimated to be over 220 GW by 2012 and the peak demand is expected to be around 157 GW and should reach around 800 GW in the next two decades [8-9]. However, some complications should be expected for the integration of IPP in the network such as limitation of programming solutions and games [10]. But these issues are being addressed with the right technological and regulatory initiatives. In addition, the transmission sector has grown at a rapid pace with 765400 circuit kilometers (ckt-km) of HVAC and HVDC transmission networks with an installed capacity

of 325000 MVA at 220 kV voltage levels including transmission 765. kV 3810 ckt-km [8], [11]. The Ministry of Power Distribution has been mandated to drive digital technology and transform energy in India and face critical challenges to meet critical challenges and achieve maximum return on investment. Technology [8].

The Electricity Act of 2003 created a free and competitive environment that encourages investment by removing energy barriers and redefining the role of national grid system operations. Introduction of new transmission price loss sharing schemes ULDC and Short-Term Open Access (STOA) schemes were based on distance and direction thus allowing power to be exchanged indiscriminately from any utility in the country to any consumption. I can do it. .[12]. Currently, India's transmission network is operated by 1 NLDC 5 RLDC, and 31 SLDC pyramids that monitor fish and bird sightings around the clock and have broadband voice and data communication infrastructure. In addition, the CIM Intelligent Energy Component Interface Specification (CIS) Wide Area Monitoring (WAM) synchro phasor technology system uses phasor measurements with enhanced visualization and other important features exclusively used such as self-healing capabilities [11].

III. Vision of India on Smart Grid (SG) Technology

Before Buzzwords like energy conservation and emission reduction, green energy, sustainable development, safety factor, reduction of T&D losses, and optimal asset utilization have become the main topic of discussion as a result of cutting-edge technology. India is having trouble keeping up with its peak load and energy demands for electricity, thus smart grids can help manage the country's power shortage and improve the condition of its power grid. A "Smart Grid" is a perception of changing the national electric power grid's situation by the application of information and operational technology to the electrical grid, providing customers with sustainable options and improving security, dependability, and efficiency for utilities [14].

Demand Side Management (DSM) is an essential technique for optimal and efficient use of electricity, especially in developing countries of India where demand for available generation is increasing. Such shortcomings can be overcome by non-technical power grid intelligence [15] integrated into the development of energy and communication protocols with the advantage of providing a complete package for smart grid needs.

In the 2003 Indian Electricity Act, the APDRP was renamed the Restructured APDRP (R-APDRP) improving operations and controls [7] [15] and attempting to seamlessly integrate generation (including distributed power resources). Information Technology (IT) is considered the basis for the adoption of new smart grid concepts in the Indian context by intervening in transmission and distribution systems using high-speed computers and advanced communication networks and open standards with vendor neutrality.

A clear study of the power scene is shown in a short timeline in each series of renderings. In the past, the entire system was monitored and controlled by telephone with power strategy management being purely a blue-collar job. This system relies only on single-generation units or interconnected substations. The system is monitored 24 hours a day using advanced data communication protocols based on further advancements in science and technology. In addition, the substation has an islanding facility with immediate power backup to maintain grid stability. India as a developing country has a rapidly changing power system landscape. Moreover, the system is expected to become more reliable and flexible with advancements in data communication and data analysis facilities. Figure 1 shows the immediate progress and results during future implementation. The ultimate vision of India's Smart Grid will be envisioned with state-of-the-art technological developments and enhanced features as shown in Figure 2 [16].

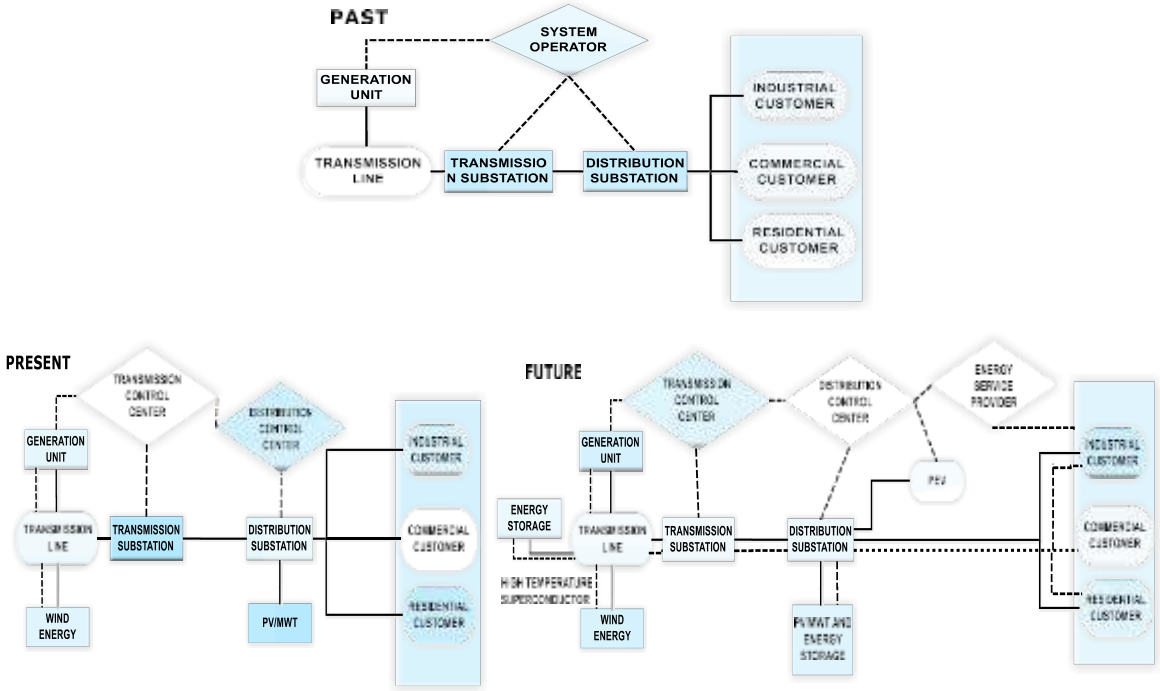

Fig.1. Smarter electricity systems

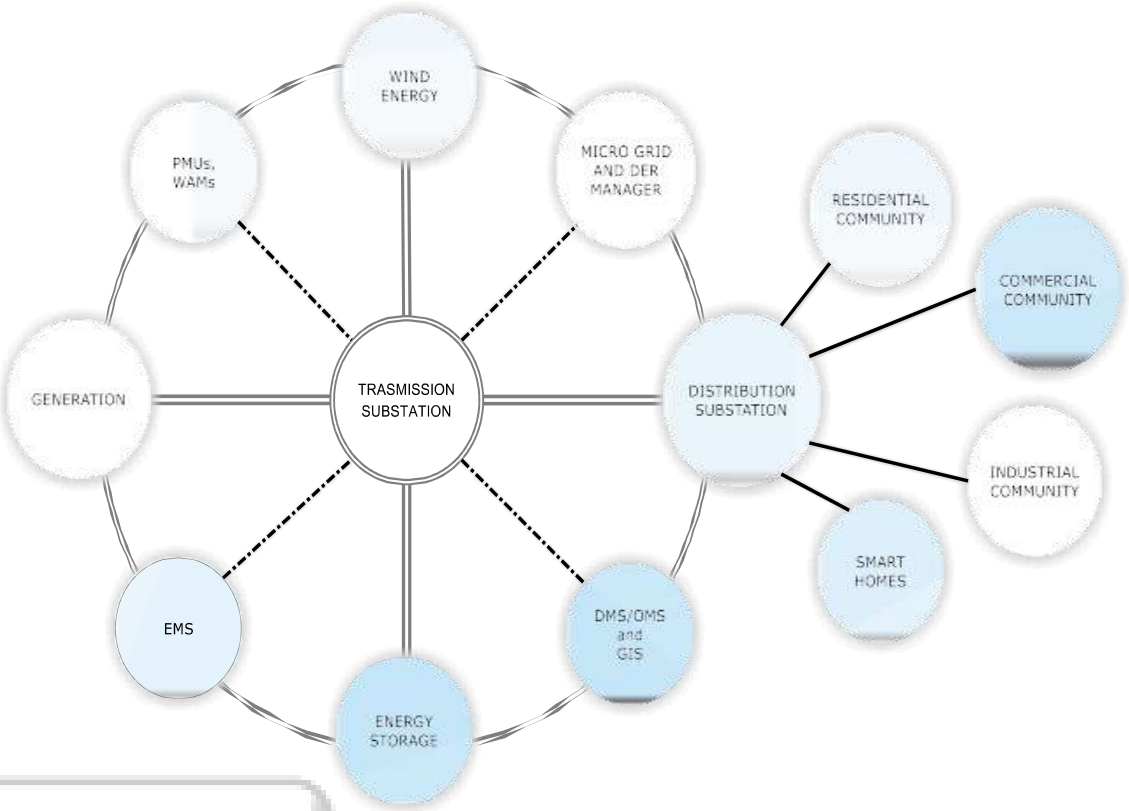

Fig.2. Hierarchy of Indian Smart Grid

IV. SMART GRID INITIATIVE IN INDIA

As mentioned earlier smart grid technology has a comprehensive vision to transform the Indian grid from a technology-based to a performance-based standard. In October 2008 the Ministry of Power (MoP) joined the Climate Group [17] and the Global e-Sustainability Initiative (GeSI) in SMART 2020 [7] to publish relevant reports to key stakeholders in India. Unfortunately, a possible way forward has not been worked out and remains a question mark for the government. Although the distribution network has been thoroughly expanded to facilitate demand management and IT support has been upgraded the grid network has been improved and customer service has changed.

Table 1 presents a brief analysis of several initiatives carried out under the auspices of several public and private organizations and collaborators [18-23]. Support government regulatory and policy initiatives to move towards a smart grid. India is on the cusp of achieving much more Control and monitoring technology one of which is ADA [24]. Further research is being carried out in several elite national institutes in collaboration with several multinational corporations and the country's energy sector.

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 fiber 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 key 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

Table I: Smart Grid Initiative in India by Various Organizations

V. ENHANCED SMART GRID TECHNOLOGY

Due to the advent of advanced information and communication technology (ICT) and the proliferation of green energy, it is possible to develop more sophisticated and advanced smart processing technologies. Some new approaches such as rural electrification and integration of renewable energy into micro-grids have been presented [25].

A. Renewable Energy Integration

Current environmental awareness has led to increased interest in the development of modern smart grid technology and the integration of coal-fired power plants with green and sustainable energy. Table 2 provides a brief analysis of the development of renewable energy in India according to the five-year plans of the Government of India and the Ministry of New and Renewable Energy (MNRE).

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 II: Installed Capacity of Renewable Energy in India According To Five Year Plan

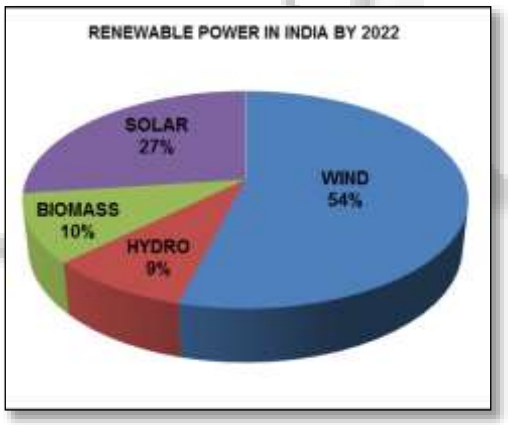

Fig. 3: Renewable Power in India by 2022 (by end of the Thirteenth Five-Year Plan)

Energy changes with the concept of renewable energy. Carbon Footprint Reduction Clean Environment Plug-in Electric Vehicles Distributed Electric Power Systems Improving Quality of Life Improving Quality and Grid Reliability Power Quality Conversely power quality includes voltage regulation power systems transient and harmonics reactive power compensation grid synchronization energy storage load management and failover measures etc. It also brings some potential problems like [27]. These questions focus on large-scale renewable energy sources such as wind and solar power. Other energy sources such as biomass hydropower and geothermal pose no significant grid integration challenges. Integrating renewable energy into the smart grid makes the system more reliable and flexible in delivering economic loads not only to specific locations but to wider geographies. Even between countries. Nordic countries have already implemented such grid integration in neighboring countries and are focusing on future implementations [28]. However, many research and analysis groups are developing estimation methods designing algorithms and other models, and implementing them in many parts of the country. Figure 4 below provides a brief analysis of power system engineering for the adoption of renewable energy in network-wide smart grid technologies. Because wind and solar cells are inherently unpredictable, they must be supported by future technologies such as microgrids and ICT [27]. These emerging technologies play an important role in sustaining living standards amid economic downturns. Implementing renewable energy on a large scale requires promoting government policies and good standards. Adequate financial support for a developing country that is generationally behind such as India is a matter for the government.

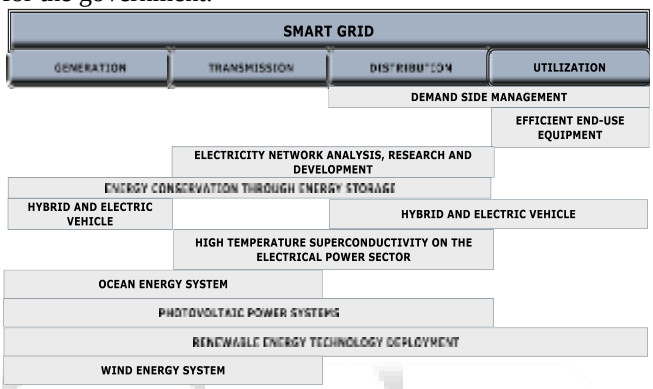

Fig. 4: Renewable energy sources in Smart Grid Technology

B. Rural Electrification

Technologies are developing day by day. Smart distribution technologies that enable greater levels of distributed generation have saturation and minimize construction costs transmission losses and maintenance costs associated with large transmission grids. Rural transmission network. 20 A leading public infrastructure finance company in India's energy sector finances and promotes rural electrification through a network of 13 project offices and 5 area offices. Rajiv Gandhi Gramin Vidyutkar a Yojana (RGGVY) has launched 20 such major programs to promote and implement rural electrification with the Government of India. Other schemes like Pradhan Mantri Garmodaya Yojana (PMGY) three-phase power supplies-single phase meters it 20 Jyoti Program (KJP) Accelerated Rural Electrification Program (AREP) Rural Electrification Technology Mission (REST) Accelerated the transformation of 20 villages and 10 million homes. villages are eligible for the renewable energy program (RVREP) and villages connected to the renewable grid P20 [P20] [29-30]. have achieved significant success but some of them have encountered non-technical problems [31] [32]. The main features of such projects are to reach 100 villages and the population in India. Providing electricity access to all households and BPL households through DDG smart electricity metering system facilitates fund funding and facilitates alternative approaches Light 20 Lightning System for remote villages and its villages. Table 3 provides a detailed analysis of the various rural electrifications of 20 governments in India. The current rural electrification scenario is uncertain and has been approved by the Ministry of Energy (MOP) and the Ministry of New and Renewable

Energies (MNRE). 600000 villages are considered electrified [33]. Therefore, the Indian ds 20 sector is introducing more such projects and schemes for smart metering of low-tech renewable energy sources and resource-efficient infrastructure.

C. Micro Grid

Renewable energy does not work well in a completely stand-alone mode due to reliability issues such as erratic behavior and turbulence in weather conditions. In this case the generator is supported by another generation technology or the storage facility consists of two or more distributed generation systems eg wind-solar wind-diesel supplying a mixed load. This technology is called hybrid energy [34]. Hybrid connectivity of different resources and/or storage devices increases system reliability and is technically and economically sustainable and combining all these technologies in a single microgrid is the most ethical approach. There are many similarities between smart grids and microgrids or smart microgrids. But the size and type of decision makers involved and the expected growth rates of both are all different. Smart grids are implemented at the utility and national grid level and consist of large-scale transmission and distribution lines while smart microgrids integrate various DG technologies into the distribution network and are characterized by rapid implementation [2534]. Smart microgrid aims to create an ideal power system using smart technologies. . . 5. describes a smart microgrid structure with multiple AC and DC buses of AEDG devices with centralized and decentralized control systems [35].

RURAL ELECTRIFICATION SCHEMES	YEAR OF IMPLEMENTATION	OBJECTIVES OF THE SCHEME	GOVERNING BODY
Rajiv Gandhi Grameen Vidyutikaran Yojana (RGGVY)	2005	To achive 100% electrification of all villages and habitation in India to provide electricity access to all households, to provide free-of-cost electricity connection to BPL households	Rural Electrification Coorporation (REC)
Three phase feeder-single phasing and Smart card metering	NA	reliable service that meets the needs of agriculture, household supply, irrigation facility etc	Govt. of India
Pradhan Mantri Gramodaya Yojna (PMGY)	2000-2001	NA	Rural Electrification Corporation (REC) and State Electricity Board
Kutir Jyoti Program (KJP)	1988-89	provide single point light connection, provide electricity access under-developed villages	Govt. of India, later merged with RGGVY under REC
Minimum Needs Program (MNP)	NA	targeted states with less than 65% RE and provide 100% loan for last mile connectivity	Govt. of India, later merged with RGGVY under REC
Accelerated Rural Electrification Program (AREP)	2003-2004	electrification of non-electrified villages/electrification of hamlets/dalit bastis/ tribal villages and electrification of households in the villages through conventional and non-conventional source of energy	State utilities, Govt. of India, later merged with RGGVY under REC
Rural Electricity Supply Technology Mission (REST)	2002	identify and adopt technological solutions, promote fund, finance and facilitate alternative approach to RE, coordinates with various ministries, apex institutions and research organizations to facilitate meeting national objectives, etc.	Govt. of India, later merged with RGGVY under REC
Grid-connected Village Renewable Energy Programme (GVREP)	2007-2012	development of solar thermal system and biogas plant	Planning Commision of India, Govt. of India
Accelerated Electrification of one hundred villages and 10 million households	2004-2005	merging interest subsidy scheme AREP and KJP, 40% capital subsidy was provided for RE projects and balance amount as a soft term loan through REC	Govt. of India, later merged with RGGVY under REC
Remote Village Renewable Energy Programme (RVREP)	2007-2012	decentralized renewable electricity system, remote village solar lightning programme (RVSLP)	Planning Commision of India, Govt. of India

Table III: Rural Electrification Schemes Initiated By the Government of India

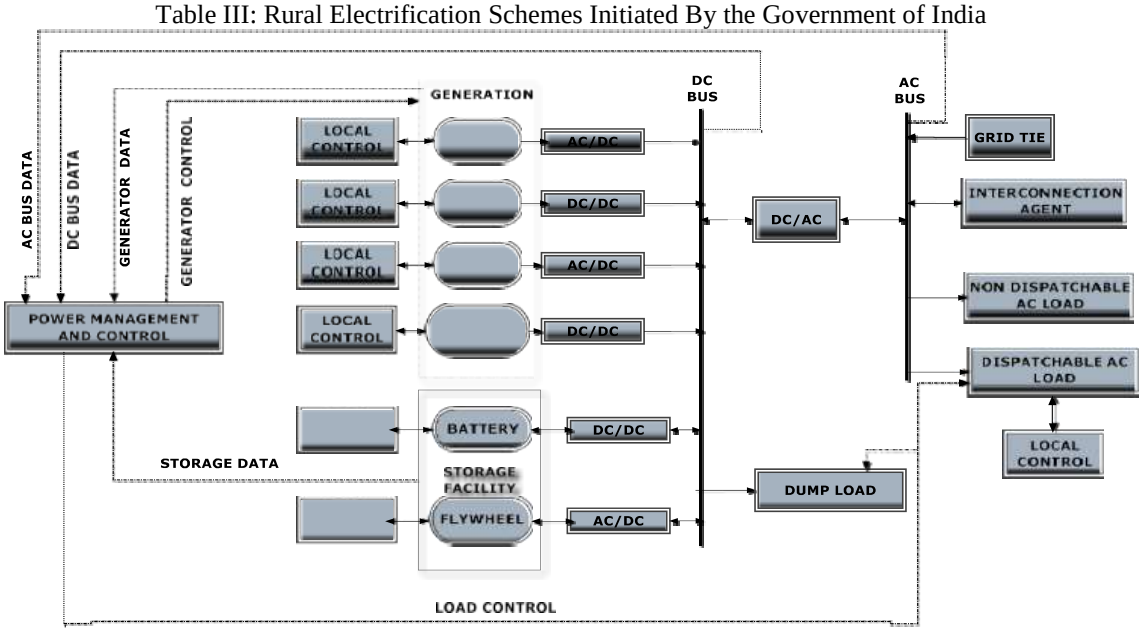

Fig. 5: Smart Micro Grid Architecture

MICRO GRID PROJECTS	JOINT VENTURES	TECHNOLOGY USED/ OBJECTIVES	INSTALLED CAPACITY	REMARKS
Sagar Island Micro Grid Sundarban Region	Funded by MNRE, Govt. of India, Indo-Canadian Environment Facility (ICEF) and West Bengal Renewable Energy Development Agency (WBREDA)	Solar Power Plant	300kW	Serving more than 1500 consumers
		Solar Home Lightning	3200kW approx.	6000 nos. serving about 10,000 people
		Bio-mass Gasifier	1000kW	Serving around 1000 consumer
		Wind Farm	1000kW	Grid connected
Asia Pacific Partnership (APP) Programmes or Asia-Pacific Partnership Development on Clean Development and Climate	Leadership of US alongwith 6 nation (Japan, Australia, Korea, China, India and Canada)	Formation of Renewable Energy and Distributed Generation Task Force (REDGTF) to conduct preliminary and feasibility studies of development of SE	NA	Facilitate cost-effective, cheaper, cleaner, more efficient technologies and practices, pollution reduction, energy security etc

Table IV: Micro Grid Project

VI. Conclusions

This paper presents a strategic approach to India's energy strategy along with various technical and non-technical themes to develop the concept of a smart grid. An overview of the Indian power market is provided along with a brief analysis of power system units. The Indian electricity market generally responds to poor demand management and a lack of adequate infrastructure and awareness. Smart grid technology can intuitively overcome these problems. In addition, reducing line losses can help overcome overall power shortages improve supply reliability improve power quality control and protect revenue prevent theft, etc. It is published in government newspapers and many private institutions. Out of this variety of sustainable energy and off-grid solutions, rural electrification (RE) microgrid development and various policy and regulatory issues in India are also covered here. In this context, this article should serve as an advocate to bring out the importance and power of the Smart Grid philosophy and integrate it into the proposed conceptual framework in the Indian subcontinent.

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