Deployment of Smart Grid in India: Challenges, Prospects and Current Status

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Abstract - **Smart grid encompasses the enormous advantages brought in by the application of communication technologies and data processing into the traditional electricity grid in order to make it more efficient, effective, reliable and consumer oriented. India is a vast country with one of the largest synchronously operating electricity grid in the world. Adopting a smart grid infrastructure for such a gigantic network is not an easy task. This paper presents a detailed investigative study on adoption of smart grid in Indian scenario, the accomplishments made so far and also the challenges lying ahead.**

keywords - **Smart Grid, Indian Power Sector, Smart Grid Challenges, Power System, Solar, Renewable**

I. INTRODUCTION

Successful implementation of smart grid has the capability of providing the traditional power system the much needed facelift. With the twin advantages of internet facility and communication technology, a smart grid is capable of solving a number of recurrent issues faced by power industry in a more efficient manner; e.g. reducing AT&C losses, controlling the power theft, balancing the supply and demand, providing IT based improved energy auditing system, increasing overall generation capacity by widespread allowance of distributed generation with renewable sources, improving consumer behavior etc. to name a few. The emergence of "smart" devices backed by intelligent communication and information technologies are playing a vital role in making smart grid a reality. Today there is two-way communication possible between the control centre and the consumer with advent of Advanced Metering Infrastructure(AMI). Employment of Wide Area Management(WAM), Phasor Measurement Unit(PMU), Remote Terminal Unit(RTU) etc. are making the grid more responsive towards emergency situations and self-healing in nature. Smart grid takes into account the contribution made by each and every stakeholder associated with it; directly or indirectly e.g. utility, policy maker, researchers, consumer, technology provider etc. With increased decentralization of the traditional power system and deregulation of the power market, the customers are able to play a more active role. Increased penetration of DERs like rooftop solar, wind turbine, fuel cell etc. leads to power generation right where it is being used. Through practices like net metering, customers can earn revenue by selling the excess power they produce through DERs to the grid. In India, roof-top solar systems are gradually gaining popularity among the masses as it gives the customer a chance to play the role of energy producer.

But in addition to the benefits, smart grid implementation has got its own share of challenges and obstacles too. These challenges can mainly be categorized as technical and socio-economic. Under technical challenges, the adoption and adaptation of fast evolving technical advancements and implementation of some common standards is a major concern. The other technical challenges include storage concerns, cyber security, communication infrastructure and data handling. In countries like ours, improving the grid infrastructure to match the needs of a smart grid needs a lot of investment in terms of money; hence it brings in the economic constraints too. The successful implementation of any technology depends not only in the technology itself but also in the socio-economic conditions of the country. Lack of investors or lack of general awareness among people may lead to failure of smart grid initiatives.

In India, efforts are also being made by the government for nationwide implement of the smart grid projects. The Indian national grid has an installed capacity of 399.467 GW as on 31st March 2022. Nehru National Solar Mission, India Smart Grid Forum (NSGF), National Smart Grid Mission (NSGM) are some of the initiatives taken to gradually equip the national grid with smart infrastructure. Under NSGM, smart grid pilot projects are being implemented in different states. In this paper, an investigative analysis is being done about the current status of smart grid implementation in India and underlying challenges.

II. INDIAN ELECTRICITY GRID: THE HISTORICAL PERSPECTIVE

During the colonial period, the power generation, transmission and distribution were at a very infant stage. The concept of long distance power transmission was not there. Back then, India was not politically united but was a fragmentation of numerous princely states and British ruled provinces. The colonial rulers prioritized on electrifying major cities, administrative centers and ports. The first demonstration of light bulbs took place on the streets of Kolkata on 24th July 1879 by P.W. Fleury & Co. The first installation of Electric street light was in Harrison Road Kolkata by Kilburn and Co. In 1897, the company got renamed as Calcutta Electric Supply Corporation with it's headquarter still in London. In 1970, the control of the company was transferred from London to Calcutta in 1970.

One of the mentionable events during this period was the framing of The Electricity Act of India in 1910. During this time power generation and distribution was largely in the hands of private companies. The act of 1910 allowed the private companies to generate and distribute power to the public. The range of consumers was limited to mostly industries, banks, government offices, clubs, public utilities etc. It had not yet reached the common masses. Some of the important milestones in this regard are mentioned below:

i) The first ever hydroelectric power station was commissioned in 1896 in Sidrabong, Darjeeling with a capacity of 130KW

ii) The first hydroelectric power station installed by government in Kateri, Nilgiris was commissioned in 1902

iii) The first thermal power station of India was the Emambagh Power Station commissioned by Calcutta Electric Supply Co. in 1899

iv) The Sivasamudram Power Station over the Kaveri river with a capacity of 42MW was commissioned in 1902 by the Mysore government.

v) The TATA hydro-electric power supply company commissioned the Khopoli hydro-electric station in Maharashtra in 1915 with an installed capacity of 40MW.

vi) Pykara power station was commissioned with an installed capacity of 70MW in 1933 in Nilgiri district, Tamil Nadu which harnessed the hydro potentials of Pykara, Mukurthi and Sandynallah rivers.

vii) The first electric train of India ran between Bombay and Kurla on 3rd Feb,1925

Post independence and partition, the newly formed Government of India made sincere attempts to increase the generation capacity and make electricity accessible to the general public. One landmark event during this period was the passage of the Electricity Supply Act, 1948. This act led to the formation of the State Electricity Boards(SEBs) which were autonomous bodies responsible for stepping up the generation, transmission and distribution facilities in the respective states. But these SEBs were unable to match their generation capacity against the increasing demand. Hence, generation capacities were put up in central level under the Central Electricity Authority(CEA). The amendment of Electricity Supply Act in 1976 led to formation of central thermal, hydro and nuclear power generation facilities viz. NTPC, NHPC, and NPCIL.

The National Power Transmission Corporation(NPTC) was established in 1989 to facilitate the inter-regional power transmission facilities which is presently well-known as the Power Grid Corporation of India.

With the improved transmission facilities India started inter-regional grid managements from 1960s. The individual state electricity grids which were earlier isolated from each other were now connected and turned into five regional grids viz. northern, north-eastern, central, eastern and southern grids. These regional grids facilitated the transmission of surplus power from one state to another neighboring state within that region. Gradually attempts were made to establish interconnection of various regional grids through asynchronous HVDC links which were later upgraded to synchronous links with high power transmission capacity. The first interconnection between the regional grids took place in 1991 between the eastern and north-eastern grid. The other regional grids were also subsequently interconnected. India achieved the goal "one nation one grid" with the interconnection of southern grid to the central grid after the commissioning of 765KV Raichur-Solapur transmission line on 31st Dec, 2013.

III. STEPS TOWARD A SMART INDIAN GRID : VARIOUS GOVERNMENT INITIATIVES

The developed countries like UK, US have already gone a long way in making smart grid a reality. Successful implementation of smart grid involves multidimensional efforts starting from changes in policy making upto implementation at the grassroots. The problem with the Indian power sector is that it is not a planned one. Implementation of smart grid standards to such a complex system is not an easy task. Till the last century the government invested a large sum of money in installing centralized bulk power plant to meet the growing power demands of the country. But it was still not enough to meet the supply-demand gap. Since the last few years, the focus has been shifted from centralized to decentralized power generation. The government is working on various fronts to achieve the goal of smart grid implementation in the country. Some of such initiatives are enlisted below:

i) Jawaharlal Nehru National Solar Grid Mission:

It was a flagship program of Government of India with an endeavor to put India in a prominent position in the world map in terms of production of solar energy and address the country's need of energy security along with mitigating the effects of climate change. The program was inaugurated in January 2013 under the brand name "sol by then Prime Minister Dr. Manmohan Singh and was one of the several policies included in the National Action Plan on Climate Change. It had an initial target to generate 20GW solar power by the year 2022; a target already surpassed in the year 2018. The plan was later re-named as National Solar Mission and its target was revised in the 2015 Union budget to 100GW of grid connected solar photo-voltaic by the year 2022. Such a huge task can only be achieved through proper policy making, large scale deployment of projects at various sites, technological advancement etc. The solar power generation capacity (grid connected) of India has increased from a mere 2.6GW in March 2014 to 28GW in March 2021. Currently India is in 5th position in the world in terms of power generation. According to the data provided by the Ministry of New and Renewable Energy, India has currently touched 40.1GW in terms of grid connected solar power out of its target to generate 100GW by the year 2022.

ii) India Smart Grid Forum (ISGF):

India Smart Grid Forum was started by the Ministry of Power, Government of India in a Public private Partnership(PPP) mode as a policy think tank to advise it in terms of effective policy in the field of smart grid implementation. It comprises of members from varied spectrum of the society including the ministry people, technological experts, researchers, teachers, utilities, industry experts etc. The ISGF advised the government for measures to be taken for promotion of smart

grids in the country keeping up with international technology standards along with helping in capacity building and providing training. ISGF comprises of eight working groups(WG) viz Grid Modernization & Smart Cities(WG1); IoT, Smart Metering, AI & Analytics(WG2); Digital Architecture and Cyber Security(WG3); Policy, Regulations and Business Models(WG4); Renewables & Microgrids(WG5); Flexibility & Electric Mobility(WG6); Smart Gas(WG7);Smart Water(WG8).

iii) National Smart Grid Mission (NSGM)

National Smart Grid Mission was established by the Government of India under Ministry of Power in the year 2015. This mission is tasked with planning, implementing and monitoring activities related to smart grid implementation in the country. It has a three-tier organizational structure with a Governing Council with the Minister of Power as the Chairman at the top level.

Under NSGM, smart grid pilot projects are being implemented in 11 locations in the country. These projects are sanctioned by the Ministry of Power. The locations are listed below:

Table 1 Table Type Styles

Sl. no.	Location	State/UT	Implementing Agency
1	Kala Amb	Himachal Pradesh	HPSEB
2	Manesar	Punjab	Powergrid
3	IIT Kanpur	Uttar Pradesh	IITK
4	Siliguri	West Bengal	WBSEDCL
5	Panipat	Haryana	UHBVN
6	Agartala	Tripura	TSECL
7	Assam	Guwahati	APDCL
8	Naroda	Gujarat	UGVCL
9	Mysore	Karnataka	CESC
10	Jeedimetla	Telengana	TSSPDCL
11	Puducherry	Puducherry	PED

Various features and functionalities of smart grid are being implemented in these locations in experimental basis to check its credibility to be employed in large scale. Some of these functionalities are: Advanced Metering Infrastructure, Peak Load Management, Time of Use Models, Net metering, Outage Management, Distributed Energy Integration, Micro Grid etc.

Another aspect related to the NSGM is the deployment of smart digital meters in the entire country. As per the data given in the website of NSGM, around 47 lakh smart meters have been deployed in the entire country out of a target to deploy 66 lakh meters.

IV. CHALLENGES INVOLVED

India has to overcome a lot of challenges involving technical and socioeconomic factors in order to realize a smart grid in true sense of the term.

i) **Technical challenges:**

India took a centralizing approach in developing its power grid with priority being given to bulk power generating and transmission facilities. There was less focus on renewables prior to the last two decades. The Indian grid is still struggling to cover the 100% population of the country with energy supply. Such a grid setup in unplanned manner is not adequate to accept the challenges of design, operation and maintenance of a smart grid. There needs to be a complete overhaul of the existing infrastructure which needs a lot of financial investment.

Another issue in this regard is related to cyber security. As soon as the grid gets connected to cyber network, there will be vulnerabilities which need to be taken care of with proper technical tools. Otherwise the valuable and secret customer information may get exposed to cyber crime.

As distributed energy resources play a major role in smart grid and most of these resources generate DC power hence storage technology also needs to be developed in large scale. Schemes like V2G (Vehicle to grid) becomes useful in this regard.

A smart network generates enormous amount of data every second which act as vital information indicating the health of the system. Data from the metering devices, sensors, remote terminal units needs to be stored and processed efficiently as these information can prevent future emergency situations and also helps in proper planning, forecasting etc.

A smart grid is nothing but a traditional grid along with added arm of communication network. The available range of communication technologies for using in smart grid include GSM, GPRS, PLCC, 3G, ZigBee, Broad band over PLC etc. However none of these technologies are 100% foolproof to be adopted in large scale for smart grid deployment. They variably suffer from disadvantage of limited range, limited bandwidth, high economic cost etc.

ii) Socio-economic Challenges:

The success of any technology in real life depends on the socio-economic constraints of the particular country. The need of high amount of initial investment required to improve the presently inadequate grid structure, the smart grid deployment is getting delayed in India in comparison to the other developed countries. In this regard, it is important to create awareness among the customers, utilities and potential investors about the vast opportunity the smart grid will bring, once implemented. There are many myths among the general public about smart grid which needs to be busted and the economic and environmental benefits need to be highlighted.

One of the common concerns among the consumers is about the breach of privacy. There has to be concrete security protocols and regulations so that the personal data is not exposed to potential cyber threat. Winning consumer trust is important for widespread acceptance of new technologies like smart grid.

There are also issues about adopting new billing schemes like TOD(Time of Day), TOU(Time of Use) etc. Customers fear that under these new schemes, energy will be costlier. Some customers are unwilling to participate in such schemes and happy with a flat rate. A large population of the country is unable to understand the complexities of these conditional billing pattern and they are only concerned about getting the power supply; irrespective of its quality.

IV. CONCLUSION

Upgradation of the existing traditional power grid into a smart grid is itself a mammoth task. It involves fulfillment of numerous criteria, creating latest technical facilities and investment of unaccounted sum of money. We must do it taking into consideration the concerns of all stakeholders involved in the process. It can be hoped that with the latest accelerated efforts from the government's side and increased awareness among the common people it will be realized very soon.

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