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Role of IoT for Smart Grids: A Review of Systems, Technologies and Design Challenges

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Abstract: With the growing demand for electricity, India is struggling to meet the electric power demands of a fast expanding economy. According to the Ministry of Power, India's transmission and distribution losses are amongst the highest in the world, averaging 26 per cent of total electricity production, and as high as 62 per cent in some states. This scenario has propelled the implementation of Smart Grids. Recently, the convergence of emerging embedded computing, information technology, and distributed control became a key enabler for future Smart Grid technologies. Among others, a new generation of systems, known as Internet of Things (IoT), with integrated computational and physical capabilities that can interact with Humans through many new modalities. Now the IoT technology will be widely deployed in future smart energy systems. The purpose of this research paper is to provide a brief overview of smart grids and its role in the development of electricity systems. We define smart grids; highlight the major drivers for deployment, challenges outlining the range of technologies that need to be engaged, and a vision for electricity system development. This work also reviews the progress made in Smart grid technology research and development since its evolution. We also highlight the current and future issues involved for the development of Smart Grid technology for future demands in Indian perspective.

***Keywords** : Electricity, smart grids, IoT, information technology, embedded computing, smart energy systems*

I. The Smart Grid Concept

Smart Grid is an ill-defined term covering various functionalities geared towards modernizing the electricity grid. At its core, a smart grid utilizes digital communications and control systems to monitor and control power flows, with the aim to make the power grid more resilient, efficient and cost effective. The basic objectives of smart grids are to enable informed participation by customers; accommodate all generation (solar, wind etc.) and storage options; enable new products, services, and markets; provide the power quality needed for the range of needs in a 21st century economy; optimize asset utilization and operation efficiently; address disturbances through automated prevention, containment and restoration; and operate resiliently against all hazards. The various components and the interlink ages between them for implementation of a smart grid are shown in Fig 1.

"Smart grid" generally refers to a class of technology that people are using to bring utility electricity delivery systems into the 21st century, using computer-based remote control and automation. These systems are made possible by two-way communication technology and computer processing that has been used for decades in other industries. They are beginning to be used on electricity networks, from the power plants and wind farms all the way to the consumers of electricity in homes and businesses. They offer many benefits to utilities and consumers -- mostly seen in big improvements in energy efficiency on the electricity grid and in the energy users' homes and offices.

The general understanding is that the Smart Grid is the concept of modernizing the electric grid. The Smart Grid comprises everything related to the electric system in between any point of generation and any point of consumption. Through the addition of Smart Grid technologies the grid becomes more flexible, interactive and is able to provide real time feedback.

A smart grid is an electricity network that can intelligently integrate the actions of all users connected to it – generators, consumers and those that do both – in order to efficiently deliver sustainable, economic and secure electricity supplies. A smart grid employs innovative products and services together

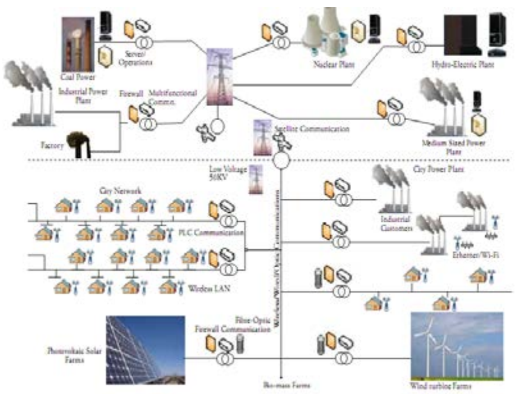

Fig..1. Components of Smart Grid and inter linkages

with intelligent monitoring, control, communication, and self-healing technologies to: facilitate the connection and operation of generators of all sizes and technologies; allow consumers to play a part in optimizing the operation of the system; provide consumers with greater information and choice of supply; significantly reduce the environmental impact of the whole electricity supply system; deliver enhanced levels of reliability and security of supply.

II. The Indian Scenario

The economic growth of an India depends 80% on reliability and availability of its electric power supply. Global energy demands are expected to grow by 60% over the next 25 years subjected to three significant factors; population growth, rate of gross domestic product (GDP) and energy intensification. The future pathways for India's energy demand are presented in Fig. 2 [1].

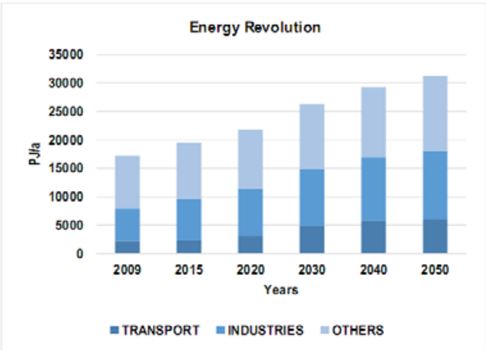

Fig. .2 (a)

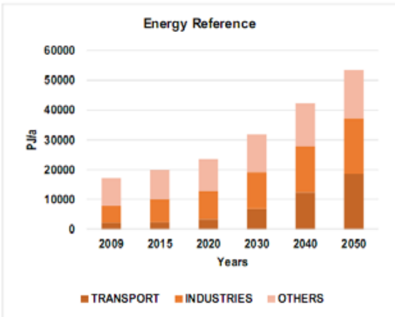

Fig..2 (b)

India losses money for every unit of electricity sold, since India has one of the weakest electric grids in the world. Some of the technical flaws in the Indian power grid are - it is a poorly planned distribution network, there is overloading of the system components, there is lack of reactive power support and regulation services, there is low metering efficiency and bill collection, etc. India is venturing very fast into renewable energy (RE) resources like wind and solar. Solar has great potential in India with its average of 300 solar days per year. The government is also giving incentives for solar power generation in the form of subsidies for various solar applications; and has set a goal that solar should contribute 7 per cent of India's total power production by 2022. With such high targets, solar is going to play a key role in shaping the future of India's power sector.

A problem with renewable resources is that their supply can be intermittent i.e. the supply can only be harnessed during a particular part of the day, like day time for solar energy and windy conditions for harnessing wind energy, also these conditions cannot be controlled. With such unpredictable energy sources feeding the grid, it is necessary to have a grid that is highly adaptive (in terms of supply and demand). Hence, the opportunities for building smart grids in India are immense, as a good electric supply is one of the key infrastructure requirements to support overall development.

Indian Institute of Engineering, Science and Technology (IIEST) is all set to unveil the country's first smart grid project. This project is said to generate power from renewable resources of energy such as solar, wind and vegetable waste, through smart grids. was inaugurated by Manohar Lal Khattar, the CM of Haryana in the presence of Keniko Sone, a minister from Japan, in 2018 at Panipat this project will enhance the possibility of providing power supply to the isolated communities in remote areas. On the other hand, Union Minister of State for Power, Coal and New & Renewable Energy, Piyush Goyal, has released a booklet on 'Rural Electrification Status in India' in a press conference in the

Smart grid efforts in India

Implementing organisation	Details
Bangalore Electricity Supply Company Limited (BESCOM), Bangalore, Karnataka	USD 100 million smart grid pilot project.
North Delhi Power Limited (NDPL), New Delhi	Collaboration with GE for smart grid.
Indian Institute of Technology Kharagpur (IITK) and Indian Institute of Technology Madras (IITM)	Collaboration with IBM for smart grid research.
Management Development Institute (MDI), Gurgaon, Haryana	Smart grid educational programme at the School of Energy Management.

Fig..3. Smart Grid Efforts in India

capital. The booklet Electrification Status in India' in a press conference in the capital. The booklet provides insights on the measures taken by the central government to electrify these villages. Under the Deen Dayal Upadhyaya Gram Jyoti Yojana (DDUGJY), the government had taken up the mission of illuminating villages in India which lived in the dark without electricity.

These underprivileged villages were deprived of the basic standard of living even after more than five decades passed post-independence. Thereon, the

Government of India started working on these villages to provide distributed power supply. In the period from August 2015 till present, 593,467 villages have been electrified out of the total 597,464 census un-electrified ones. The scheme has a total expenditure of Rs 75,893 crore. The scheme is being viewed as a success following the signing between states for "Power for All" programme. The programme is yielding results for expeditious urbanization.

III. The Smart Grid Architecture based on IoT

Internet of Things (IoT) is a connection of people and things at any time, in any place, with anyone and anything, using any network and any service. Thus, IoT is a huge dynamic global network infrastructure of Internet-enabled entities with web services. One of the most important applications of IoT is the Smart Grid (SG). SG is a data communications network which is integrated with the power grid to collect and analyze data that are acquired from transmission lines, distribution substations, and consumers.

The trend is in line to the smart-grid concept, which represents an unprecedented opportunity to move the energy industry into a new era of reliability, availability, and efficiency that will contribute to our economic and environmental health. During the transition period, it is critical to carry out testing, technology improvements, consumer education, development of standards and regulations, and information sharing between projects to ensure that the benefits we envision from the smart-grid become a reality. More specifically, the benefits associated with the smart-grid include (but not limited):

- More efficient transmission of electricity;
- Quicker restoration of electricity after power disturbances;
- Reduced operations and management costs for utilities, and ultimately lower power costs for consumers;
- Reduced peak demand, which will also help lower electricity rates;
- Increased integration of large-scale renewable energy systems;
- Better integration of customer-owner power generation systems, including renew-able energy systems;
- Improved security.

The above objectives make Smart Grid look from an IoT view point as depicted in Fig. 4 below.

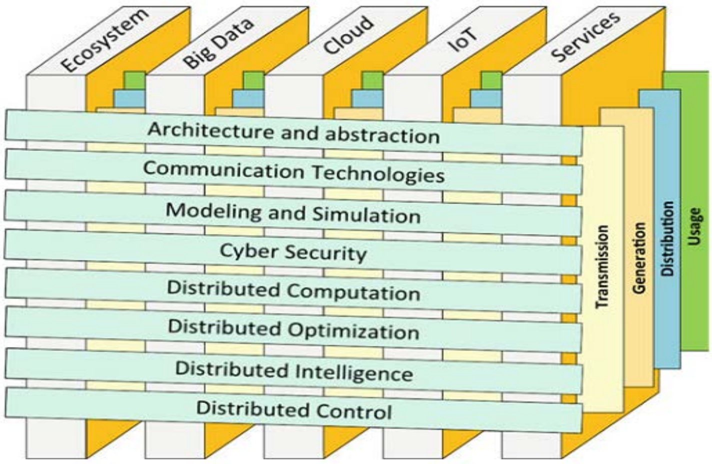

Fig..4 : Smart Grid looks from an IoT view point [5]

To sum up smart-grids, as shown in Fig. 5, are energy networks that can automatically monitor energy flows and adjust to changes in energy supply and demand.

When coupled with smart metering systems, smart-grids reach consumers and suppliers by providing information on real-time consumption (Fig. 6). With smart meters, consumers can adapt in time and volume - their energy usage to different energy prices throughout the day, saving money on their energy bills by consuming more energy in lower price periods (Fig. 7).

IV. Technologies

The main components of a future Smart Grid is presented in Fig. 7. There is a very broad range of smart grids technologies. Some of those are commonly applied in many systems today (e.g., smart meters, SCADA and FACTS) and some are still in development or early deployment stages (e.g., PMU, and V2G technologies). Some of the technologies are specific to electricity systems, some cross over into other energy systems and others still are common information and communication technology (ICT). Transmission systems are typically “smarter” today compared to distribution systems. This is mainly due to the

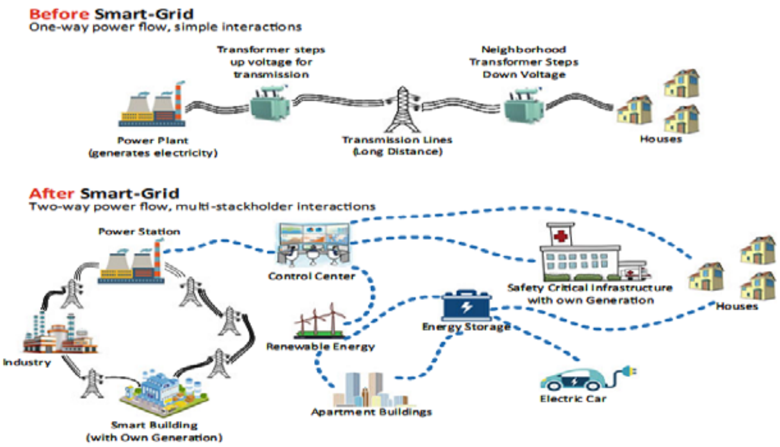

Figure.5 Smart Grid environment [5].

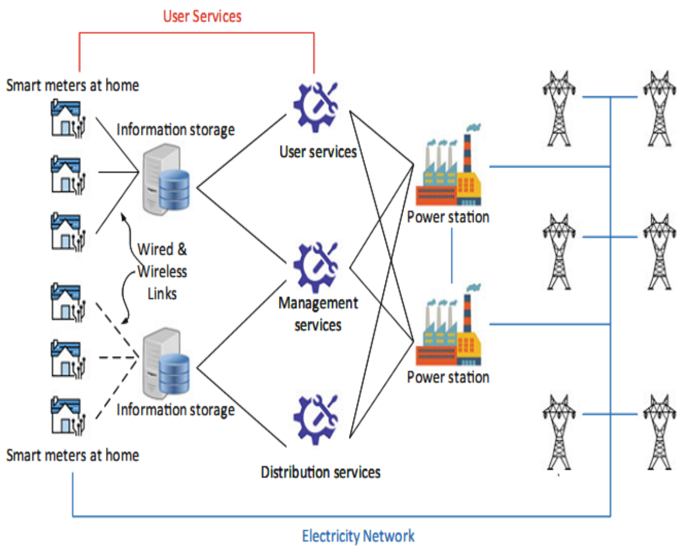

Figure 6. Smart Grid environment- Functional cloud computing service clusters [5].

Typical scale of transmission systems relative to the respective number of nodes that are managed.

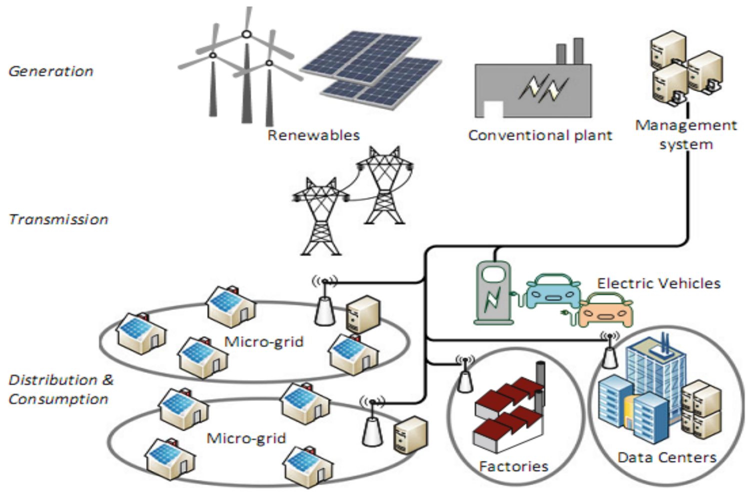

Fig. 7. The main components of future Smart Grid

A. Telecommunication

Telecommunications is the heart of the Smart Grid. All smart grid strategies and visions are founded upon the availability of telecommunications network capability. Whether the smart grid objectives are focused upon local, regional or national objectives the majority of Smart Grid applications will rely upon the availability of a telecommunications network for interconnection of the particular generation source, network sensor or smart meter into the power utilities operational processes. The demands of climate change and the 21st century information based society however now requires the development of a smart grid which is founded upon communications networks that can deliver centralized real time monitoring and control, eventually across the entire power distribution domain.

B. Smart meters

Smart meters are microprocessor based devices that provide a two way communication capability. They help homeowners and the suppliers to manage the respective electricity usage and supply in a more efficient and cost effective manner. With the help of the information provided by such smart meters the power companies will have the capability to set up real time pricing systems for electricity.

C. Virtual power plants

The goal of virtual power plants (VPPs) as depicted in Fig 8 is to allow discrete energy resources (DERs) to access the energy market i.e. to feed the electricity grid constantly and reliably.

D. Micro grids

A micro grid as presented in Fig 9 is a cluster of local DERs and loads in such a way that an operation is possible within the grid or in independent mode. Usually it is connected at the low voltage level but sometimes also at the medium voltage level. All these technologies can be used in India in different forms depending on the applications. Different algorithms can be used for the control of smart grids, VPPs etc.

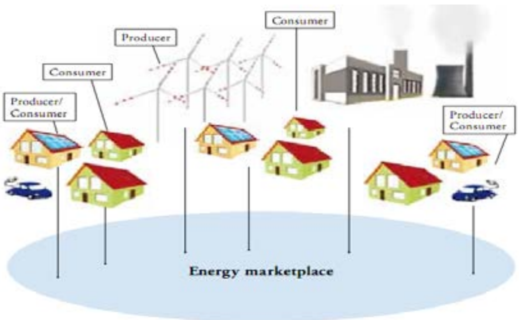

Fig. 8. A virtual power plant.

Fig. 9. A Micro Grid

V. Challenges

To begin with is the absence of Policy and regulation. There are no clearly defined standards and guidelines exist for the regulation of smart grid initiatives in India. Second is the Cost is a major hurdles in implementing smart grids. Some older equipment that cannot be retrofitted to be compatible with smart grid technologies will have to be replaced. Further, Lack of awareness of consumers about how power is delivered to their homes is often low.

With the transition from analogous to digital electricity infrastructure comes the challenge of communication security and data management. Since digital networks are more prone to malicious attacks from software hackers, security becomes a key issue. In addition to this, concerns on invasion of privacy and security of personal consumption data arise. The data collected from the consumption information could provide a significant insight into a consumer's behavior and preferences. Tis valuable information could be abused, if correct protocols and security measures are not adhered to.

CONCLUSION

India is steadily marching towards renewable energy resources like wind and solar. With such unpredictable energy sources feeding the grid, it is necessary to have a grid that is highly adaptive (in terms of supply and demand). A good electric supply is one of the key infrastructure requirements to developing nation. Further, India's energy generation and consumption are on high growth rate. Power market in India is generally characterized by the poor demand side management and response for lack of proper infrastructure and awareness. This emphasizes the immediate implementation of Smart Grid Technology to overcome these issues.

The integrated electricity system of the future can provide electricity in a more efficient manner, demonstrating net savings through better asset utilization of the grid, generation and end-use resources. Smart grid technologies will play a huge role in this, but technology on its own will not be sufficient, rather supportive policy and regulation will be essential. By enabling smart grid technology deployment through flexible policy and regulations the learning process needed to find technically and culturally relevant solutions in countries around the world can be accelerated.

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