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Implementation Opportunities and Challenges for Renewable Energy Resources based Smart Micro Grids in India

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Abstract

The current interest of many cities in India is to become smarter and technically advanced, which would eventually alter the electricity consumption patterns. On the other side, the existed centralized electric grid system may not be a reliable source in meeting such altered patterns. Demand-based supply would become very difficult in the conventional electric grid. It is believed that smart grid systems are the best option to serve such loads by allowing distributed energy generation. But, developing smart grid systems is not an easy task, where they involve the amalgamation of power technologies with information and communication technologies. In this study, we tried providing an overview of the smart grid infrastructure and the functionalities. The scope for smart grid systems in the Indian context is studied. The role of renewable energy sources and their potential in India is also discussed. Apart from this, various opportunities for implementing smart grids in India, along with the challenges, are explored.

Keywords: Smart grids, Microgrids, Electric utility, Smart grids, Renewable energy.

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1 Introduction

Energy is vital for any nation to have development, and this is because of the energy-intensive nature of the applications that modern society has seen [1]. The energy is available in many forms, and utilizing it in a required form needs the technology. In earlier days, many of us have seen the energy utilization process, that is filled with hotness, smoky, and indistinct lighting. As the industrialization and technological advancements begin, the process of energy utilization also changed [2]. The energy sector transformed to a greater level with the invention of the electric bulb. With that, electrification using the alternating current has become the tradition [2]. Many power generation systems have elevated and lead to the development of the centralized electric grid. In countries like India, the situation of the electric grid is still centralized. No much difference and changes have seen in the Indian electric power grid.

The role and duties of energy generation, transmission, and distribution are still following the conventional mechanism in many areas or grid zones of India. However, the rapid growth in the consumption patterns and demand variation, as well as the strive towards green energy generation, this process of centralization has taken a shift to decentralization. Many technical issues can be addressed by this shift; these include the energy loss minimization, grid outage detection, enhancing grid stability, accessibility in energy supply [2].

In the current centralized grid concept, most of the power generation in India is comes from fossil fuel sources such as coal, diesel, natural gas [3]. Apart from this, India is most dependent on oil in other activities such as transportation, industrial energy needs, etc.

The oil dependence (mostly imported from other countries) has resulted in a decrease in the economy. If we see the statistics, India stands in the seventh position in the economic race with the nominal gross domestic product [4]. As per the International Monetary Fund-World Economic Outlook, India is in the third position in the Purchasing Power Parity. The current target in India is to achieve energy independence, where the microgrid and smart grid development using the available resources in India would benefit. Say, for example, shifting to the electric vehicles would limit oil consumption, and this will come true if Indian energy sectors start producing renewable electricity.

Many developed countries in Europe are shifting towards onsite power generation, developing the concept of microgrid, nano-grids, and smart grids. It is obvious for us to create such systems in India and to have a transformation in the energy sector as well as to see a big change in the energy-dependent sectors [4].

The objective of this paper is: the first objective is to provide an overview of smart grid systems in the Indian context, infrastructure, and functionalities. The second objective is to explore the scope for renewable-based smart grid systems in India. The third objective is to study the various implementation opportunities and to explore multiple challenges in smart grid implementation.

2 Smart Grid Systems

Smart grid systems are an intelligent version of the conventional electric grid systems. The functional differences between the smart grid and other systems are presented in Table 1. The operation of the smart grid system is more of an automation.

Table 1. The compassion of the smart grid with microgrid and conventional grid systems

Functional parameter	Smart grid	Microgrid	Conventional grid
Reliability	High	Medium	Low
Security	High	Intermediate	Very low
Renewable integration	Possible	Possible	Possible but with lot of difficult
Monitoring and control	Easy and fast	Easy and moderate	Not easy
Emergency response	Very high	High	Low
Electric vehicle integration	Yes	Yes	Possible but with few changes
Energy storage options	Yes	Yes	Yes
Fairness in energy trade	Very high	High	Low
Interoperability	Yes	Yes	Difficult
Power quality issues	Yes, but little	Yes, but moderate	Yes, but very high
Operational efficiency	High	High	Medium

In a way, when compared to the traditional electric grid, the smart grid systems can make decisions related to energy transmission and distribution. Apart from this, they can also store the energy and regulate it as per the need

[4-9]. One more important feature of the smart grid system is communication. They can able to communicate between the network of energy producers and consumers, and related responses can be made easily and quickly. These systems enhance the electrical system performance by improving the reliability, efficiency, and availability.

In many situations, the availability of the generation system is not 100%, in one recent study, the availability factor of the solar photovoltaic plant is evaluated, which is 96 to 98% [26]. In this situation, if the load demand is very high, the generation system fails to meet the load, to avoid such systems, if a network energy producer is there, then smart grid systems can take decisions on compensating the demand by shifting to another source. Apart from this, they are capable of handling many computing-related services. The decision making and monitory of the system become much easier when the communication technologies are better integrated with the electrical power system. In the smart grid, the trading of electricity becomes much simpler and easier [4-9]. It is also believed that smart grid systems improve the business values of the electricity sector and allows the bidirectional energy flows. The overview of the smart grid system is shown in Figure 1. This shows the clear view of the smart grid system indicating all the sources of energy (Fossil fuel and renewables), energy consumer network (residential, industrial, etc.), communication layers (Ethernet, signal cables, and alert systems, etc.) [6].

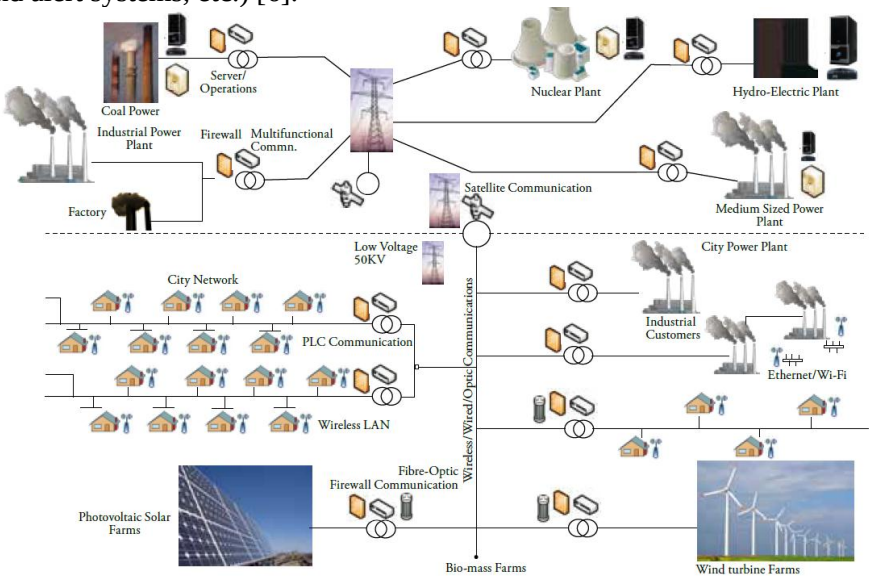

Figure 1 Overview of the smart grid system [5]

2.1 *Smart Grid Infrastructure*

Smart grid infrastructure generally refers to the design of the smart grid. It is not easy to design such a complicated system. The typical electric grid consists of the following [7, 8]:

- Power generation systems
- Electricity transmission systems
- Electricity distribution systems
- Energy storage options
- Consumers or the end-users.

In a smart grid, at every stage (preferably the above mentioned five stages), the energy values with the time step are monitored on a real-time basis. For monitoring such a huge system (having a network with multiple stakeholders), we need a real-time system with computing capabilities. In the smart grid infrastructure, the role of power line communication and information flow is essential. Hence, as shown in Figure 2 (a) [7], a wide area multi-tier network should be essential. This infrastructure can be able to connect the homer area network with the power distributors/generators and the operators through a means of the internet system. With this infrastructure, the power consumption patterns of the users at home are network is continuously monitored considering their dynamic variation nature. The architecture is shown in Figure 2. (b) [7], enables the bidirectional flow of energy from the consumers to the grid (when excess electricity is available with the consumers), and grid to consumers (whenever electricity is consumption is high, and generation is less at the consumer side power plants). For example, by having prior knowledge of the end-users energy consumption, the dynamic control of real-time power generation can be controlled [4-9]. Meanwhile, the end-user can visualize the real-time power usage of the home and can obtain the real-time cost of the power supplied from the power provider. In a smart grid, electricity can also be returned to the grid by users. In these situations, the smart grid elements, as mentioned previously, must share every information; when involved, stakeholders increase the control would be very difficult.

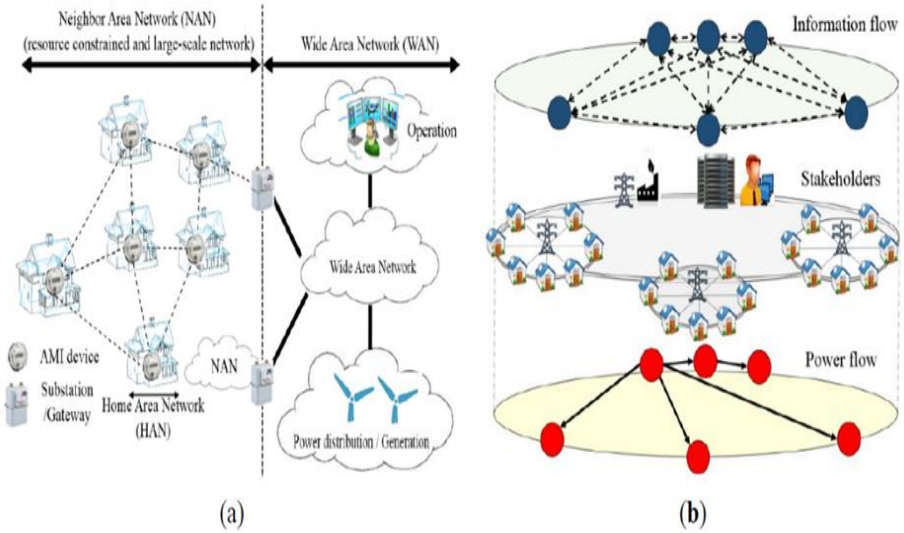

Figure 2 (a) Architecture of the smart grid with a multi-tier network [7]; (b) smart grid infrastructure for the data and power flow [7]

In Figure 3, the controller which can be capable of handling the smart grid function is shown [7].

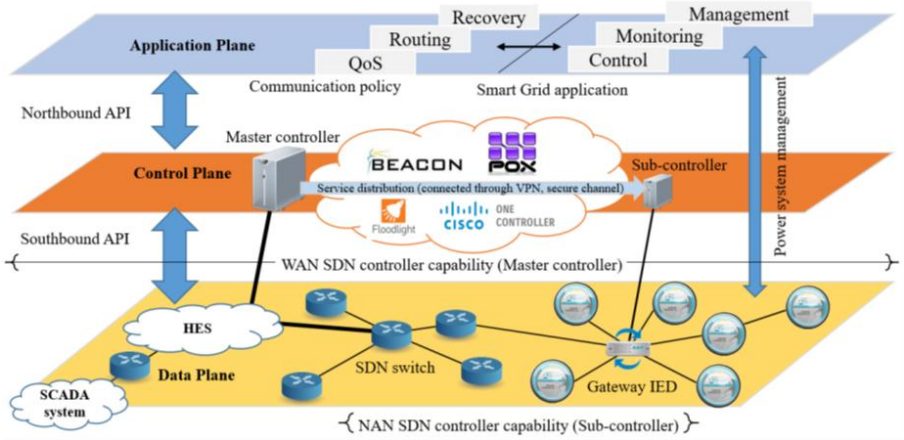

Figure 3 Smart grid infrastructure using based on SDN controller [7]

2.2 *Smart Grid Functionalities*

Smart grid systems have numerous functionalities when compared to conventional electric grid systems. Here, in this section such functionalities are listed and briefly described below [4-9];

- The reliability of the electric grid is improved.
- The security of the electric grid is improved when compared to the conventional one.
- Operational efficiency improvement of the electric grid can be achieved.
- The deployment of multiple renewable and non-renewable sources will become easier.
- It allows the integration of distributed resources and helps in boosting the generation capabilities of the energy system at any time, making the system available for energy consumers.
- The functionality of demand response and demand-side resources management is possible.
- It allows us to deploy advanced metering techniques.
- It helps in boosting the energy trade with fair monitory regulation and allows the distribution automation in the system.
- It is easy to deploy and integrate many consumer devices and other smart and intelligent assets.
- Timely scheduling and advanced electricity storage options are possible.
- Easy to enable the charging facilities to hybrid electric vehicles.
- Provide a wide range of control and monitory authority over the system with timely information tracking provision.

3 Renewable Energy Sources in India and Role in Smart Grids

In this section, the role of renewable energy in smart grid development, focusing on the Indian context is discussed. Various renewable energy sources such as solar energy, wind energy, biomass, hydropower, and hydrogen fuel cells are focused, and their potential availability in India is studied. Year-wise installations in India are shown in Table 2.

Table 2. Year-wise power plant installation capacities in India [10,11]

Installation period	Energy sources (GWh)					
	Solar	Wind	Biomass	Large hydro	Small hydro	Others
2014-15	4600	28214	14944	129244	8060	414
2015-16	7450	28604	16681	121377	8355	269
2016-17	12086	46011	14159	122313	7673	213
2017-18	25871	52666	15252	126134	5056	358

3.1 Solar Energy

India is blessed abundantly with solar energy. Being a tropical nation, the amount of solar radiation reached on to the horizontal plane of Indian cities is quite high and more suitable for energy harnessing using photovoltaic or solar thermal technologies[12-16]. Depending upon the energy harnessing system installation site, the average daily energy that can be harnessed from the sun radiation is around 4–7 kWh/sq. m. Not all locations in India might lie with the mentioned average; there exists a variation due to seasonality and other influential factors. India receives bright sunshine hours, and the number is approximated to around 1500–2000 per annum18. The average temperature recorded would be around 25 to 27.5 °C17, but the maximum temperatures would go around 48-50 °C, and this makes most of the places suitable for solar thermal energy harnessing. This available potential can be harnessed, and on the other side, the targeted 20 GW of Solar Power by 2022 could also be possible [12-16]. The year-wise installed capacity of the solar energy system is given in Table 2.

With the current potential, India has gone to stage to explore different solar energy harnessing ways such conventional photovoltaic installations [27], building-integrated installation [19], building applied installations [19], roof-integrated [20] or attached installation, façade installations [21], and floating solar installation [22].

Depending upon the location, one such installation option can be selected, and solar energy can be harnessed effectively. The current practice of harnessing solar energy is more suitable for smart grid or microgrid energy systems

3.2 Wind Energy

Apart from solar energy, India is also blessed with wind energy potential. The wind is one of the clean and green energy sources. With the current developed technology, the energy can be harnessed with greater efficiency

ranging from 35 to 45%. As per the recent statics, the wind potential is very high in India. The practical wind energy system capacity factor is estimated for a commercial wind turbine installed at 80 m height is around 25%. For harnessing wind energy, very limited land is required. Currently, the potential for wind energy systems is around 253 GW. As per the Ministry of New and Renewable Energy, India's wind energy installations reached the fifth position at the global level with an installed capacity of 11087 MW [12-16]. There are various types of wind energy systems that include; horizontal axis wind energy systems, vertical axis wind energy systems (two blades, three blades), convergent and divergent systems. In recent years a new concept called the Invelox wind energy system has shown greater efficiencies in harnessing wind power. For wind power data, one can refer to the National Wind Resource Assessment Programme (NWRAP), National Institute of Wind Energy (NIWE), located in Chennai city, Southern India. Under the NWRAP, a total of 794 wind monitoring stations are installed at different locations in India [12-16]. These systems are capable of monitoring the wind speeds at a wide range of heights, starting from 20 m to 120 m. The current installed capacity of the wind energy systems is given in Table 2.

3.3 Biomass Energy

The scope for biomass energy in India is huge, and this is due to the agricultural background of the nation. Countries like India are developed based on agricultural resources, and they mostly influenced by the economy due to agro products and related outcomes. In India, numerous biomass resources are available, which can be used for biogas generation, biofuel production, etc. These sources include rice husk, jute waste, cotton seeds, straw, coconut shells, and other agro waste. Apart from this, the use of waste plastic oil and ethanol is becoming popular these days [28,29]. In India, 90% of rural areas still depend on the bioresources for energy needs. This is also possible in many urban areas. Currently, around 15 % of urban areas are still using biomass as a fuel for their energy needs. The current estimated potential of bioresources due to agricultural activity in India is around 350 million tons/year.

If this amount of bioresource is used in the energy conversion process, around 200 million tons of energy is possible. States like Andhra Pradesh, Bihar, Gujarat, Karnataka, Punjab, Tamil Nadu, Uttar Pradesh are in the race for biomass energy systems development [12-16, 23, 24]. The current installed capacity of the biomass energy systems is shown in Table 2.

3.4 Hydropower

Hydropower is one of the predominant sources of electricity in India, and the potential for hydropower is quite high. The current estimated potential of hydropower in India is around 20,000 MW as per the MNRE statistics. Currently, India has a lot of installations categorized into large hydro, micro-hydro, and mini-hydro. The first installation in India was at Sidrapong in 1897. The installed capacity is around 130 KW. In the later years, numerous developments happened in the hydropower. These include 200 kW at Shivasamundram in Mysore, 40 kW at Bhoorisingh in Chamba, 3000 kW at Galogi in Mussoorie, 50 kW in Jubbal, and 1750 kW at Chhaba in Shimla [12-16, 25]. In the current situation, India has installation capacities whose range is greater than 25 MW. Recent installations as per the year wise are shown in Table 2.

3.5 Hydrogen Fuel Cells

Hydrogen fuel cells are the recent developments in renewable energy systems. These are highly efficient systems when compared to other renewables. The potential for hydrogen production is very high in India. Say, for example, hydrogen can be produced by means of water electrolysis, bioenergy systems, etc. The produced hydrogen energy can be used for fuel in hydrogen-based vehicles. In some situations, fuel cell-based electric vehicles need hydrogen as input to drive the system. In India, with the growing use of hydrogen in industries, in the transportation sector, the scope of converting excess energy into useful hydrogen is very high. In microgrid and smart grid, if any excess energy is possible, the energy can be stored in the form of hydrogen gas and can be used to variety applications [21,22].

4 Implementation Opportunities

Opportunities for implementing smart grids in India are very high due to the current policies established by various ministries that are related to smart grid technologies. The opportunities are listed below:

- Energy access is very limited in most of the places in India; this is more obvious in rural areas.
- Indian's electric power system is mostly mechanized, and the scope for digitalization is very high. On the other side, the current smart city mission in India1 and make in India concepts are in favor of smart grid developments.

- To meet the energy demand requirements and to provide energy access to everyone, India is trying to shift from the centralized power generation facility to a distributed or decentralized power generation network.
- In the current national grid or the electrical power network, privacy and security concerns are very high. There are considerable opportunities to improve them, and the smart grid implementation in replacement with traditional facilities can provide improvements.
- Shifting to smart grids provide faster response in tackling the issues in an emergency. Many are opting to have a quick response in solving the energy issues. It is believed that smart grids provide faster responses in addressing the problem with a better solution.
- The digital India movement and Swatch Bharat movement's motive is to have systems that serve the needs of humanity in more environmentally friendly. We believe the smart grid integration with renewable is huge scope in India.
- India has enough energy resources, for example, all kinds of renewable resources, which can help in promoting the distributed concept of energy generation with smart grid features.
- Funding and subsidies related issues are quite less in India for such project development. In the implementation of renewable energy-based smart grids, the MNRE and other associated organizations are providing subsidies and capital with certain terms and conditions.

5 Challenges

Even though the opportunities for smart grid implementation in India are very high, there exist a few challenges, and these include:

- The first and foremost is the lack of enough governance in executing such projects within the timeline as taken up.
- Lack of skilled workforce to operate and maintain smart grid systems effectively.

- Lack of data monitoring systems allows us to identify the issues that prevail during operation and maintenance.
- Even though the capital subsidy and other supports on energy tariff rates are provided, but still, the projects are not financially viable.
- Policy issues related to such project development. Not all the states and central has similar policies in India. This variation in the policies limits the progress of such projects.
- Cybersecurity issues are more common.
- Lack of awareness and strong opinion on the benefits of implementing smart grids.

6 Conclusions

This paper focused on the smart grid systems in India. A brief discussion on the smart grid systems, their infrastructure, and functionality are carried out. On the other side, the role of renewable energy systems focusing on the Indian context is discussed. The potential availability of various renewable energy options for smart grid integration is explored. Lastly, the implementation opportunities for smart grids in India are explored and listed. However, it is not always easy to implement such projects in a developing nation. Hence, the possible challenges for smart grid development in India are also explored and listed. Finally, we believe this piece of work would be useful for the researchers and academicians working towards smart and micro related research.

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