Chapter 12
Smart Grid Initiatives Towards Sustainable Development: Indian and Worldwide Scenario

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Abstract The electrical power sector globally is experiencing an advanced evolution and expansion of the conventional electrical grid. This transformation is in response to the advanced technologies and the latest environmental policies. The conventional grid has many alarming problems associated with it such as harmful emissions, poor efficiency, poor reliability, poor monitoring and control, lacking smart field devices and sensors, etc. Thus, the smart grid has evolved as a vital tool to address the shortcomings of the conventional power grid with increased reliability, efficacy, security, and sustainability. However, the implementation of smart grid technologies has been a challenging issue. The electricity regulatory commissions (ERCs) of the respective countries are undergoing frequent amendments in the electricity regulating policies and standards. Thus, to assess the impact of initiatives taken in the implementation of smart grid policies requires comprehensive analysis. This work presents a review of the initiatives undertaken by the electricity regulating utilities for the prolific implementation of smart grid technologies. Various policies and measures taken by the respective countries are also presented in this work, enlisting the objective of each measure.

Keywords Smart Grid · RES · DER

12.1 Introduction

It is a glorious time for the power sector industry, as the transformational changes restructured the process of power generation, transmission, and distribution to the consumers. The modern evolution of the power sector industry has originated the term 'Smart Grid' which has emerged widely and critically approved by the electrical power industry across the globe. One of the most vital component of the smart grid is the distributed energy resources (DER) comprising renewable energy sources (RES). The degrading environmental conditions (harmful emissions) and depleting

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fossil fuel reserves have led to the transition from conventional power generation to RES-based DER generation. A steep transition from centralized generation to RES-based DER is observed in the past few years [1]. Solar photovoltaic (Solar PV) and wind power have emerged as a stepping stone on the path of sustainable energy development programs worldwide. Countries are seeking to achieve renewable portfolio standards by enhancing strategic measures and policy implementation. The increasing rate of DER penetration required suitable standards and guidelines for interconnection with the grid. Thus, electricity regulating policies of the respective countries underwent frequent amendments and revision [2, 3].

A smart grid comprises of multi-objective components [1], each component has its significance in enhancing the grid capabilities, Fig. 12.1 lists some of these components. The smart grid initiatives are focused on upgrade of the conventional grid with advanced transmission and distribution systems. Smart grid initiatives have deployed several advanced concepts such as substation and distribution automation, wide area monitoring system (WAMS), advanced metering infrastructure (AMI), cyber security, energy storage systems, electric vehicle, RES integration, power quality management, Internet of things (IoT), supervisory control and data acquisition/Energy management system (SCADA/EMS) units, etc. The different components of the smart grid function collectively, exhibiting superior coordination, and

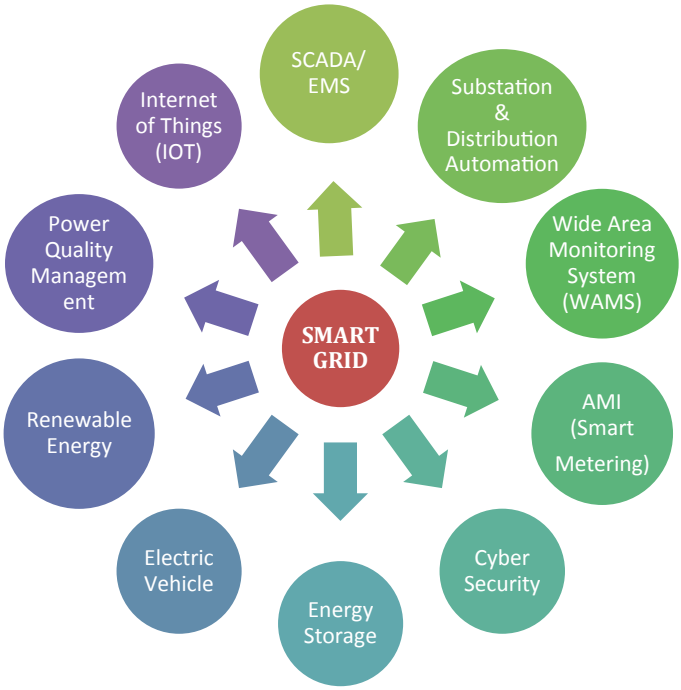

Fig. 12.1 Smart grid and its components

control. Thus, making the grid well structured, more reliable, and customer friendly. With the upgrade of monitoring and control structure, the faulty conditions can be rectified or avoided with superior action of control, making the conventional grid a smart grid [4].

A smart grid is an electrical grid incorporated with advanced automation systems enhancing the real-time monitoring and control of grid parameters, RES-based DER integration, infrastructure for the electric vehicle, data security from cyber attack, and secure communication channels for bi-directional flow of information [1–3, 5, 6]. The drivers of the smart grid are as follows:

1. Deployment of DER and producing sustainable energy and contributing to the reduction of harmful emissions [7].
2. To develop a smart interface platform by integrating technologies such as SCADA/EMS, WAMS, smart metering with advanced bi-directional communication channels and distribution automation, cyber security, etc. [8, 9].
3. To provide an environment and infrastructure for the excessively growing market of electric vehicle and battery energy storage [10, 11].
4. To escalate the application of Internet of things (IoT) [12] and improve issues such as grid efficiency, power quality [13], etc.
5. To enhance grid reliability, meeting the viability of economic constraints [14].

One major component of the smart grid development program is consumer empowerment. In which, the consumers are marked as active entities by providing the infrastructure and facilities. This establishes a bilateral relationship between utilities and consumers, which results in effective demand side management (DSM). And results in the empowerment of prosumers and consumers [15].

The integration of smart grid components (Fig. 12.1) is a well-known and widely addressed issue in the literature. It has been a challenging task to implement smart grid technologies. This work is majorly focused on the initiatives taken by different countries in implementing smart grid technologies. The measure took and policies implemented are discussed in detail with special context to the Indian scenario.

The objectives in support of renewable portfolio standards are listed providing the motive for an increase in smart grid activities. A collective worldwide comprehensive review of the current status and future prospect of development of smart grid activities is provided in this work.

12.2 Smart Grid Framework: Policy Initiatives and Measures Undertaken (Indian Scenario)

Indian smart grid forum (ISGF) is established by the government of India in May 2010 aiming to accelerate the deployment of smart grid technologies in India. The government of India has launched the National smart grid mission (NSGM) in March 2015. The prime objective of NSGM is to strengthen the existing power system infrastructure and make it more economical and efficient. To strengthen the mission,

16 smart grid pilot projects, and 1 smart city research and development platform are in the implementation phase [16]. Indian has a clear vision to deploy smart grid technologies through the smart grid development roadmap discussed in Table 12.1. Ministry of renewable energy of India aims to accomplish a target of installing 175 GW power from renewable energy sources by the year 2022. The total installed capacity of 87.02 GW is achieved by Mar 2020, and India is ranked 5th globally in terms of total renewable power installed [17]. The world's largest 2000 MW solar park, named 'Shakti Sthala' is developed in Karnataka which is spread across 13,000 acres.

The initiatives put into action by India towards the growth in the renewable energy environment are stated as follows [17–19]:

Table 12.1 Smart grid development roadmap through implementing smart grid technologies in India [17–19]

S. No.	Objectives	Targets	
		2022	2027
1	Quality power access to all	The aim is to provide 24 * 7 power supply in urban areas and at least 12 h a day in rural sectors	To provide secure, reliable, and quality power to all
2	Regulating policies and tariff rates	The aim is to provide the consumers to have choice of electricity supplier in metro cities and selected urban areas. To support an environment for active consumer participation by regular monitoring of policies and tariff rates in context to DER integration	To provide all the consumers to choose among the multiple options of power suppliers across country. The prosumer being marked as active entities with direct supervision on the power feed/absorbed through net metering
3	Renewable energy and energy efficiency	The aim to have an installed capacity of 175 GW by RES	Implementation of dynamic energy efficiency programs
4	Deployment of smart grid technologies	Implementing of stronger communication channel for advanced metering infrastructure (AMI), micro-grid development for villages and industrial parks	All substation automation, AMI across country, around 20,000 developed micro-grids
5	Electric vehicles and energy storage	To develop and implement the road map structure for electric vehicle environment in some urban cities	To have a significant production of electric vehicles along with a developed infrastructure for their smooth interface. To provide charging station in all cities and national highways
6	AT&C loss reduction	To achieve the reduction in AT&C losses to under 12%	To achieve the reduction in AT&C losses to under 3%

1. **Feed-In tariff**: Here, the DER owning utilities are provided with a guaranteed payment for the power they produce. A fixed standard tariff rate is made available to the DER utilities to provide investors financial perks making DER a low-risk investment. Tariff rates are monitored by the regulating utility from time to time.
2. **Accelerated depreciation**: This financial scheme provides a fiscal incentive to investors to claim 40% of depreciation in the first year, helping the DER utilities to write off their capital cost early. In India, around 70% wind power projects are built on the accelerated depreciation scheme.
3. **Generation-based incentives**: This financial incentive scheme provides the tariff rates for the power produced by RES-based DER. Wind power-based DER is provided with the standard tariff rate for the power they inject into the grid which is decided by the regulating committee. DER utilities could only be benefitted if they continue their generation for a period between 4 and 10 years. Under this scheme disbursement of the incentives is provided in parts and it must be within the one-fourth of the total amount of incentive provided in a fiscal year.
4. **Viability gap funding (VGF) for solar**: The solar energy corporation of India (SECI) purchase the power produced by solar PV-based DER at a fixed tariff level. The DER utilities would make their bids following which the payment of VGF is generated. The VGF is limited to Rs. 2.5 crore/MW maximum. The latest reforms have caused significant cut down in prices of tariff plans, for solar PV-based DER.
5. **Net metering**: Net metering enables the facility to consumers of electricity with DER (solar PV) at the local end to sell excess generated power to the distribution utilities. Smart meters are installed which runs on AMI accounting for both power absorbed and power feed. All the state electrical utilities have developed the net metering policies and slowly started implementing.
6. **Renewable energy certificate**: Renewable purchase obligations (RPO) are defined by the respective state electricity regulators (SERCs) in India. The RPO provides financial support to the DER utilities. With the reduction in the cost of semiconductor material in a solar PV cell, the generation from solar PV-based DER has got significantly cheaper than conventional power generation techniques. Solar tariffs have decreased by 64% in the last 6 years [20].

India has immense potential to harness its renewable energy capacity due to its favorable atmospheric condition. Till now, India has only harvested 0.25% of its total renewable energy potential. Thus, this deficit opens up an immense opportunity to be explored in the future and reducing the dependence on the conventional generation.

12.3 Smart Grid Framework: Policy Initiatives and Measures Undertaken (Worldwide Scenario)

The annual growth of 2.2% electric power is expected from 2012 to 2035, according to a report from the international energy agency (IEA). The ever-rising electricity demand has led to the infusion of a higher budget by the government in the power sector by respective countries. To upgrade the conventional grid into the smart grid requires a lot of infrastructure investment. Hence, the smart grid development programs are kept on the priority list and a higher sum of the budget is allotted to it by the countries. Different countries suggested different definitions of the smart grid, varied on their policy framework and regulatory guidelines. Countries like the USA, China, India, Germany, Russia, and Japan are the leading producer of Co_2 globally. Hence, a much needed and dedicated efforts are made by these countries for sustainable and eco-friendly growth [3]. Table 12.2 enlists the various initiatives taken with underlining objectives for enhancing smart grid development programs by different countries. The policies framed/implemented enroute to the smart grid development roadmap are also discussed in Table 12.2.

12.4 Conclusion

The objective to attain sustainable green energy with lesser environmental impacts is the goal of all the smart grid development programs. The periodical up-gradation of the power sector has efficiently improved the quality of access to electricity to the consumers. With these advancements, hand in hand goes the investment cost in this sector. The investment in the power sector is peaking globally with supportive measures from electrical utilities and the government authorities. For the smooth operation of the grid, all the policies and measures undertaken have to be monitored at regular intervals to estimate its effectiveness. And if any amendments required, should be taken timely by the utilities. DER interconnection standards and guidelines such as IEEE P1547, California Rule 21, UL 1741 SA, and IEC 61727 are under intensive revision. With the advancing technology comes new challenges in the implementation of those technologies. The major threats which arise with DER integration and needs to be mitigated are as follows [24]: to maintain grid stability in the occurrence of any fault in the system, to control line active and reactive power flows, protection devices need to be coordinated and control because of the bi-directional power flows in the grid, arising power quality issues due to inverter-based power injections in the grid, temporary over-voltages (TOVs) under light loading conditions, deterioration of on-load tap changers (OLTCs), voltage regulators, and capacitor banks due to frequent operation, etc. Hence, it opens up a widespread field to be explored by the researchers.

Table 12.2 Initiatives taken for enhancing smart grid activities world-wide [4, 20–23]

S. No.	Country	Objectives	Policy's implemented/targeted
i.	European Union [19]	Implementing smart metering, reduce greenhouse gases (GHG), increase renewable generation, and improve energy efficiency	• 80% of households will be incorporated with smart meters by the year 2020 • The European Union on its energy and climate policy of 2030 has targeted a total reduction of 40% in domestic GHG emissions • To obtain renewable power penetration to 20% in the grid by the end of 2020
ii.	USA [21]	Environment protection through reduced emissions, energy by renewable sources at higher efficiency, and considering economic constraints	• Developing organizations like Office of Electricity Delivery and Energy Reliability, Smart Grid Consumer Collaborative for implementing the sustainable smart grid benefits • Major stepping stone in deploying smart grid activities by forming organizations like – Smart Grid Investment Grant program (SGIG) and the Smart Grid Demonstration Program (SGDP) • Providing heavy investment grants in implementing smart grid technologies stipulating through the American Recovery Act of 2009
iii.	Canada [20]	Reduce harmful emission of gases	• Target for 2020 is the reduction in harmful emissions of gases by 17% below 2005 levels • Running major smart grid pilot projects in the Ontario, Provinces of Quebec, and other provinces • Forming organizations like National Smart Grid Technology and Standards Task Force, Smart Grid Canada, Natural Resources Canada, for facilitating smart grid developments

(continued)

Table 12.2 (continued)

S. No.	Country	Objectives	Policy's implemented/targeted
iv.	South Korea [22]	Self-dependent on generating total required power through sustainable generation Aim to reduce harmful emissions	• To obtain renewable power penetration to 11% in the grid and reduction in the Transmission and Distribution (T&D) losses to 3% by the end of 2022 • Target for 2020 is the reduction in harmful emissions of gases by 30% • All households will be incorporated with smart meters by the year 2020 • Formation of Smart Grid Promotion Act for enhancing and successfully deploying smart grid activities and projects
v.	China [23]	Energy conservation, lower harmful emissions, diverse development, expanding international cooperation, increasing domestic resources	• For harnessing and utilizing the total renewable capacity amended Renewable Energy Law of 2009 is passed • Formation of special Smart Grid Science and Technology Industrialization Projects under the planning of 12th Five-Year Plan • Formation of organization like the National Development and Reform Commission (NDRC) to monitor smart grid development activities
vi.	Australia [23]	Increased use of RES-based DER for power production	• It has the privileged to be the first country to form the law for achieving renewable energy portfolio standards • To obtain renewable power penetration to 20% in the grid by the end of 2020

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