Smartgrids/Microgrids in India: A Review on Relevance, Initiatives, Policies, Projects and Challenges

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Abstract Microgrid and smartgrids are quickly moving from laboratories/demonstration benches to being deployed in increasing number across wide range of applications along with integration of renewable energy sources. This paper attempts to (i) Explain the concept of renewable energy-based microgrid/smartgrids and their relevance in solving India's energy needs in a smart and sustainable way. (ii) Describes the various initiatives taken by Govt. to achieve the smartgrid vision of India along with brief on acts/policies enabling Renewable Energy Integration. (iii) Tracks the present status on smartgrid/microgrid activities across various parts of the country and does a comparative study on features of those projects. (iv) Analyzes the key benefits, opportunities as well the challenges faced during implementation of such smart and sustainable projects. (iv) Lastly, the author proposes a brief framework for deployment of new projects concerning microgrids/smartgrids.

Keywords Microgrid (MG) · Renewable energy · Smartgrid

1 Introduction

Total installed capacity of power generation in India as on 21/08/2019 is 360,456 MW [1]. The energy mix consists of conventional as well as renewable sources as shown in Table 1. While share of energy obtained from oil/coal/gas is reducing, at the same time, the share of renewable energy has gradually increased from 7.8% in 2008 to 22% in 2019 (Source CEA Statistics).

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Table 1 Percentage share of different sources in meeting India's energy needs

Type of energy source		Contribution in percent (out of total installed capacity of 360,456 MW)
Thermal	Coal (54.3%)	63.2%
	Lignite (1.7%)	
	Gas (6.9%)	
	Diesel (0.2%)	
Hydro		12.6%
Nuclear		1.9%
Renewable energy		22%
Total		100%

With increasing focus of Govt. to meet our energy needs from renewable sources, it has become more essential to have a highly adaptive grid which is smart enough in meeting the variable dynamics of demand and supply, especially considering the intermittent nature of renewable energy which cannot be controlled. Thus, the relevance of smartgrids and microgrids has increased considerably for meeting India's energy needs.

Traditional grids are inclined toward centralized generation mostly from conventional sources with one-directional power flow but microgrids are basically small networks of energy having own local energy source and they are capable of bidirectional power transfer in grid-connected mode but at the same time, they can function independently on stand-alone basis for off-grid applications or during islanded mode of operation.

Generally, microgrids integrate local power generation from renewable sources like solar, wind, etc., but considering the intermittent nature of generation from renewable sources, there is a need for energy storage systems which are discussed in [2, 3]. Then at the heart of microgrid is the controller which monitors overall parameters. Details related to microgrid controller are given in [4, 5]. Bidirectional power flow increases the complexity for need of system protection and stability as discussed [6, 7]. PCC or point of common coupling serves as a junction between local microgrid and utility grid allowing it to function in either grid-connected mode or islanded mode. A sample schematic diagram of microgrid is presented in Fig. 1.

When several clusters of local microgrid connected to main grids are enhanced with smart technologies involving digital communication, control and monitoring which are dynamic in nature, then it forms smartgrids. Various components of smartgrids are smart meters, advanced storage, smart integration, SCADA, etc. Detailed reviews on smartgrid technologies are mentioned in [8]. The various stakeholders are mentioned in Fig. 2

The remaining of this paper is organized as follows. Initiatives by Govt. of India are elaborately described in Sect. 2, while Sect. 3 describes the status of various projects in India and Sect. 4 demonstrate the challenges, opportunities and benefits. Lastly,

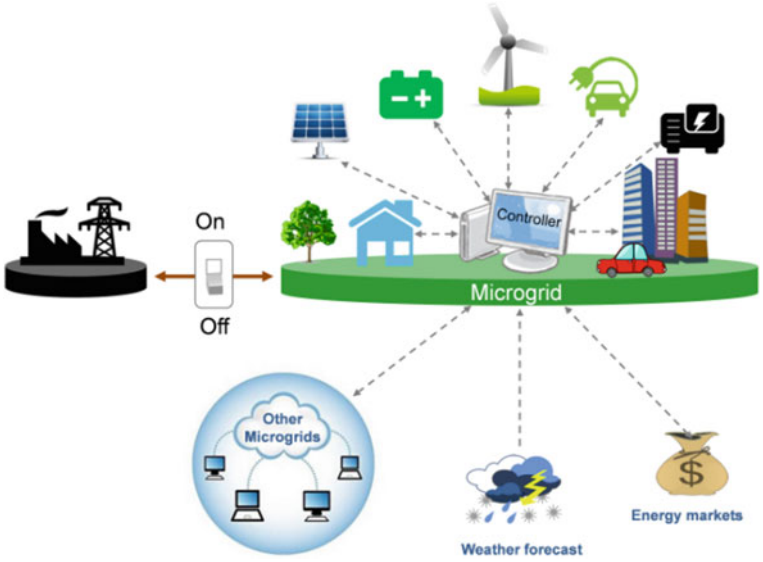
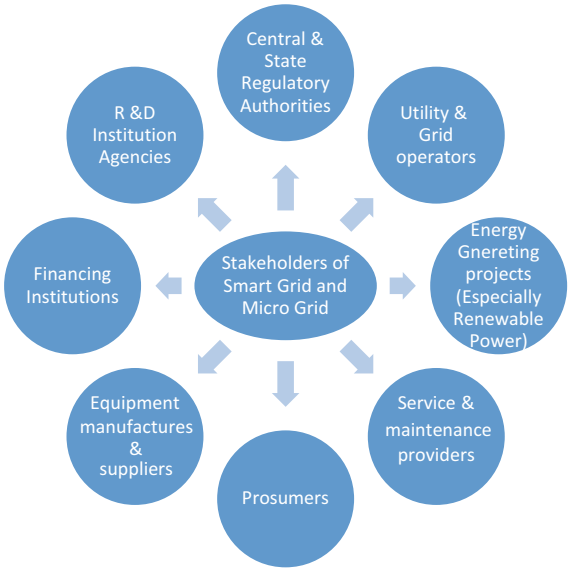


Fig. 1 Schematic of a basic microgrid. *Image source* Berkeley Laboratory Microgrid

Fig. 2 Stakeholders of microgrid and smartgrid



Sect. 5 describes the brief framework for implementation of microgrids/smartgrid projects. The closing comments of this paper are indicated in Sect. 6.

2 Initiatives by Govt. of India

Electricity is a concurrent subject in constitution hence while Central Govt. frames overall rules and regulations, whereas each state formulates its own policy inside the overall regulatory framework.

The vision statement of Govt. on smartgrids is to "Transform the Indian Power sector into a secure, adaptive, sustainable & digitally enabled ecosystem that provides reliable & quality energy for all with active participation of stakeholders" [Source: National Smart Grid Mission (NSGM)].

Given the necessity of transition from traditional grids to smartgrids and microgrids, Ministry of Power (MOP)—Govt. of India approved a vision and roadmap document in August 2013 and accordingly National Smart Grid Mission (NSGM) started in 2015. It plans, monitors and implements various activities related to smartgrids on national level and focuses on capacity building at state level by establishing state level project management units (SLPMU). Huge investments have been made under NSGM for study, research, consumer awareness and encouraging participation in various initiatives. Similarly, an alliance of many countries named as International Solar Alliance was initiated by India on November, 30, 2015. Some of the NSGM key milestones are showcased in Table 2, while the legal and institutional frameworks of our country dealing with our energy infrastructure are presented in Table 3.

Table 2 Some of the NSGM milestones for smartgrid rollout

Goals relation to smartgrid rollout	Phase 1 (up to 2020)	Phase 2 (2020–2025)
State level project management unit setup	100%	
SLPMU regulations and policies for SG	100%	
SLPMU roadmap for SG		100%
Preparedness of utility in mature-level framework for SG and self-assessment in a finalized frame work	100%	
Utility with AMI rollouts	10%	100%
Network mapping and consumer indexing by utilities	100% (urban)	100% (rural)
Automation of distribution system (SCADA/DMS)		100%
Utility with ability to manage RE integration	10%	100%
Utility with ability to deploy infrastructure for EV	10%	100%

Table 3 Legal and institutional framework

Electricity Act 2003	It provides for policy formulation by central Govt. and mandates SERC of states for optional utilization of all resources
NEP 2005	It targets to exploit RE resources, reduce capital cost, promote competitive building and encourage Pvt. sector participation
NTP 2006	Among other things, it formulates preferential tariff determined by SERC for procurement of RE
Integrated Energy Policy IEP 2006	Emphasis importance of RE to meet energy demand of industry
NAPCC 2008	It identifies eight core national mission to address global warming and some of it relates for gradual increase of RE percentage
JNNSM 2009	It is one of the eight mission of NAPCC and it promotes solar energy development for both on-grid and off-grid
NCEF 2010	It is a fund which uses carbon tax/cess for providing funds to promote R&D in clean energy technology

NSGM has targeted strengthening of existing Grid by IT and SCADA implementation which is ready to support smartgrids technology under RAPDRP programme and automation of T&D activities.

Components in smartgrids implementation are basically as follows [9]

(i) Deploying of advanced metering infrastructure (AMI) and smart meters, renovation and modernization of sustain along with integrating GIS wherever possible (NSGM will promote microgrids in islands special industrial facilities, research institutions and commercial complexes).
(ii) Development of microgrids and distributed generation.
(iii) It will seek to promote RE generation as well as its seamless integration.
(iv) Deployment of charging infrastructure facility for EV under national mission for electric mobility can be coordinated with NSGM.
(v) Promotion off-grid-connected roof top solar under JNNSM (National Solar Mission) shall be encouraged.
(vi) Projects related to real-time monitoring and control of distribution transformers with improving power factor like having provision for harmonic filter and reliability shall be partially funded under NSGM.
(vii) Outage/blackout management system.
(viii) Some other enabling components are peak load management, cyber security, network management, smart appliances, energy storage, rules for consumer data privacy and protection, dynamic pricing, etc.

3 Projects in India

Many small-scale microgrid projects (mostly solar based) are operating across India, some prominent among them are those running by M/S Husk Power System (villages across Bihar, UP, Odisha, Jharkhand, etc.); MeraGao Power (Villages across UP); Sagar Island Microgrid in West Bengal, etc. Similarly, Under NSGM the Govt has implemented many smartgrid projects whose detailed status report as obtained from [10, 11] has been concisely presented in Tables 4 and 5.

4 Challenges, Opportunities and Benefits

This section describes briefly the challenges, opportunities and benefits for any microgrid or smartgrid project.

4.1 Challenges

The major challenges faced by smartgrids and microgrids are discussed in [12] which can be summarized as (i) Integration of RE sources with the grid considering the intermittent nature of supply (ii) High capital required for implementing smart IT-enabled technologies for modernizing existing grids (iii) High cost of renewable technology installation especially when storage technology is integrated (iv) lack of sufficiently trained manpower for service, installation and maintenance (v) Some States still have absence of cohesive/comprehensive policy and regularity frame work for smartgrid development (vi) Obtaining finance for the projects from financial institutions (vii) Considering the complex technologies involved protection and control of power (viii) Cost sensitive Indian market.

4.2 Opportunities in India

(i) Regulations, policies and institutional frameworks have already been developed at level of central Government along with budgetary support and subsides extended at various levels (ii) Renewable resource potential is very good in India (iii) Gradual emergence of indigenous manufacturing companies and technology developers providing on-grid and off-grid solutions (iv) Inadequate access of energy in many remote rural off-grid locations can be solved by implementing the concept of stand-alone microgrid rather than extension of grid which will be uneconomical (v) Considering the frequent disruption of power due to natural calamity or otherwise microgrids for critical installations can provide power backup for longer period.

Table 4 Status report on NSGM smartgrid projects [10]

S. No.	Name of project	Project as status on August 2019	Area catered	Project funding data		Implementing agency	No. of consumers	Functionality
				Total cost	Govt. share			
1	CED, Chandigarh	Design of Network in Progress. Inspection call of 500 smart meters started on 03.09.19	Sub-division 5 of Chandigarh	28.58 Crore	8.57 Crore	M/S Analogics, M/S synergy	29,433	AMI, DTMU, SCADA
2	JBVNL, Jharkhand (Ranchi)	Bids opened on 05.07.19. Technical Education is Progress	Ranchi	228.06 Crore	68.6 Crore	NA	3.6 Lakh	AMI, DTMU
3	OPTCL, Odisha (Rourkela)	Bid opening date 05.09.19	Rourkela	96.9 Crore	29.09 Crore	NA	0.87 Lakh	AMI, SCADA, DTMU
4	CED, Chandigarh (complete city exclude, SD-5)	Sanction Accepted	Chandigarh City (except SD-5)	241.4 Crore	72.4 Crore	NA	1.84 Lakhs	AMT, SCADA, DTMU
5	KSEB, Kerala (Kochi)	Sanction Letter issued on 28.09.18	Kochi City	90.07 Crore	27.26 Crore	NA	0.9 Lakhs	AMI, PLM, DTMU, EVCI, PV

Table 5 Status report on smartgrid pilot projects in India as on August 2019

S. No.	Project name	Project status	Area catered	Project funding data		Implementing agency	No. of consumer	Functionality
				Total cost	GOI share			
1	CESU Mysore	Completed	VV Mohalla, Mysore	32.5 Crore	16.28 Crore	M/S Enzen	21,824	AMI, OMS, PLM, DG
2	UHBVN, Haryana	Completed	Panipat city sub-division	Grant given by NEDO (Japan)		M/S Fuji Electric	10,188	AMI, OMS, PLM
3	Manesar smartgrid knowledge Center	Completed	Powergrid complex, Manesar	5.96 Crore	5.96 Crore	M/S Genus	NA	AMI, OMS, DG, EV, HEMS, Cyber security
4	HPSEB, Himachal	Completed	Kala Amb Industrial Area	19.4 Crore	9.73 Crore	M/S GE T&D	1335	AMI, OMS, PLM
5	UGVCL, Gujarat	Project completed	Naroda	23.1 Crore	11.59 Crore	M/S Genus	22,230	AMI, OMS, PLM, PQ
6	PED, Puducherry	Project live on Dec 2018	Div 1 of Puducherry	35.5 Crore	17.76 Crore	M/S DFE, China	33,499	AMI
7	WBSEDCC, West Bengal	Project live on 31.12.18	Siliguri Town	7.03 Crore	3.53 Crore	M/S Chemtrols	5265	AMI, PLM
8	TSECL Tripura	Project live on 30.06.19	Electrical Division 1 Agartala	63.4 Crore	31.7 Crore	M/S Wipro	45,290	AMI, PLM
9	TSS PDCL, Telangana	Project live on 30.03.19	Jeedimetla Industrial Area	32.9 Crore	17.4 Crore	M/S ECIL	11,906	AMI, PLM, OMS, PQ
10	APDCL, ASSAM	Project live on 02.05.19	Guwahati Division	20.9 Crore	10.4 Crore	M/S Fluentgrid	15,083	AMI, PLM, OMS, PQ, DG

AMI advanced metering infrastructure, *PLM* peak load management, *OMS* outage management system, *PQ* power quality, *PQM* power quality monitoring, *HEMS* home energy management system, *EV* electric vehicle

4.3 Benefits

(i) For consumers—They become "Prosumers" by possibility of two-way power transfer, i.e. they can sell power to grid during excess generation by RE sources and importing from grid during shortages. In case of consumers with critical loads, when there is power blackout, backup power shall be available for longer periods by operating microgrids in islanding mode of operation.
(ii) For environment—Integration of renewable sources and distributed generation into microgrids is environment-friendly as it reduces our dependence on power generated from conventional sources thereby reducing greenhouse emissions and carbon.
(iii) For utilities—Energy cost can be reduced by load shifting, peak load management, reduction of T&D losses by decentralized power generation, etc., leads to better efficiency and management of power dynamics and also preservation of critical loads.
(iv) For society—Society will get access to reliable and better quality of power, people in remote locations/islands can benefit from off-grid microgrids using renewable energy as this is economically a better alternative than extending traditional grids to remote location.

5 Brief Framework for Implementation of Microgrids/Smartgrid Projects

In this section, an attempt has been made toward presenting a concise framework which can be followed during implementation of a microgrid or smartgrid project.

(i) Resources assessment (Extensive mapping for identifying RE potential of a place)
(ii) Load profiling (Demand variation across various time periods needs to be studied)
(iii) Identification of financial instruments and supports (Enhancing loans and finances, interaction with bank and investors)
(iv) Project valuation and technology deployment (Implementation of suitable hardware and technologies based on optimal resource mix and load profiling and integration of RE technology with grid)
(v) Strategy to upscale deployment if pilot project area is successful.

6 Future Scope and Conclusion

With advent of Internet of things (IoT), scope of research is huge in integrating the concept of microgrids with IoT which can alter the future of energy infrastructure and some of latest researches in the area have been discussed in [13].

Successful implementation of smart/microgrids will require participation of all stakeholders for which a structural approach is necessary along with necessity to adapt, understand and evolve based on consumer behavior. If we look at scale of implementation of smart grid/microgrid projects, then they are still at nascent stages in our country but there has been consistent rise in interest from all stakeholders to adopt these new technologies and given governments encouragement, in next few years, the stage is all set for exponential increase of such projects. Microgrids will hence no doubt be the building block for a smarter and superior grid of future which can meet the energy needs of our nation.

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