MISSION INNOVATION
Accelerating the Clean Energy Revolution

सत्यमेव जयते
Department of Science and Technology
Government of India

Mission Innovation
Challenge#1: Smart Grids

India Country Report

Research, Development, Demonstration and Deployment of Smart Grids in India

Government of India
Ministry of Science & Technology,
Department of Science & Technology
New Delhi

June, 2017

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Department of Science and Technology
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Abbreviations

AC	Alternate Current
AMI	Advanced Metering Infrastructure
BESCOM	Bangalore Electricity supply company Ltd.
CAGR	Compound Annual Growth Rate
CEA	Central Electricity Authority of India
CERC	Central Electricity Regulatory Commission
ckm	Circuit Kilometer
CPP	Critical Peak pricing
CTU	Central Transmission Utility
DC	Direct Current
DER	Distributed Energy Resources
DG	Distributed Generation
DISCOMs	Distribution Companies
DRE	Decentralized Renewable Energy
DTs	Distribution Transformers
EERE	Energy Efficiency and Renewable Energy
EHV	Extra High Voltage
EV	Electric Vehicle
FACTS	Flexible AC Transmission System
FOR	Forum Of Regulators
GBCI	Green Business Certification Inc.
GPRS	General Packet Radio Service
GW	Gigawatt

HCL	Hindustan Computers Limited
HT	High Tension
HVDC	High Voltage Direct Current
IIT	Indian Institute of Technology
ISGF	India Smart Grid Forum
ISGTF	India Smart Grid Task Force
KEMA	Keuring van ElektrotechnischeMaterialente Arnhem
L&T	Larsen &Toubro
LBNL	Lawrence Berkeley National Laboratory
LT	Low Tension
LVDC	Low Voltage Direct Current
MoP	Ministry of Power
MVA	Mega Volt Ampere
NBSG	National Board for Smart Grids
NCR	National Capital Region
NCSG	National Council for Smart Grids
NDPL	New Delhi Power Limited
NSGM	National Smart Grid Mission
NSGM - PHU	National Smart Project Management Unit
PACE-D	Partnership to Advance Clean Energy - Deployment
PACE-R	Partnership to Advance Clean Energy – Research
PEER	Performance Excellence in Electricity Renewal
PHEV/EV	Plug-in Hybrid and/or Electric Vehicles
PGCIL	Power Grid Corporation of India Limited

PLC	Programmable Logic Controller
PLF	Plant Load Factor
PMU	Phasor Measurement Units
POSOCO	Power System Operation Corporation Limited
R-APDRP	Restructured Accelerated Power Development and Reforms Program
RE	Renewable Energy
RF	Radio frequency
RPO	Renewables Portfolio Obligation
RTP	Real Time Pricing
SCADA	Supervisory Control And Data Acquisition
SERC	State Electricity Regulatory Commission
STU	State Transmission Utility
TOD	Time of Day
TPDDL	Tata Power Delhi Distribution Limited
TWh	Terawatt-hours
UDAY	Ujwal DISCOM Assurance Yojana
USAID	United States Agency for International Development
USD	U.S Dollars

1. General Framework and Implementation

Indian electricity sector has witnessed tremendous growth in its energy demand, generation capacity, transmission and distribution networks. Keeping pace with the recent technological advancements, it is deploying new types of devices and ICT infrastructure, adopting new monitoring, control and energy management tools, and aiming at fast deployment of smart grid concepts at distribution as well as transmission level. Electricity, being a concurrent subject in India, both central government and state governments are responsible for its growth, operation and control. The central government frames overall regulations whereas each provincial (state) government formulates their policies within the overall regulatory framework. There are separate utilities owning generation, transmission and distribution. Ministry of Power, Government of India deals with perspective planning, policy formulation, processing of projects for investment decisions, monitoring and implementation of power projects, training & manpower development, administration & enactment of legislation in regard to the power generation, transmission and distribution. According to CEA Report, All India Transmission System Capacity as on 30.04.2017 is as follows:

765KV :	**400 KV:**
31,616 ckm	1,59,058 ckm
1,70,500 MVA	2,43,307 MVA
220 KV:	**HVDC:**
1,63,420 ckm	15,556 ckm
3,14,503 MVA	19,500 MW
Total	
3,69,650 ckm	
7,47,810 MVA	

Figure 1: Power Transmission System Capacity *(Source: CEA)*

Central Electricity Authority of India (CEA) advises the government on matters related to the National Electricity Policy and formulates short term and perspective plans for the development of electricity systems. Central Electricity Regulatory Commission (CERC) and State Electricity Regulatory Commissions (SERCs) regulate tariff, formulate policies regarding subsidies and promote efficient and environmental benign policies at central and state levels, respectively. Central Transmission Utility (CTU) and State Transmission Utility (STU) ensure development of an efficient, coordinated and economical system of interstate and intra state transmission systems, respectively. The central transmission utility, Power Grid Corporation of India Ltd (POWERGRID), is responsible for national and regional power transmission planning, while the state sectors have separate state transmission utilities.

The grid management in India is being carried out on a regional basis. The country is electrically demarcated into five regions namely, Northern, Western, Southern, Eastern and North Eastern Region (Figure 2). In December, 2013, Indian grid is operational as a single synchronous grid operating at single frequency. As per the Electricity Act, 2003, each of the five regions has a Regional Load Despatch Centre (RLDC), which is the apex body to ensure integrated operation of the power system in the concerned region. At national level, National Load Despatch Centre (NLDC) has been established for optimum scheduling and despatch of electricity among the regions. The RLDCs, in conjunction with State Load Despatch Centres (SLDCs), are responsible for carrying out the real time operation of the grid and despatch of electricity within the region through secure and economic operation of the regional grid. All activities are undertaken in accordance with the Grid Standards stipulated by the CEA and the Grid Code / other Regulations notified by the CERC. Power System Operation Corporation Limited (POSOCO), as an independent government company, operates the NLDC and RLDCs with effect from the 3rd January, 2017. It ensures independent system operation and provides level playing field to all stakeholders. Private sector participation is increasing in generation, distribution sectors following the Electricity Act 2003, allowing increased competition.

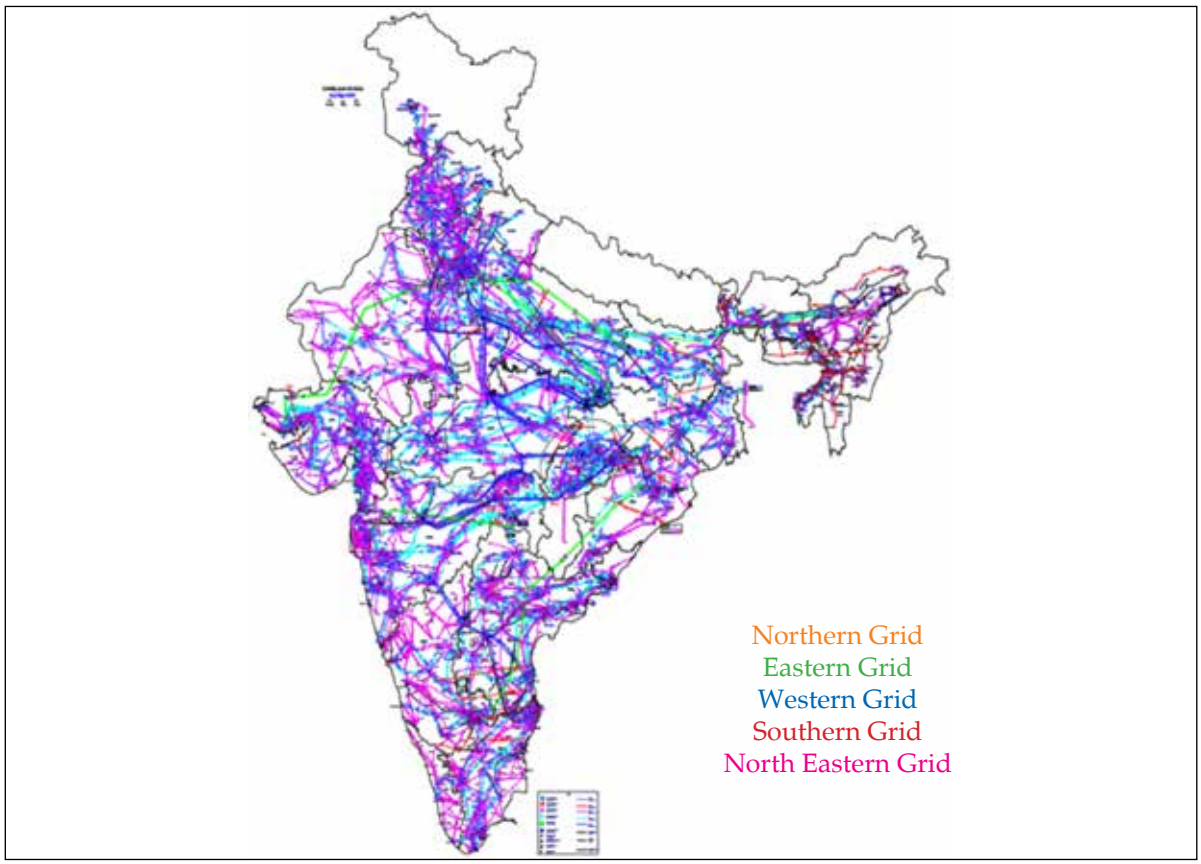


Figure 2: Regional grids in India

The population of India is 1,326,801,576 as of March 2017, while occupying 3.287 million km² surface area. The utility electricity sector in India has a National Grid with an installed capacity of 326.8 GW (as of 31 March 2017) (Figure 3). The country's power installed capacity as on 31st March 2017 and energy consumption during April 2016-March 2017 have been 326.8 GW and 1114.41 TWh, respectively, as given in Table-1 in Annexure-II.

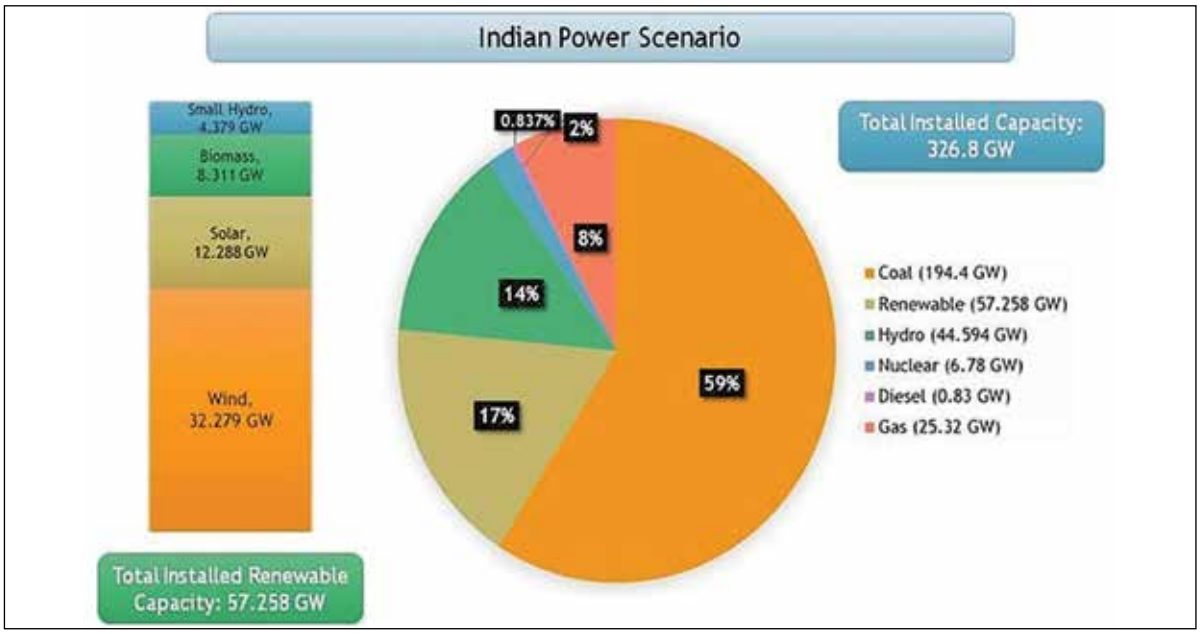


Figure 3: Indian power sources mix

During the fiscal year 2016-17, the gross electricity generated by utilities in India was 1159.835 Billion Units, whereas the per capita electricity consumption in the year (2015-16) was 1,075 kWh [1]. The country's energy mix has been gradually increasing with a share of oil, coal, gas, nuclear power and hydro power. The transmission & distribution losses during the year 2014-15 (provisional) including commercial losses were about 22.77%[1]. The target on distribution utilities is to reduce the Aggregate Technical and Commercial (AT&C) losses below 15% by 2017, below 12% by 2022, and below 10% by 2027, transmission utilities to reduce transmission losses to below 4% by 2017 and below 3.5% by 2022 in the country[2].

[1] http://www.cea.nic.in/reports/monthly/executivesummary/2017/exe_summary-04.pdf
[2] Smart grid Handbook for Regulations & Policy makes prepared by ISGF & supported by Shakti Sustainable Energy Foundation.

In 2014, the Government of India embarked on an ambitious plan to increase the share of renewable energy in the country's energy mix, setting targets to achieve 175 GW of installed renewable energy capacity by 2022. In order to meet this target by 2022, the renewable energy sector in India will require $189 billion additional investment.

2. Status of Renewable Energy Sources

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 providing incentives for solar power generation and also for various solar applications, and has set a goal that solar should contribute to 8% of India's total consumption of energy by 2022. With such high targets, solar is going to play a key role in shaping the future of India's power sector.

As of March 31, 2017, India's cumulative grid interactive or grid tied renewable energy capacity (excluding large hydropower) reached about 57.24 GW with 57% of the renewable power from wind, while solar contributed nearly 21% [3] (Figure 4). Large hydro installed capacity was 44.48 GW as of March 31, 2017. Energy generation from renewables in the country is given at Table-2 in Annexure-II.

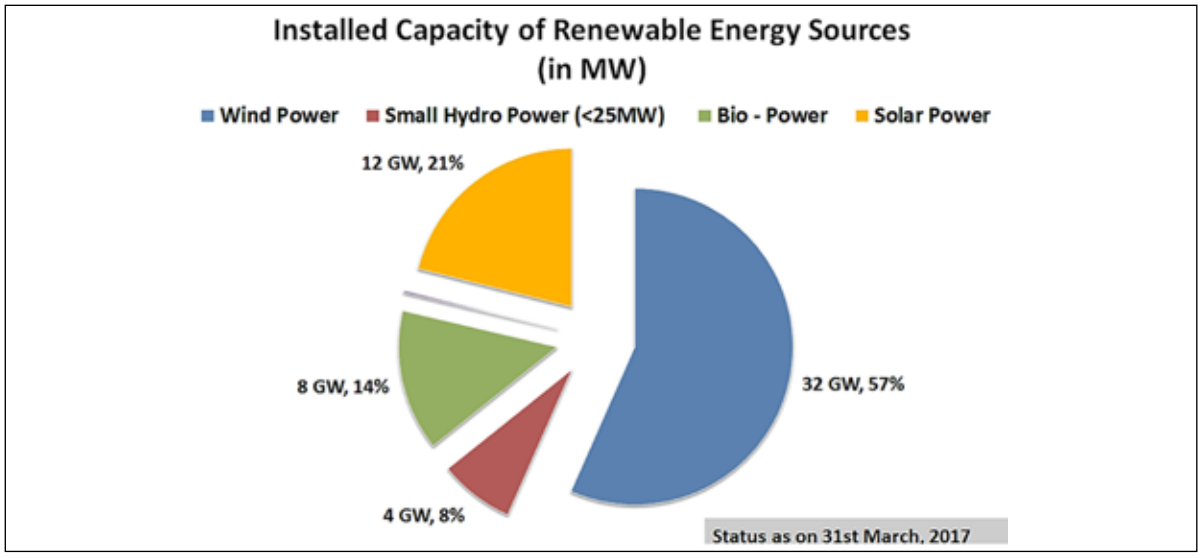


Figure 4: Installed capacity of renewable energy sources

In Indian context, the off-grid energy can be defined as the demand which is not connected to the central electrical grid and is underserved by the grid i.e. less than four hours of electricity per day. In addition to this, Decentralized Renewable Energy (DRE) system comprises of smaller power plants that generate and feed into the distribution network, and can connect multiple households and businesses.

The Government of India has rolled out "Power for All" programme to address India's energy security challenge through renewable energy based mini-grids. The Government of India has set a target of 175 GW renewable power installed capacity by the end of 2022 (Figure 5). This includes 60 GW from wind, 100 GW from solar, 10 GW from biomass and 5 GW from small hydropower [4]. The Central Government has taken several initiatives to increase the penetration of renewable energy through policy initiatives including enactment of a national offshore wind energy policy. M/s Suzlon Energy is already working on a 600 MW offshore wind energy project in the state of Gujarat, India.

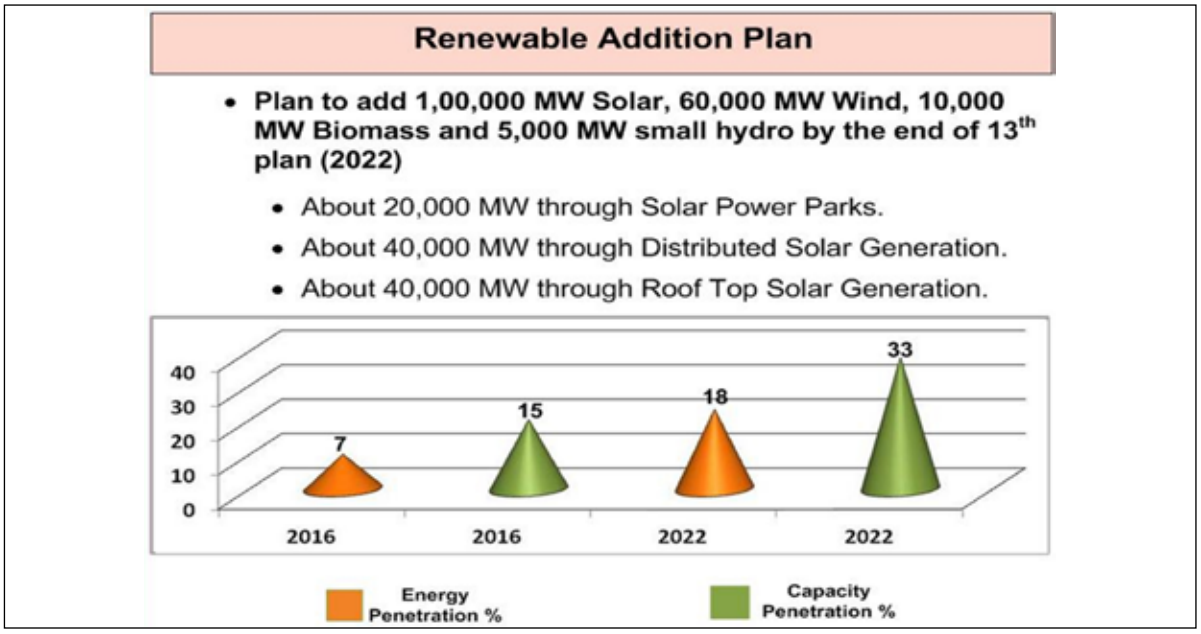


Figure 5: Plan for addition of renewables

Government of India's (GoI) new initiatives in order to enhance the renewable energy penetration into the grid is as follows:

1. Policy Initiatives

a. Revision in Tariff Policy: The revised Tariff Policy, notified by GoI in January 2016 has several provisions aimed at accelerating deployment of renewable energy in the country, including, inter alia, provisions for (a) 8% solar Renewable Purchase Obligation (RPO) by the year 2022; (b) Renewable Generation Obligation (RGO) on new coal/lignite based thermal plants; (c) bundling of renewable power with power from plants in case of fully depreciated power plants whose Power Purchase Agreements (PPAs) have expired; and (d) exemption of renewable energy from inter-state transmission charges. The Government has also issued guidelines for long term growth of RPOs for non-solar as well as solar energy.

b. **Expert Committees at GOI level on Large Scale Integration of RE:** A high level Technical Committee was constituted by GoI in April, 2015 for various issues relating to large scale integration of renewable generation. It recommended several actions such as bringing flexibility in the conventional generation, frequency control, maintaining generation reserves, introduction of ancillary services, forecasting, scheduling, deviation settlement mechanism, balancing mechanism and robust data telemetry and communication systems. It also emphasized on establishment of Renewable Energy Management Centres (REMCs), augmentation and strengthening of Transmission system as well as compliance to Regulations & Standards by renewable generation .

c. **Guidelines on Cross Border Trade of Electricity, 2016:** Government of India has issued guidelines on Cross Border Trade of Electricity in Dec 2016 with the objective of facilitating cross border trade of electricity between India and neighboring countries. It aims to promote transparency, consistency and predictability in regulatory approaches across jurisdictions and minimize perceptions of regulatory risks. Accordingly, a draft regulation on Cross Border Trade of Electricity has also been notified on 16th February 2017. These guidelines would ensure establishment of a larger footprint suitable for RE integration[3].

2. Regulatory Interventions

a. **Regulatory Framework for Intra-State Balancing, Accounting and Settlement System:** Robust metering, accounting and settlement is a fundamental requirement for effective RE integration. A Technical Committee of Forum of Regulators (FOR) has been constituted to evolve roadmap for implementation in November, 2015. Accordingly, implementation of Scheduling, Accounting, Metering and Settlement of Transactions (SAMAST) in Electricity in the States has been taken up by the Technical Committee of the Forum of Regulators. The recommendations covered, inter-alia, Facilitating Economic Despatch, Ensuring Interface Meter Adequacy, Implementation of Scheduling Mechanism, Real-Time Generation Despatching, Implementation of Energy Accounting System, Implementation of Settlement System, Transparency, Integrity and Probity of Accounts, HR Skill Development, Human Resource and Logistics. A copy of the report of the Technical Committee, released in July, 2016 is also available at the web-link: http://www.forumofregulators.gov.in/Data/WhatsNew/SAMAST.pdf

   Model Regulations have been formulated by FOR in March 2017, regarding Imbalance Handling (Deviation Settlement Mechanism) at intra-state level for adoption by respective State Electricity Regulatory Commissions (SERCs).

b. **Amendments to Indian Electricity Grid Code 2010:** Following amendments have been done by CERC for facilitating large scale integration of renewables:

[3] https://www.powermin.nic.in/sites/default/files/uploads/final_consolidated_report_RE_technical_committee.pdf

i. **Forecasting:** The Central Regulator has mandated that forecasting may be done both by the wind/solar generator(s) and the concerned Regional Load Despatch Centre (RLDC). The choice is given to wind/solar energy generator to carry out own forecast or take the forecast given by concerned RLDC.

ii. **Scheduling:** Wind/solar generators at the inter-state level whose scheduling is done by the RLDCs may be scheduled like any other generator and are to be paid as per scheduled generation. A maximum of 16 revisions for each one and half hour time slot in a day starting 00:00 hrs. is allowed to the Wind/solar generators to revise their schedules.

iii. **Incentivizing Flexibility:** Additional compensation for degradation of Station Heat Rate (SHR) has been allowed along with defining 55% of installed capacity as the technical minimum considering the flexibility requirements of conventional plants in high renewable scenario. PLF of conventional plants has also seen a decline over the years[4].

Model Regulations have been formulated by FOR in November 2015 regarding Forecasting, Scheduling and Imbalance Handling of RE generators at intra-state level for adoption by SERCs. 10 states have floated the draft regulations for stakeholder consultations and 1 state (Karnataka) has notified the final regulation.

c. **Imbalance Handling Mechanism:** Deviation Settlement Mechanism (DSM) for imbalance pricing has been introduced in India by CERC since February, 2014 replacing erstwhile Unscheduled Mechanism (UI) in vogue since 2002, with amendments in Nov 2015/May 2016 for renewables. Following specific provisions related to RE have been included:

i. In case of deviations from the schedule, CERC has fixed a percentage of error in a 15-minute time block and Charges for Deviation payable/receivable to/from Regional DSM Pool by the renewable generators.

ii. These charges for deviations by renewable generators have been delinked from the frequency. When the error is less than or equal to 15%, the charges for deviation are computed at a fixed rate for the shortfall energy for absolute error upto 15%. When the error is more than 15%, there are additional charges for deviation along with the fixed rate. The methodology for computation of fixed rate has been specified by the Central Regulator in the regulations.

iii. "Renewable-rich State" has been defined as a State that has 1000 MW or more of installed wind/solar capacity. Two categories of RE-rich states have been created taking into account the quantum of renewable penetration in the state grid. Deviation limits have been increased for such RE rich states.

[4] https://posoco.in/download/flexibility_requirement_in_Indian_Power_System/?wpdmdl=711

d. **Ancillary Services Operations:** This mechanism, launched in April, 2016, utilizes un-despatched surplus in Pan-India regulated generating stations. There is a regulatory framework for both Regulation Up and Regulation Down service by Reserves Regulation Ancillary Services (RRAS) providers. NLDC, designated as the Nodal agency, in coordination with RLDCs, operate these services in events such as unprecedented weather events, tripping of generating unit or transmission line outage and load generation imbalance. It is a layer of centralized Ancillary Despatch over decentralized layer of generating station scheduling process. The generating stations are also incentivized for participating in Ancillary Service framework[5].

e. **Interconnection of RE generators to the grid:** CTU has been mandated to carry out the transmission planning process including renewable capacity addition plan issued by MNRE. The RES generating stations have been given a must-run status. The Central regulator has mandated that RE projects having an aggregate installed capacity of 50 MW and above may seek connectivity to the Inter-State Transmission System (ISTS) network with a provision for one player acting as the lead generator to discharge all operational and commercial responsibilities.

f. **Reserves:** Adequate reserves are an essential requirement for balancing renewables and a roadmap for implementation of reserves has been provided by CERC in October, 2015. In order to handle the variability in a large grid like ours, automatic controls are essential. In this direction, a pilot project for implementation of Automatic Generation Control (AGC) is being implemented and scheduled for completion by June, 2017. This would be followed by country wide rollout of AGC. Provision of Primary Response has also been made mandatory for the generators to control sub-minute fluctuations.

g. **Transmission Planning for Renewables:** Reform in transmission planning is required considering the requirement of RE integration. In this regard, draft regulation on transmission planning has been notified by CERC in April 2017. It proposes that transmission system may be planned by CTU/CEA based on estimated capacity additions in perspective plan and RPO of each State and approach CERC for regulatory approval for the same. In addition, the Standing Committee on Transmission Planning may consider margins to cater to renewable capacity additions. Sensitivity analysis may be carried out for low, moderate and high renewable capacity addition.

h. **Technical Standards for RE Connectivity to the Grid:** CEA has also floated draft amendments in the provisions related to connectivity requirement for RE in 'Technical Standards for connectivity to the Grid, Regulations, 2007' for stakeholder consultations. These amendments include provisions related to frequency response, HVRT, LVRT, ramping requirements, voltage regulations requirements, compliance monitoring etc[6].

[5] https://posoco.in/download/half-year-feedback-to-cerc/?wpdml=8916
[6] http://www.cea.nic.in/reports/regulation/draft_technical_std_grid_regulation.pdf

i. **Regulatory Framework for Communication in Power Sector:** The Users including renewable energy generators shall be responsible for provision of compatible equipment along with appropriate interface for uninterrupted communication with the concerned control centres and shall be responsible for successful integration with the communication system provided by CTU or STU for data communication as per guidelines issued by NLDC.

j. **Changes in Electricity Market Design:** The introduction of sub-hourly bidding in power exchanges in 2012 has facilitated consistency with scheduling, metering and accounting timeframes leading to better portfolio management by utilities. The issue of providing flexibility in terms of market participation to renewable sources of energy is largely addressed by sub-hourly market as it enables them to bid with more precision on the Day Ahead Market in power exchange(s). Also, Regulatory Framework for more opportunities to trade in electricity market has been provided through the Power Exchanges with 24x7 extended market sessions from July 2015. FOR "Technical Committee for Implementation of Framework on Renewables at the State Level" formed a Sub-Group in May, 2017 to examine the various modalities of migrating from 15-minute to 5-minute scheduling, metering, accounting and settlement at the inter-state level to facilitate large scale integration of renewables.

k. **RE Integration Studies:** In order to assess the impact of 175 GW RE on the power system, RE Integration studies were undertaken under a broader program, Greening the Grid (GtG), which is an initiative co-led by India's Ministry of Power and the U.S. Agency for International Development (USAID).

l. **Electricity Storage:** A staff paper on "Introduction of Electricity Storage System in India" has also been issued by CERC to address issues with the shifting of generation, regulating electricity despatch, maintaining flow control in the transmission system and strengthening the reliability of the power system without adding capacity from traditional and variable sources of power.

m. **Capacity Building:** Intense capacity building exercises are being undertaken for stakeholders through various agencies such as National Power Training Institute, NIWE, NISE etc. including support from international agencies such as USAID, GIZ, NREL, LBNL, etc. Exchange programs for Regulators are also being organized to facilitate exposure to international best practices. A Specialist Level Course for System Operators of NLDC/RLDC/SLDCs in RE Integration is also being conducted.

The central government has immense support mechanism but the other dimension that impacts these mechanisms are the role of the provincial / state-level distribution utilities, which are the

Figure 6: New Initiatives of Government of India

decision-makers when it comes to consumption. In almost all states / provinces, Steps taken by utilities towards renewable integration have been top-down imposed, either through state policy, or regulatory requirements, or through a Renewables Portfolio Obligation (RPO). The utilities are concerned with variable and intermittent source of renewable energy that costs more than its average supply costs today and offer a Capacity Utilization Factor (CUF) close to 20 %, whereas coal plants easily operate at 75-80 %PLF.

The Union Budget 2017, focuses on clean power and energy security. It energises 20 Giga Watts

Figure 7: Green Energy Corridors for integration of renewables

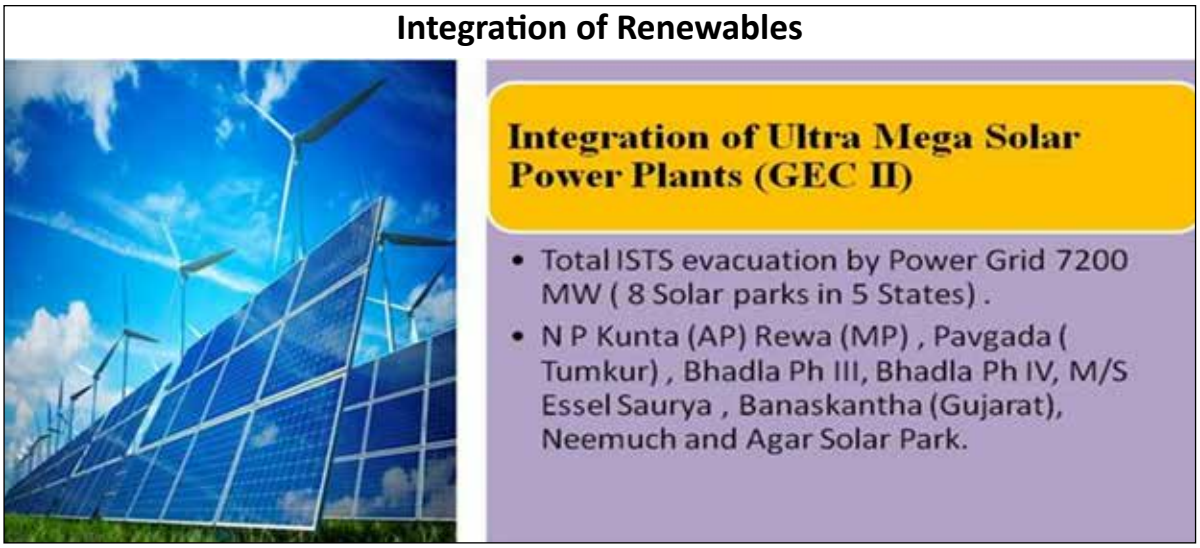


Figure 8: Integration of Ultra Mega Solar Power Plants

(GW) of solar capacity addition and higher spending on electrification of 18,452 villages identified in 2015 with a deadline of 1st March, 2018.

3. Status of Smart Grids Activities

There is plenty of untapped potential in the Indian electricity sector. The relevance of Smart Grid and Micro-grid for the country has been emphasized by government officials and the representatives of the energy industry, creating a promising business opportunity. The primary goal of India is electrification of all households, provide adequate power for agriculture sector and 24x7 availability of power to every citizen by 2019. A limitation of renewable resources is the intermittent nature of supply i.e. the energy 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 at distribution as well as transmission level, as reliable electric supply is one of the key infrastructure requirements to support overall development.

The Vision of India on Smart Grids is to "Transform the Indian power sector into a secure, adaptive, sustainable and digitally enabled ecosystem that provides reliable and quality energy for all with active participation of stakeholders".

There are several challenges facing the implementation of the Smart Grid systems. The main challenges that policy makers face are high capital costs and benefit constraints within the same cost to the consumer as seen by the regulator. Since there is a necessity of reliable communications

network, it escalates the capital and hardware cost to a great extent. The successful operation of the Smart Grid requires seamless connectivity of technology. The available communication technology in India is at par with many developed nations in the world. However, there are issues in terms of interoperability of devices and systems with reference to smart grid deployment in utility environment. Even if the technological developments are aligned, there is an issue of integration of the entire hardware system to manage high volumes of data. It requires complex data models to manage the various data formats that flow into the system.

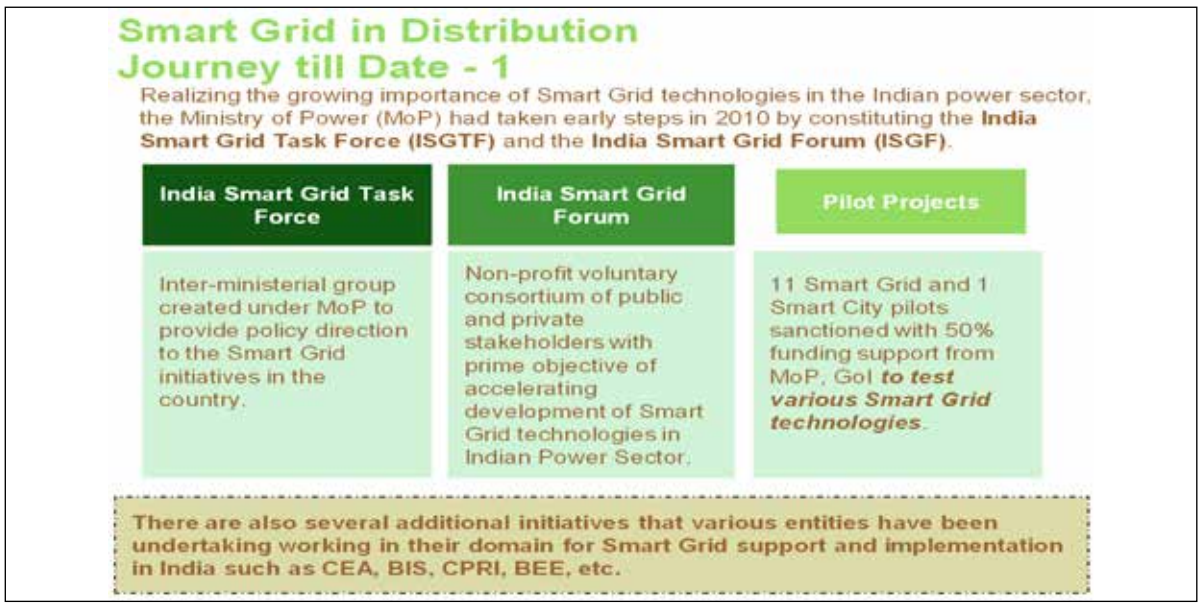


Figure 9: Smart Grid in Distribution *(Source: NPMU)*

Figure 10: Smart Grid opportunities in India *(Source: NPMU)*

In 2015, Ministry of Power, Government of India, established National Smart Grid Mission (NSGM) to plan and monitor the implementation of policies and programs related to the smart grid activities in India. Role of ISGTF was merged into NSGM, NSGM is also coordinating for development of smart grids in the smart cities under Smart Cities Mission. NSGM promotes deployment of Smart Grid technologies like Advanced Metering Infrastructure (AMI), substation renovation and modernization with deployment of Gas Insulated Substations (GIS) wherever economically feasible and Distributed Generation in the form of Rooftop Solar PVs, real-time monitoring and control of Distribution Transformers, creation of Electrical Vehicle (EV) charging Infrastructure for supporting proliferation of EVs, development of medium sized Micro-grids and provision of power quality improvement measures. Government of India is promoting deployment of Smart Grid projects under the NSGM through funding support of 30% on capital expenditure.

Department of Science & Technology (DST), Government of India has funded around US$ 46.5 million towards R&D on Smart Grids. Indian academic institutions including Indian Institute of Technology (IITs), Indian Institute of Science (IISc) and private industries have been engaged in R&D on Smart Grids in India. Some of the projects undertaken by the academic institutions, which are funded by Department of Science & Technology, Government of India, are at advance stage of completion. These funded projects include national as well as bilateral programmes with countries like US, UK and Netherlands. The salient features of few Research, Development, Demonstration & Deployment projects implemented in India (case studies) are given in Annexure-I. Smart Grid technologies involve deployment of ICT and IT infrastructure. Some of the functionalities/ technological advancements adopted for smart grids in Indian scenario are:

3.1 Advanced Meter Infrastructure

Advanced Metering Infrastructure (AMI) facilitates monitoring and measurement of consumer information and control through Smart Meters installed at customer premises. It supports bidirectional flow of information between consumer and utility control centre through communication mode such GPRS / PLC / RF. Smart meters will also enable Time of Use (TOU) and Critical Peak Pricing (CPP)/Real Time Pricing (RTP) rate metering for demand response.

3.2 Peak Load Management

The peak load management refers to controlling the demand and matching it to the available supply at the instant of peak. The peak load management function shall take inputs from SCADA/EMS regarding power availability and volume of shortage. Based on the shortage, the peak management function shall run algorithms considering various constraints and priorities predefined on the basis of customer profile by System Integrator (SI) in association with Employer/ Utility personnel, and suggest the recommended options. The approach shall be to avoid tripping of feeders for load shedding and manage peak load either by load curtailment through AMI or by price incentives/disincentives in the form of ToU pricing.

3.3 Power Quality Management

Power Quality Management addresses events like voltage flickering (Sags/Swells), unbalanced phases voltages and harmonic distorted supply, etc. This will facilitate efficient and reliable operation of the power system, reduce losses, improve customer satisfaction and minimize equipment (utility/consumer) failures. Power Quality management shall include voltage/VAR control, load balancing, harmonics control etc.

3.4 Outage Management

Outage Management System (OMS) manages unscheduled distribution infrastructure like Distribution Transformers (DTs), HT/LT feeders etc. It collects and coordinates information about outages including customer calls and report the operator for taking corrective actions through crew management and remote control enabling customer satisfaction, improves system availability and reliability.

3.5 Micro-grids

A Micro-grid is an integrated energy and communication system consisting of interconnected loads and Distributed Energy Resources (DER), which mainly operates in standalone mode or in parallel with the grid (macro grid) in case of emergency. Micro-grid generation resources include micro turbines, wind, solar, fuel cells or other energy sources. Ability of the micro-grid to isolate from a larger network provides highly reliable electric power to its consumers.

3.6 Distributed Generation

Development and implementation of new and innovative technologies for distributed generation including technologies and solutions related to PHEV/EV (Plug-in Hybrid and/or Electric Vehicles), wind, photovoltaic and other distributed generation technologies, systems and solutions supporting flexibility of interaction with customers, energy usage/exchange, demand and loss management, management of transactions, pricing and billing, etc[7].

The Government, utilities, universities, research institutions, industries supporting smart girds in India is detailed in Annexure - IV.

4. National Programs in the Fields of Smart Grids and Renewable Energy

National Smart Grid Mission

Figure 11: National Smart Grid Mission *(Source: NPMU)*

Twelve (12) smart grid demonstration/pilot projects were sanctioned by Ministry of Power with 50% Government of India grant amounting to US$ 29.56 million and 100% funding for Smart Grid Knowledge Centre for managing research and innovation activities in 2012 (source: NSGM). Subsequently, three full Smart Grid projects# were also sanctioned in 2016 with 30% funding from Ministry of Power. In addition, the country strives to install 35 million smart meters by 2019 [5].

[7] http://www.nsgm.gov.in

The details of smart grid projects being implemented under NSGM are given below.

	S. N.	Utility	Smart Grid Implementing Agency	Date of Award	Sanctioned Cost (million US$)	Consumer Base
Pilot Projects	1	CESC, Mysore	Enzen	Mar'14	5.05	21824
	2	UHBVN, Haryana	NEDO Japan	Apr'14	5.57	11000
	3	HPSEB, Himachal Pradesh	Alstom	Feb'15	3.01	1554
	4	APDCL, Assam	Phoenix IT	Mar'15	4.64	15083
	5	PSPCL, Punjab	Kalkitech	Mar'15	1.57	2737
	6	WBSEDCL, West Bengal	Chemtrols	Jun'15	1.09	5265
	7	TSECL, Tripura	Wipro	Sep'15	9.83	45290
	8	TSSPDCL, Telangana	ECU	Oct'15	6.48	11906
	9	PED, Puducherry	Dongfang	May'16	7.14	33499
	10	AVVNL, Ajmer	USAID PACE-DTA	Sep'15	Not Available	1000
	11	UGVCL, Gujarat	Genus and Fluentgrid	March 17 (LOI)	12.81	23760
	12	IIT-K Smart City Pilot	IIT Kanpur	OCT'15	1.94	20 households
				Sub Total	**59.12**	
Under NSGM	1	Chandigarh, CED#	-	Under Progress	4.43	29433
	2	Amravati, MSEDCL#	-	Under Progress	13.95	148000
	3	Congress Nagar (Nagpur), MSEDCL#	-	Under Progress	21.56	125000
	4	Kanpur, KSEC	-	Under Progress	49.51	539000
				Sub Total	**89.44**	

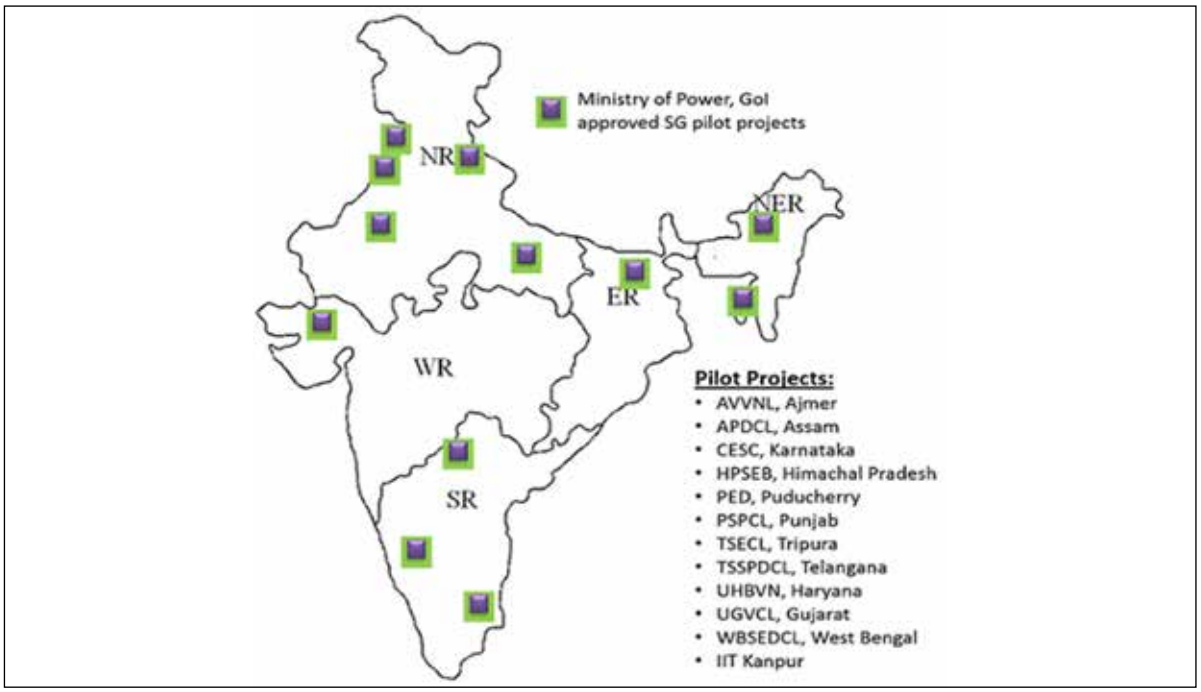


Figure 12: Smart Grid Projects implemented by NSGM

The business cases in Indian smart grids are present in various forms, such as:

- Accurate and well-timed meter reading enables an intervention for loss reduction.
- Remote connection disconnection of consumer load.
- Accurate temper alert such as sanctioned load violation, DT overloading.
- Rooftop solar power speeds up a shift to green energy and produces consumer cost savings in the long run.
- Time-based pricing (Time-of-Use Tariff) signals the consumer to be more dynamic. The Indian Electric Vehicle (EV) rollout requires a functional charging infrastructure – and its management.
- Distribution Companies (DISCOMs) provide the anchor infrastructure for smart grids and cities creating a need for value added services and new business models. However, there is critical need to establish business cases for self-finance of these investments.

Furthermore, a similar need for value added services is recognized with the large electricity consumers. In addition, smart grid utilities require a variety of digital technologies such as analytics, mobility solutions and customer touch points. The distributed generation based on hybrid sources could provide a sustainable and cost effective power supply to the un-electrified pockets. Option of negotiating smart grid projects with the campus owners (educational, special economic zones, industrial parks, etc.) is a viable market entry option for smaller companies and

company consortiums. Moreover, several large Public-Private Partnership smart grid projects present a true mega opportunity for the companies that already operate in the Indian market.

India Smart Grid Forum (ISGF), which is a Public-Private Partnership (PPP) initiative. The ISGF is divided into working groups focused on specific areas:

Working Group	Working Group Activity
1	Advanced transmission Systems
2	Advanced Distribution Systems
3	Communications for Smart Grids
4	Metering
5	Consumption and Load Control
6	Policy and Regulations
7	Architecture and Design
8	Pilots and Business Models
9	Renewables and Micro-grids
10	Cyber Security

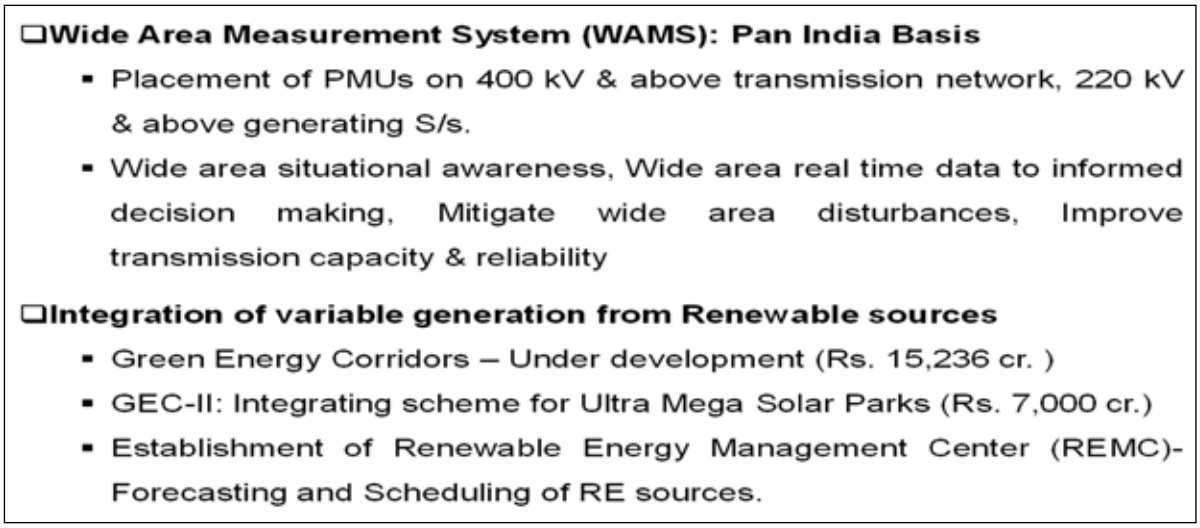
Figure 13: ISGF working groups

Tata Power Delhi Distribution Limited (TPDDL), previously North Delhi Power Limited (NDPL), is a joint venture between Tata Power and Delhi Government. NDPL is among the earliest adopter of Smart Grid approach. They have collaborated with General Electric (GE) for using various Smart Grid approaches for efficient distribution of electricity. NDPL serves the National Capital Region (NCR).HCL Technologies Limited (HCL) has partnered with Echelon (A Smart Grid product Development Company) for providing smart metering and network infrastructure services. It has also roped in Oncor as a client for its Smart Grid infrastructure services. Telvent recently announced that it is going to partner with L&T for Smart Grid Projects in Maharashtra State. In India, KEMA is going to serve as knowledge partner to Bangalore Electricity supply company Ltd. (BESCOM) for its Smart Grid project.

Power System Operation Corporation Limited (POSOCO), a Government of India Enterprise, is also implementing various projects on Synchro-phasors/WAMCPS (Wide Area Monitoring, Control and Protection System) in India. Synchro-phasors/WAMS are the most essential part of Smart Grid at transmission level. A pilot project is already operational at national load Despatch center with more than 60 Phasor Measurement Units (PMUs) already installed starting 2010 in the regional grids. The country felt large scale deployments of WAMCPS with PMUs at transmission grid, after its major grid disturbances on July 30 and 31, 2012. Under Unified Real Time Dynamic State Measurement (URTDSM) project [10], the Powergrid is installing about 1700 PMUs covering all 400 kV and above voltage level substations and major generating station for enhanced dynamic security monitoring and visualization of the system. Some of the analytics are being developed by IIT Bombay.

In order to facilitate seemless integration of large scale deployment of Renewables and allowing power flow and power exchange through regional grids, a green transmission corridor [11] is being developed by Powergrid in the country. Separate renewable desks have been set up at Regional Load Despatch Centers and such Renewable Energy Management Centres (REMCs) are to be co-located with the state, regional and national load centres as per the recommendation of a Technical Committee formed by MoP in April 2016 [12]. This report also suggests measures required to address intermittency of renewable sources in terms of flexible generation and balancing mechanism.

Smart Grid in Transmission



Smart Grid in Transmission

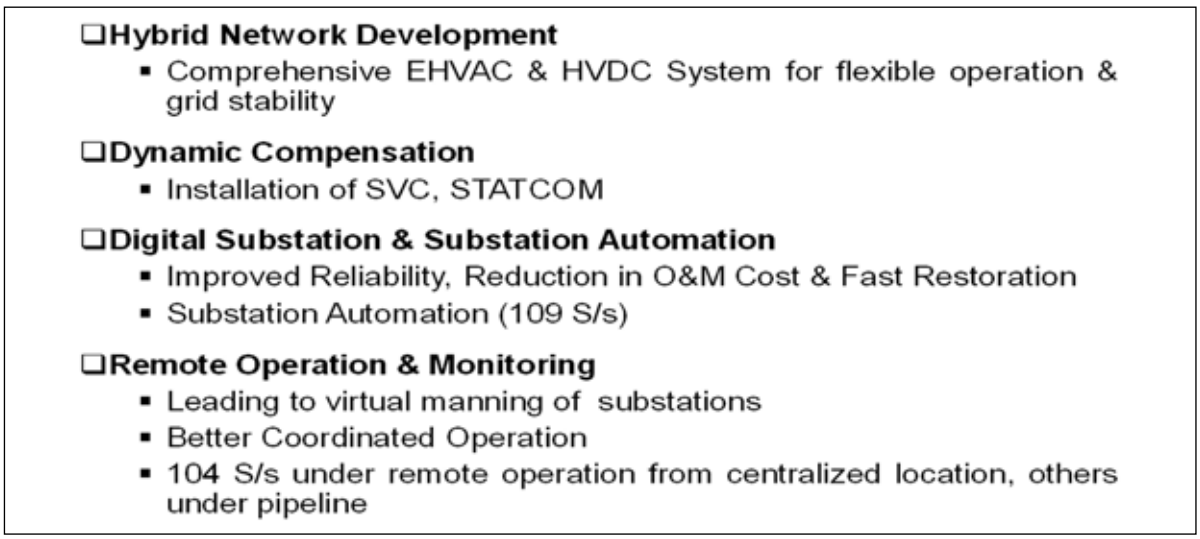


Figure 14: Smart Grids in Transmission *(Source: POWERGRID)*

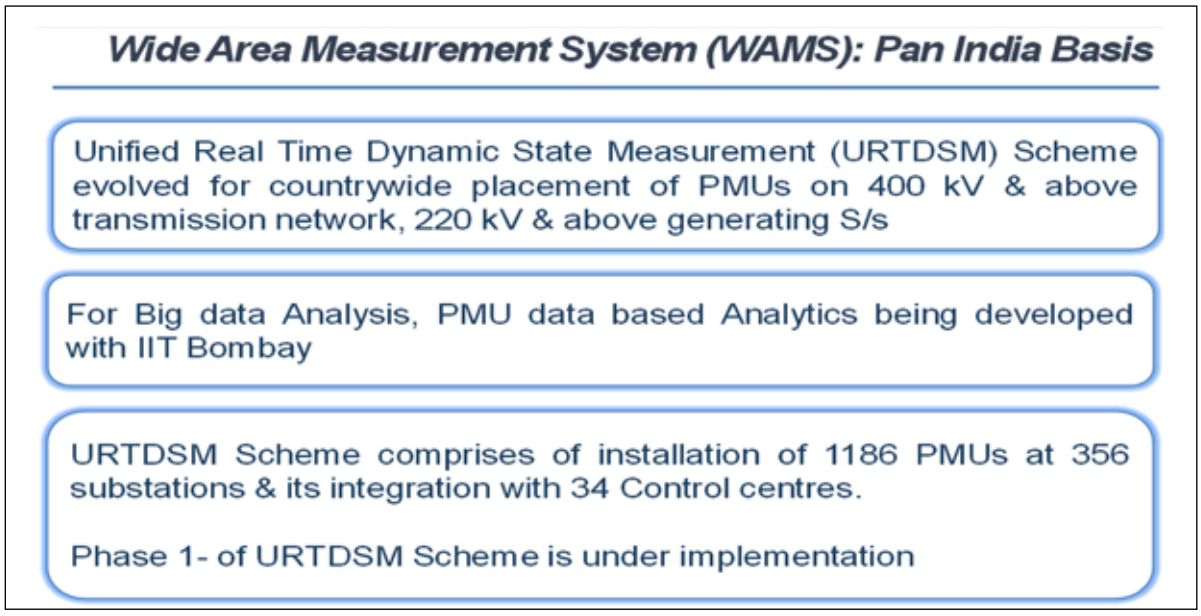


Figure 15: Wide area Measurement System in India *(Source: POWERGRID)*

Green Business Certification Inc. (GBCI) and India Smart Grid Forum (ISGF) announced collaboration on sustainable power systems in India and Southeast Asia designed to accelerate market transformation of smart grid technologies and sustainable power systems in the region through GBCI's PEER (Performance Excellence in Electricity Renewal) program. PEER is designed to measure and improve sustainable power system performance. Through PEER certification, power grids have an opportunity to gain a competitive advantage by differentiating their performance, documenting the value produced and demonstrating meaningful outcomes to accelerate transformation of the electricity sector in the market place. Under the U.S.-India Energy Dialogue, the Energy Department's Office of Energy Efficiency and Renewable Energy (EERE) is promoting U.S. demand response technologies in India by supporting a partnership between the Lawrence Berkeley National Laboratory (LBNL), the Indian utility Tata Power Delhi Distribution Limited (TPDDL), and Honeywell. The U.S.-India collaboration is demonstrating Demand Response (DR) technologies in a pilot program involving 167 buildings with more than 25 MW of enrolled peak load in the northern region of India's capital, New Delhi. First of its kind in India, the field tests serve as a platform for evaluating technologies and suppliers' capabilities, product specifications, determining consumer and utility benefits, and assessing regulatory readiness before rolling out detailed DR and Smart Grid plans in other utility territories and locations in India.

Partnership to Advance Clean Energy - Deployment (PACE-D)

Under this flagship, U.S.-India bilateral program, USAID supporting the Ministries of Power and Ministry of New and Renewable Energy to boost the growth of clean energy in India. PACE-D program is successfully assisting the Government of India in the deployment of energy efficient technologies and decentralized renewable energy systems, such as distributed solar power, by strengthening policy and regulatory institutions, increasing access to finance, and enhancing institutional and human capacity.

USAID-PACE-D program is supporting NSGM-PMU (NPMU) for capacity building programs. PACE-D has supported one pilot project at AVVNL, Ajmer to demonstrate Smart Metering functionality by deploying 1000 meters[8].

Partnership to Advance Clean Energy –Research (PACE-R)

Under Partnership for Advance Clean Energy – Research (PACE-R), US Department of Energy (DOE) and Department of Science and Technology (DST), Govt. of India have jointly agreed to fund smart grids and Energy Storage systems at a total cost of US $ 30 Million with matching government and industrial contributions from both sides.

5. Capacity Building

NSGM is mandated with the role of Training and Capacity Building for Smart Grids. Regular capacity building programs are being conducted for DISCOM officials and other stakeholders.

The Smart Grid Knowledge Center (SGKC) being developed by POWERGRID with funding from Ministry of Power will act as a Resource Centre for providing technical support to the Mission in all technical matters, including development of technical manpower, capacity building, outreach, suggesting curriculum changes in technical education etc. Ministry of Power has sanctioned US $ 0.15 million in this regard.

NSGM with the help of United States Agency for International Development (USAID), launched its first series of training programs aimed at building the capacity and skills of utility personnel to develop India's Smart Grid infrastructure. Last year two Smart Grid training programs were conducted with the help of USAID that was attended by more than 80 DISCOM officials associated with Smart Grid projects in the country. This training will help the Government of India to achieve its target of having 10 percent of personnel from 14 of India's state utilities trained in Smart Grid functions.

[8] https://www.usaid.gov/india/energy-environment-and-globle-climate-change

6. Cyber Security

Cyber security of Critical Infrastructure is a growing concern among business and Governments worldwide. The Government of India (GOI), through Information Technology Act-2000 laid the foundation of Indian Computer Emergency Response Team (CERT-ln), an organization dedicated to the cause of Cyber Security standards, compliances, incident response and guidance. The Government of India, after reviewing the needs of cyber security in critical infrastructure sector, created dedicated sectoral CERTs. Following the directives of GOI/ CERT-In, MOP created four sectoral CERTs, namely

- CERT - Thermal - NTPC
- CERT - Hydro - NHPC
- CERT - Transmission - POWERGRID
- CERT - Distribution - DP&D Division, CEA

Further, the Government of India, under the provision of Information Technology Act, 2000 created National Critical Information Infrastructure Protection Centre (NCIIPC).

Following the best practices in the area of Cyber Security, a central coordinating agency to share and analyze various cyber security incidents in the Power Sector, Information Sharing and Analysis Centre (ISAC-Power) was conceived. The ISAC-Power will be the common platform for the four sectoral CERTs under Ministry of Power. The ISAC-Power will focus to be the Central Information Resource pooling and sharing platform.

7. Smart Metering

Several government initiatives and policies, such as Restructured Accelerated Power Development and Reform Program (R-APDRP) and Central Electricity Authority (CEA) guidelines, have paved the way for intelligent smart metering in the country. The current size of the energy metering market is approximately US$ 340.82 million and it is expected to grow at a Compound Annual Growth Rate (CAGR) of 8-10 per cent over the next 4-5 years. Further, UDAY - a scheme for operational & financial turnaround of DISCOMS (Figure 16) and estimated to install 35 million smart meters by 2019 [5]. India exported over 400,000 of its electricity supply and production meters to Australia, followed by over 50,000 meters to Malaysia, the United Kingdom, and the United Arab Emirates. India's imports of electricity supply and production meters were very limited—less than 5,000 meters each from Hungary, Singapore, Indonesia, and China in 2012; by value, Germany and the United States were the leading foreign suppliers (Figure 17 & 18). The details of smart meters installed, electric vehicles manufactured in India, installation of automated sub-stations are given at Table-3 in Annexure-II.

Smart Cities Awas Yojna Mission (Smart City Mission) was launched by Prime Minister of India in June 2015. Smart Cities Mission is an urban renewal and retrofitting program by the Government of India with a mission to develop 100 cities all over the country making them citizen friendly and sustainable. Smart meters are one of the areas identified by Government of India in this mission. Implementation of FACTS & PMU for transmission grid is looked after by Central Transmission Utility and funded through their resources.

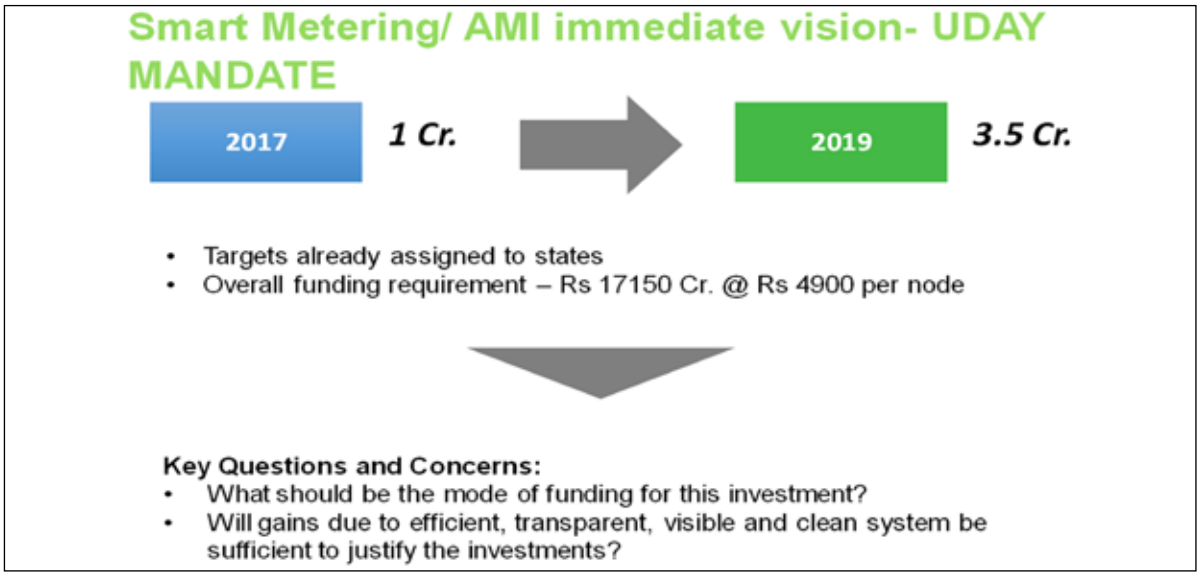


Figure 16: Mandate of UDAY *(Source: NPMU)*

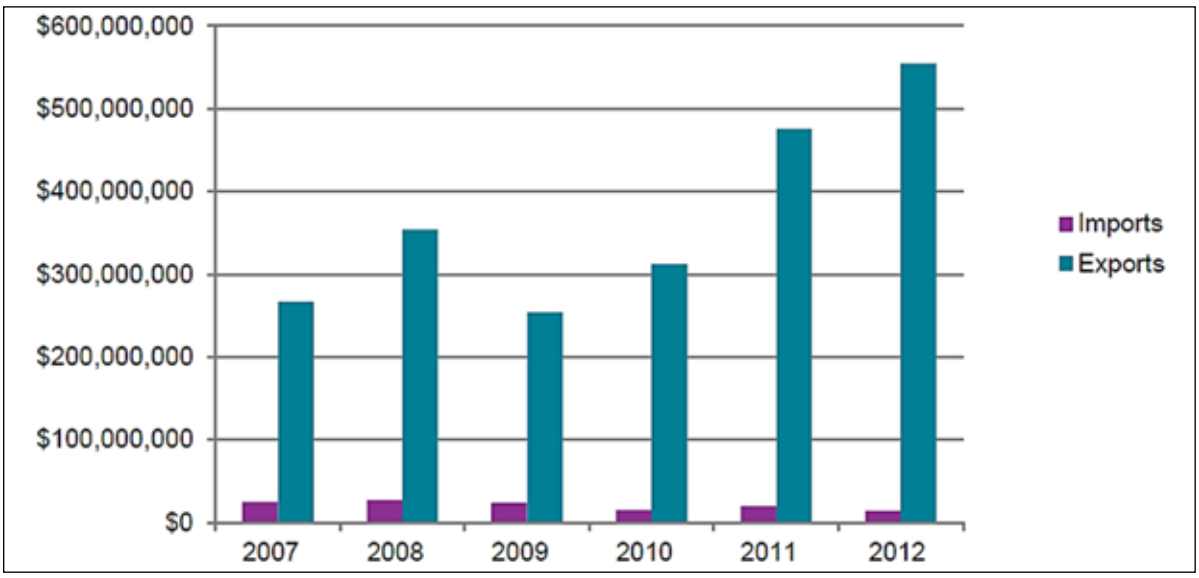


Figure 17: Share of India's imports and exports of electricity meters, by value [9]

[9] GTIS, Global Trade Atlas (access Jan 6, 2014)

Smart Meter Deployment: Success Story Tundla

Tundla Town: Challenges(October 2014)

Billable consumers :9572 Monthly Input energy :2.20 MU	ATC Loss: >35% Thru Rate:< Rs 3.5

- 87% of LMV-1 consumer avg consumption 47.44 units per KW pm(rest 292.9 units)
- 72% of LMV-2 consumers avg consumption 29.47 units per KW pm(rest 150 units)

Scope of Work:

Supply and Installation of RF based Single Phase and Three Phase Electric meters
Single Phase Meters- 8,500
Three Phase Meters- 500
Supply, Customization, Integration, Testing and Deployment of AMR Application
Supply and setup of IT hardware like Server, UPS and Printer
Set-up Data Centre at Tundla Sub- Division Office
Meter Reading, Bill Printing and Bill Distribution for 60 months
Data Analysis and Reporting for 60 months

Performance metrics: Actual Revenue Vs ATC Loss

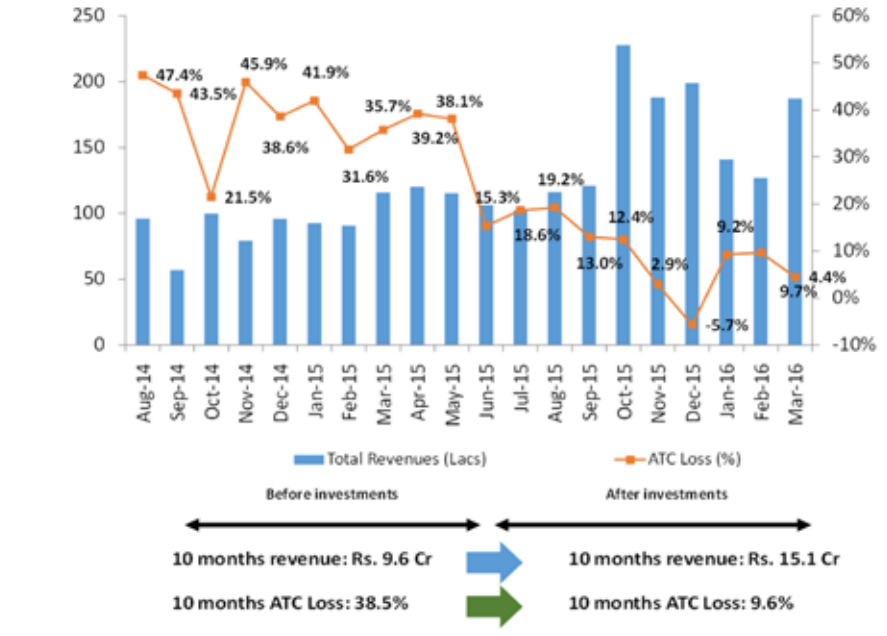


Figure 18: Success Story of Smart Meter Deployment *(Source: NPMU)*

8. Research & Development Priorities on Smart Grids

A national workshop on 'Smart Grid' was held on 22nd May 2017 at IIT Delhi involving various stakeholders to discuss challenges and identify various Research & Development (R&D) priority areas. A list of the areas identified under four different themes, based on the need of the country and having potential benefit of collaborative efforts with the MI country partners, are listed below.

8.1 Operation, Control & Protection

- Operation and control of large, medium and small scale renewable energy sources (R,D,M,C)
- Protection technologies for AC and DC smart grids (R,D,M)
- Wide area monitoring, protection and control (WAMPC) (R,D,C)
- Energy management techniques(R,D,M,C)
- Supervisory control of network with multiple micro and nano grids(R,D,M,C)
- Network analysis and optimal power flow(R,D)
- Modeling and simulation of large power grids (including cyber systems)(R,D,C)
- Seamless Grid operation involving TSO and DSO (R,D,M,C)
- Forecasting of renewable and loads (R,D,M,C)

8.2 ICT & Cyber security

- Reliable wired and wireless communication technologies(R,D,M,C)
- Interoperability and ICT architecture (R,D,M,C)
- Audit and validation tools for cyber security features (R,D,M)
- HAN, WAN, and Internet of things(R,D,C)
- Threat models and Cyber security (R,D,M,C)
- Information privacy and handling challenges(R,D,M,C)
- Cloud Computing, data storage and big data analytics(R, D, M, and C).

8.3 Devices and Technology (Converters)

- Fault ride through enhancement of converter interfaced to renewable energy sources (D, M,C)
- Grid interfacing and islanding issues along with seamless transfer technology(D,M,C)
- Ancillary services participation (R,D,M,C)

(Note: R – Regional, D – Distribution, M – Micro-grid, C - Cross- Innovation)

- Optimal design of flexible power converters (D,M,C)
- Coordination and control of multiple converters and modular multi-level converters (R,M,C)
- Converter technologies for HVDC and MVDC systems(R,D,C)
- Multi-functional hardware smart grid enablers (D,M,C)
- Smart and unified control of converters (M,C)
- Hot swappable converters for smart grids (R,D,M)
- Standardization of voltage and power levels (R,D,M,C)
- Network voltage regulation and power quality (R,D,M,C)
- Wide band gap devices (GaN, SIC) (R,D,M,C)

8.4 Distributed Energy Resources, Storage and Deployment Issues

- Policy, regulatory and market design issues (R, D, M, C).
- Demand side management with optimization and forecasting techniques for storage and renewable energy source (RES)(R,D,M,C)
- Inertial issues of renewable energy resources with stochastic behavior(R,D,M)
- Optimal mix, siting and sizing of energy storages at various levels of network(R,D, M)

(Note: R – Regional, D – Distribution, M – Micro-grid, C - Cross- Innovation)

Annexure-I

Research, Development, Demonstration & Deployment Projects in India

(a) Completed Projects

S. N.	Project Title	Project Outcome	Implemented Institution	Project Investigator
1.	Analysis, Design and Control of Power Electronic converters for Grid interface solar Power Generation	Investigation on solar based power converter control for grid integration	IIT-Delhi	Prof.Bhim Singh bsingh@ee.iitd.ac.in
2.	Voltage and Frequency Control of Microgrid	Investigating different control strategies and technologies for voltage and frequency control in renewable, energy storage based microgrids.	IIT-Delhi	Prof. (Dr.) Sukumar Mishra sukumariitdelhi@gmail.com
3.	1 MW re-synchronizable autonomous grid: DC-DC conversion for Solar PV including MPPT and battery charge controller	Design of re-synchronizable autonomous grid with objective of extracting maximum power from solar and maintaining state of charge control of battery	IIT-Kharaghpur, IIT- Kanpur	Prof.Santanu Mishra santanum@iitk.ac.in
4.	A 1MW Re-synchronizable Autonomous Grid: Active Power Filters	Investigation on active power filter capability of MW scaled re-synchronizable autonomous grid	IIT Madras	Dr. Mahesh Kumar Mahesh@ee.iitm.ac.in,maheshk@iitm.ac.in
5.	Design and development of standalone Solar-PV energy generating system up to 5KW	Development of standalone microgrid based on solar- PV with effective control and energy management schemes	IIT-Delhi	Prof.A.L.Vyas, alvyas@iddc.iitd.ac.in

Research, Development, Demonstration & Deployment Projects in India
(b) Ongoing Projects:

1. High Energy and Power Density (HEAPD) Solutions to Large energy Deficits.	
Related sub-challenge of IC#1	Regional grid innovation
Type of project	Theoretical research, Technology development and Demonstration.
Topic	Ultra-fast simulation, local DC grids, DC grid control & Protection.
Objective	Investigate the mitigation of large energy deficits through mobilising mass local DC grids with storage solutions, to provide necessary demand reduction, demand shifting and demand switching, to ensure supply reliability, and also the innovations required in local DC grids.
Contractors/Project Investigators	• Prof. N. P. Padhy, IIT Roorkee • Prof. A. K. Pradhan, IIT Kharagpur • Prof. Sukumar Mishra, IIT Delhi • Dr. Rohit Bhakar, MNIT Jaipur
Period	14th November 2014- 13th November 2017.
Ongoing and achieved key findings	• Network reduction and load flow analysis of Indian transmission system • The impact of local distributed generation resources on transmission network with up scaling local DC sources is investigated. • DC micro-grid test bench is developed. • Control techniques for grid connected and autonomous DC micro-grids are developed. • DC micro-grid protections schemes are proposed.
Added value for IC#1 objectives	• Innovation in DC grid technologies to resolve large supply interruptions. • The impact of weather conditions on generation, demand and their coincidence. • New control strategies for coordinated control of various renewable energy sources and electric vehicles. • Integrated protection schemes for both ac and dc distribution systems • Analysis of network pricing of renewable generators

Research, Development, Demonstration & Deployment Projects in India

2. Advanced Communication And Control For The Prevention Of Blackouts (ACCEPT)	
Related sub-challenge of IC#1	Regional grid innovation
Type of project	Theoretical research, Technology development and Demonstration.
Topic	Prevention of blackouts, Synchronized measurement technology, Real time state estimation.
Objective	The objective of the project is to address the potential of smart grid technologies to support novel integrated protection and control tools for prevention of blackouts.
Contractors/Project Investigators	• Dr. N. Senroy, Dr. Swades De & Prof. Indra N Kar,IIT Delhi • Dr. Saikat Chakrabarti, Dr. Aditya K. Jagannatham, Dr. Ketan Rajawat, IIT Kanpur • Dr. Ashok K. Pradhan IIT Kharagpur
Period	1st November 2014 – 31st October 2017
Ongoing and achieved key findings	• A new method for identification of Tripped line after a fault with negligible computations. • Protection schemes using WAMS data is developed to prevent the system form further collapse and avoiding blackouts. • Kalman filter based tracking state estimators using PMU measurements to monitor power system in real time is developed.
Added value for IC#1 objectives	• Development of algorithms for next generation state estimators using both conventional and synchronized measurements. • Application of developed methodologies is in the design of system wide stability monitoring to avoid occurrence of system wide blackouts.

Research, Development, Demonstration & Deployment Projects in India

3. Reliable and Efficient System for Community Energy Solutions (RESCUES)	
Related sub-challenge of IC#1	micro grid innovation, Regional innovation and distribution innovation
Type of project	Demonstration
Topic	DC Micro-grids, storage technology, energy management system.
Objective	1) Develop a control strategy for the smart grid ensuring system voltage and frequency are maintained for low inertia system. 2) Examine the impact of the hybrid smart grid on the operation of the distribution network. 3) Investigate the protection requirements from faults both in the main utility and in the smart grid. 4) Determine the control and computational requirements to operate such system. 5) Identify the most cost effective storage technology.
Contractors	Dr. ChandanChakraborty-IIT Kharagpur, Dr.Bhim Singh-IIT Delhi, Dr. K S Reddy - IIT Madras, Dr. Vishal Verma - DTU, Dr.HiralalMurlidharSuryawanshi -VNIT Nagpur, Dr. A K Deb-IIT Kharagpur, GE (Technical Collaboration).
Period	36 Months.
Ongoing and achieved key findings	• Development of Double converter based system for solar power integration, advanced controller to support unbalanced loading in PV micro-grid. • Single stage and double stage solar PV systems are designed, simulated and experimented. • Numerical analysis of packed bed thermocline thermal energy storage using quartzite as storage material and solar salt as heat transfer fluid has been conducted. • Active Islanding detection scheme for grid and DG failure using Goertzel algorithm for community micro-grid has been formulated. • Soft switching based DC-DC Converters.
Added value for IC#1 objectives	• Pilot system models with detailed components. • Software algorithm that will run in central distribution management system. • A complete solution for the power converters for micro grid applications.

Research, Development, Demonstration & Deployment Projects in India

4. Intelligent Micro-grids with Appropriate Storage for Energy (IMASE)	
Related sub-challenge of IC#1	Regional grid, Distribution grid and Cross innovation
Type of project	Theoretical research, Technology development and demonstration.
Topic	On / off grid management, Storage system, Micro-grid architecture and behavior.
Objective	Investigation on integration of generation, storage, and distribution components of micro-grids and deliver adaptable robust micro-grid architectures and energy management strategies.
Contractors	Dr. Prakash C. Ghosh, Prof. Rangan Banerjee, Prof. Vivek Agarwal, Dr. Sagar Mitra, IIT Bombay. Decentralized Energy Systems India Pvt. Ltd.
Period	30/9/2014 to 29/9/2017
Ongoing and achieved key findings	• The micro-grid scenarios for the Indian context have been identified. • A typical urban residential scenario was chosen where different grid back up options were considered.Net energy analysis and cost analysis was done for the system. • An in-house Lithium Sulphur battery is in the development stage for the optimized operation of the micro-grid. • The various communication protocols for the different types of micro-grids are being studied for the optimized operation of a micro-grid in Indian scenario. • The prototype of the major part of the micro grid has been developed in the lab
Added value for IC#1 objectives	• Design of micro-grid architecture and selection of power rating. • On/Off grid energy management • Analyzing and testing of communication protocols. • Appropriate storage selection for power quality issues, daily mismatch and seasonal mismatch issues. • Storage system modeling and its life analysis.

Research, Development, Demonstration & Deployment Projects in India

5. Reconfigurable Distribution Networks	
Related sub-challenge of IC#1	Micro grid and Distribution grid innovation
Type of project	Technology development and demonstration.
Topic	on-grid / off-grid transitions, DC Micro-grid, MV and LV networks
Objective	Identify how a common set of technologies for reconfiguration of electricity distribution networks can bring benefits to both rural networks in developing countries (specifically India) and also well-developed networks (urban India).
Contractors / Project Investigators	• Dr. Prabodh Bajpai, Prof. Debaprasad Kastha, IIT Kharagpur • Dr. Parthasarathi Sensarma, IIT Kanpur • Dr.B. G Fernandes, Prof. Kishore Chatterjee, IIT Bombay • Mr. Tarun Kumar Rathore, M/s. Pan Exergy Pvt. Ltd, Noida • Mr. K.K. Bagchi, M/s. Amrit Bio-Energy and Industries Limited, Kolkata • Mr. Gautam Ray, M/s. CESC Ltd, Kolkata
Period	29/9/2014 to 28/9/2017
Ongoing and achieved key findings	• Design of proposed hybrid micro-grid test facility composed of solar PV array, wind emulator system, Fuel cell system, Diesel generator and storage of Battery and super capacitor along with control platforms to host prototype new devices is completed. • Design and detailed simulation studies of the DC grid with medium and low voltage architectures are currently being aggressively pursued. • Control algorithms for the Back to Back converter are developed to ensure active power balance between the two AC systems being linked. • Decoupled algorithms have been developed for each of the two AC ports to ensure synchronization to the respective AC grids and control of reactive power, which also includes current wave-shaping functions.
Added value for IC#1 objectives	• Development of Micro-grid facility for testing of control algorithms and prototype devices • Control of AC and DC µG interfaces and synchronization management • Systems level modeling, distributed control and simulation studies using a top-down approach. • Sensitivity analysis to include the effects of different level of meshing and specific to different distribution network sections

Research, Development, Demonstration & Deployment Projects in India

6. Ajmer VidyutVitran Nigam Ltd (AVVNL), Ajmer	
Related sub-challenge of IC#1	Implementation of AMI.
Type of project	Smart Grid Pilot in Power Distribution Sector
Topic	Test pilot for implementation of AMI with co-existence of smart meters and over-the-top module retrofitted meters for approximately 1000 consumers.
Objective	Advanced Metering Infrastructure (AMI) & Analytics
Contractors	-
Period	-
Ongoing and achieved key findings	• DT wise vital statistics, instantaneous current, voltage, power factor, and load • Near real time DT audit on daily and monthly basis • DT wise consumer dashboard providing kWh reading, current, voltage, power factor • Load violations with respect to sanctioned load get highlighted. • Environmental (Temp) monitoring for correlation with consumption data

Research, Development, Demonstration & Deployment Projects in India

7. Assam Power Distribution Company Limited (APDCL), ASSAM	
Related sub-challenge of IC#1	Implementation of AMI.
Type of project	Smart Grid Pilot in Power Distribution Sector
Topic	The pilot project covers 15,000 consumers involving 90MUs of input energy. Under RAPDRP Part-A, SCADA / DMS is also being implemented which shall be utilized as basis infra for Smart Grid development. Distributed Energy Integration (solar and available DG backup) is also considered for the pilot project.
Objective	• Advanced Metering Infrastructure- Residential (AMI-R) • Advanced Metering Infrastructure- Industrial (AMI-I) • Outage Management System (OMS) • Peak Load Management- Thru Demand Response (PLM) • Distributed Generation (DG) • Power Quality (PQ)
Contractors	M/s Fluentgrid Ltd, M/s Ericsson, M/s Sinhal Udyog
Period	March 2015 – June 2017
Ongoing and achieved key findings	• Smart Grid Control Centre Hardware and Software Installations is in progress • 6543 nos. three phase Category-A meters, 150DCUs and 7776 nos. single phase Category-A smart meters received at site • Meter Installation of single phase Category- A (Whole current) smart meters started in March 2017. Till now 3000 nos of smart meters have been installed • APDCL is about to place order to Vodafone for WAN connectivity • Factory Acceptance Test (FAT) of the three phase HT & LT CTPT Smart Meters in progress

Research, Development, Demonstration & Deployment Projects in India

8. Chamundeshwari Electricity Supply Corporation Ltd. (CESC), Mysore	
Related sub-challenge of IC#1	Implementation of AMI.
Type of project	Smart Grid Pilot in Power Distribution Sector
Topic	Project involves 21,824 consumers with a good mix of residential, commercial, industrial and agricultural consumers including 512 irrigation pump sets covering over 14 feeders and 473 distribution transformers and accounting for input energy of 151.89 MU. Additional functionality like Agriculture DSM with community portal, consumer portal to support DSM/DR, employee portal for knowledge sharing and benefit realization, KPI based MIS and data analytics for decision support are also proposed.
Objective	• Advanced Metering Infrastructure- Residential (AMI-R) • Advanced Metering Infrastructure- Industrial (AMI-I) • Outage Management System (OMS) • Peak Load Management- Thru Demand Response (PLM) • Net metering
Contractors	M/s Enzen Global Solutions, M/s Cyan Technologies, M/s El Swedy Electrometer & M/s L&T
Period	March 2014 – June 2017
Ongoing and achieved key findings	• 18076 single phase meters installed of which17,775 have been commissioned and communicating data with Control Centre. 446 DCUs installed • Installation of 3 Phase LT/CT GPRS meters isgoing on. Till date 10 meters are installed and data is flowing to MDM

Research, Development, Demonstration & Deployment Projects in India

9. Himachal Pradesh State Electricity Board Ltd (HPSEB), Himachal Pradesh	
Related sub-challenge of IC#1	Implementation of AMI.
Type of project	Smart Grid Pilot in Power Distribution Sector
Topic	The project area covers a base of 1,251 consumers dominated by HT consumers with a peak demand on 97MW. High end power quality meters are also being installed at HT consumers for capturing power quality data remotely for identifying decision on corrective actions in collaboration with consumers.
Objective	• Advanced Metering Infrastructure- Industrial (AMI-I) • Outage Management System (OMS) • Peak Load Management- Thru Demand Response (PLM) • Power Quality (PQ)
Contractors	M/s Alstom Ltd, M/s Genus & M/s Vodafone
Period	February 2015 – June 2017
Ongoing and achieved key findings	• Phase 1 SAT covering PLM, AMI and OMS (without SCADA) conducted, balance tests shall be conducted in Phase 2 of SAT with SCADA • Integration of MDM with existing billing system has been tested successfully for 1 meter on a sample basis. Installation of HT meters which was pending due to billing integration can be started now • Commissioning of RTU and field equipment in progress • PO placed to Vodafone for communication by HPSEB. Point to point connectivity for RTU and MPLS network for field equipment is in progress • Numeric relay has been commissioned in the stations and tested successfully • Installation of Distribution Transformer field equipment (sectionalizers, FPI, reclosers) in progress

Research, Development, Demonstration & Deployment Projects in India

10. Punjab State Power Corporation Limited (PSPCL), Punjab	
Related sub-challenge of IC#1	Implementation of AMI.
Type of project	Smart Grid Pilot in Power Distribution Sector
Topic	The proposed project area has 2,737 no. ofconsumers predominantly domestic consumers with an overall consumption of 112.8 MUs per annum. Unrestricted Peak demand is about 30MW.
Objective	• Advanced Metering Infrastructure- Industrial (AMI-I) • Advanced Metering Infrastructure- Residential (AMI-R) • Peak Load Management- Thru Demand Response (PLM)
Contractors	M/s Kalkitech
Period	March 2015 – June 2017
Ongoing and achieved key findings	• DRS (Data Requirement Sheets) documents for smart meters, DCUs, Control Center software and Factory Acceptance Test procedure have been approved by POWERGRID • Drafting of regulations and consumer awareness plans are in progress. • Control Centre material inspection and installation of UPS and Batteries completed.

Research, Development, Demonstration & Deployment Projects in India

11. Tripura State Electricity Corporation Limited (TSECL), Tripura	
Related sub-challenge of IC#1	Implementation of AMI.
Type of project	Smart Grid Pilot in Power Distribution Sector
Topic	The pilot project covers 45,290 no. of consumers. The proposed project area is covered under RAPDRP Scheme for IT implementation and system strengthening. Time of Use models and Net Metering tariff mechanisms were also proposed for adoption.
Objective	• Advanced Metering Infrastructure- Industrial (AMI-I) • Advanced Metering Infrastructure- Residential (AMI-R) • Peak Load Management- Thru Demand Response (PLM)
Contractors	M/s Wipro Limited & M/s JnJPowercom
Period	September 2015 – June 2017
Ongoing and achieved key findings	• About 10,000 nos. of meters installed • MDAS, MDM and PLM standalone and integrated acceptance tests have already been carried out • Meter data being received at MDM and billing will be done with remote readings. • MDM and other applications are functional.

Research, Development, Demonstration & Deployment Projects in India

12.Telangana State Southern Power Distribution Company Limited (TSSPDCL), Telangana	
Related sub-challenge of IC#1	Implementation of AMI.
Type of project	Smart Grid Pilot in Power Distribution Sector
Topic	The proposed project area covers a number of 11,904 consumers for Smart Meters installations. The project area is covered under RAPDRP Scheme for DAS, IT and SCADA implementation.
Objective	• Advanced Metering Infrastructure- Industrial (AMI-I) • Advanced Metering Infrastructure- Residential (AMI-R) • Peak Load Management- Thru Demand Response (PLM) • Outage Management System (OMS) • Power Quality (PQ)
Contractors	M/s ECIL, Hyderabad
Period	October 2015 – September 2017
Ongoing and achieved key findings	• Field survey has been completed • PoC on one DTR taken up. 28 smart meters (20 single phase, 6 three phase and 2 CT) installed for PoC study • Load profile, instantaneous values reading, measurement values reading communication flow graphs, connect/disconnect and configuring meter from prepaid to post-paid features were demonstrated

Research, Development, Demonstration & Deployment Projects in India

13. Uttar Haryana Bijli Vitran Nigam (UHBVN), Haryana	
Related sub-challenge of IC#1	Implementation of AMI.
Type of project	Smart Grid Pilot in Power Distribution Sector
Topic	The pilot project covers 11,000 consumers with 70 MU input energy consumption. The proposed project area is covered under RAPDRP Scheme for IT implementation and system strengthening.
Objective	• Advanced Metering Infrastructure- Industrial (AMI-I) • Advanced Metering Infrastructure- Residential (AMI-R) • Peak Load Management- Thru Demand Response (PLM) • Outage Management System (OMS)
Contractors	M/s Fuji Electric & Co., Japan & M/s Lotus Wireless Technologies
Period	December 2014 – June 2017
Ongoing and achieved key findings	• SCADA and AMI applications configured and deployed at Haryana Power Training Institute in the month of July 2016 • 200 single phase smart meters installed for testing. 8800 single phase meters have been dispatched. Three Phase meter is under testing • Capacity building training centre is already functional • Award for communication has been placed to M/s Airtel

Research, Development, Demonstration & Deployment Projects in India

14. Uttar Gujarat Vij Company Ltd. (UGVCL), Gujarat	
Related sub-challenge of IC#1	Implementation of AMI.
Type of project	Smart Grid Pilot in Power Distribution Sector
Topic	The pilot project proposes covering 22,230 consumers in Naroda. Some additional functionalities like Load forecasting and Asset Management are also proposed and functionalities of load forecasting, peak power management and outage management are also considered at utility level which will impact all consumers of utility indirectly.
Objective	• Advanced Metering Infrastructure- Industrial (AMI-I) • Advanced Metering Infrastructure- Residential (AMI-R) • Peak Load Management- Thru Demand Response (PLM) • Outage Management System (OMS) • Power Quality (PQ)
Contractors	M/s Genus Power
Period	March 2017 (Ongoing)

Research, Development, Demonstration & Deployment Projects in India

15. West Bengal State Electricity Distribution Company Limited (WBSEDCL), West Bengal	
Related sub-challenge of IC#1	Implementation of AMI.
Type of project	Smart Grid Pilot in Power Distribution Sector
Topic	The proposed project area had 5,265 consumers with two no. of 11kV feeders and 46 DTs. The overall consumption of around 7.46 MUs per annum.
Objective	• Advanced Metering Infrastructure- Industrial (AMI-I) • Advanced Metering Infrastructure- Residential (AMI-R) • Peak Load Management- Thru Demand Response (PLM)
Contractors	M/s Chemtrols & M/s CMS Computers Limited
Period	June 2015 (Ongoing)
Ongoing and achieved key findings	• Site survey completed. DRS for Smart Meters andDCUs were approved • FAT for 1000 single phase meters is in progress inCMS, Mumbai

Research, Development, Demonstration & Deployment Projects in India

16. IIT Kanpur Smart City	
Related sub-challenge of IC#1	Development of Smart City prototype and R&D platform for smart distribution systems.
Type of project	Smart City Pilot
Topic	The project aims to develop a Smart City prototype and R&D platform for smart distribution systems and demonstrates the future capabilities of a Smart City. The project scope includes SCADA implementation at all the substations in the campus and few selected houses for smart home system implementation. Grid connected rooftop solar PV is also installed at the selected houses for demonstrating RE integration... Robust communication network shall also be developed for seamless exchange of information across the prototype.
Objective	• Advanced Metering Infrastructure • Home Automation System • Supervisory Control and Data Acquisition • Distributed Generation
Contractors / Project Investigators	IIT Kanpur
Period	2015-17
Ongoing and achieved key findings	• First phase of installation of SCADA system is completed. RTUs are installed in all substations, and all the HT feeders are being monitored. LT feeders are also going to be included soon in the SCADA system. • 5 kW solar PV panels are installed on the rooftop of 19 houses in the campus. Internet connectivity is provided to the PV inverters, and the solar generation data are being monitored. • Android based application is being developed to enable the residents to follow the solar generation data. • Storage batteries and grid connected hybrid inverters are installed in four (4) houses. The design of the hybrid inverters in these 4 houses is unique in the Indian market. These batteryconnected solar PV systems can feed to the grid, as required by the demand response program. • Single phase smart meters are installed in 19 houses having rooftop solar PV. The meters are providing net power reading. • Nine three phase smart meters are installed in selected buildings in the campus. Data of the meters are being included in the meter data management system. • Considerable progress has been made in system integration, advanced metering infrastructure (AMI) solution, and home automation solutions. Home automation solution is currently under testing in the lab. • Customized distribution boxes (DBs) have been fitted into the smart houses. Non-essential loads in the house will be controlled through this DB with the help of SCADA input, AMI, and home automation solution in a demand response program. • As additional research effort, a low-cost scalable LED driver suitable for application in rural homes is developed. The driver can be scaled-up to drive multiple sets of LED lights without significantly increasing the cost. The packaging of the driver and cost analysis are in progress

Research, Development, Demonstration & Deployment Projects in India

17. Puducherry Smart Grid Pilot Project and Battery Energy Storage System	
Related sub-challenge of IC#1	• Demonstration of Smart Grid and Advanced Metering Infrastructure (AMI) • Development of Battery energy storage system totaling 1000 kW, 500 kWh comprising of (i) Lithium iron phosphate (ii) advanced lead acid & (iii) Zinc Iron Flow batteries
Type of project	Pilot Project
Topic	Around 1600 Smart Meters were installed along with Distribution Transformer Monitoring Unit (DTMU), Fault Passage Indicator (FPI), and Active Power Filter (API), Street Light Automation (SLA). Three different battery technologies to be demonstrated for two different applications (frequency application and energy time shift). Further 33400 consumers are to be included in AMI Smart Grid pilot project funded by MoP. All the battery energy storage systems to be equipped with battery management system, power conditioning system, power management system, monitoring & control system, protection system and necessary fire protection system.
Objective	• Indigenization of Technology • Proof of Concept for Indian conditions • Knowledge Sharing & Capacity Building • Development of a scalable & replicable model • Demonstration of benefits to stakeholders • Policy Advocacy, Regulations, Standards, etc. • Evolution of a Commercial Mechanism
Contractors / Project Investigators	M/s. Powergrid Corporation of India Ltd., M/s Dong Fang China and Electricity Department, Government of Puducherry
Period	19th October 2012 to August 2017
Ongoing and achieved key findings	**Implemented:** • Advanced Metering Infrastructure (AMI) • Demand Side Management & Demand Response (Virtual) • Outage Management System (OMS) • Renewable Energy integration through Net Metering • Power Quality Management (PQM) • Electric Vehicle with Solar Charging Station • Street Light Automation **Under Implementation:** • Battery Energy Storage System: 1.25 MW (Advaneced lead acid and Lithium Ion – 500 Kw and 250 KwH support for Half-hour each and flow battery 250 kw and 1000 KwH for four hours. Battery energy storage system totaling 1000 kW, 500kWh comprising of Lithium iron phosphate & advanced lead acid has been commissioned and is under operation, whereas third system on Zinc Iron Flow batteries would be commissioned by August 2017.

Puducherry Smart Grid Pilot Project – a Snap Shot

Jointly developed by POWERGRID & Puducherry Electricity Department

About 60 collaborators presence & joint effort in the project execution

The main objectives of the project include:

- ✓ Indigenization of Technology
- ✓ Proof of Concept for Indian conditions
- ✓ Knowledge Sharing & Capacity Building
- ✓ Development of a scalable & replicable model
- ✓ Demonstration of benefits to stakeholders
- ✓ Policy Advocacy, Regulations, Standards, etc
- ✓ Evolution of a Commercial Mechanism

Puducherry Smart Grid Pilot Project – a Snap Shot

Attributes / Functionalities:

Implemented:

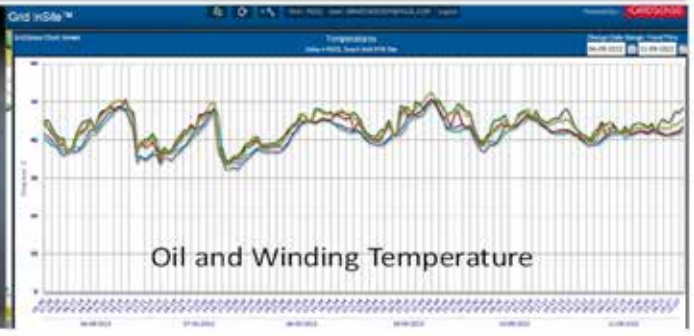
- ✓ Advanced Metering Infrastructure (AMI)
- ✓ Demand Side Management & Demand Response (Virtual)
- ✓ Outage Management System (OMS)
- ✓ Renewable Energy integration through Net Metering
- ✓ Power Quality Management (PQM)
- ✓ Electric Vehicle with Solar Charging Station
- ✓ Street Light Automation

Under Implementation:

- ✓ Battery Energy Storage System: 1.25 MW support for Half-hour

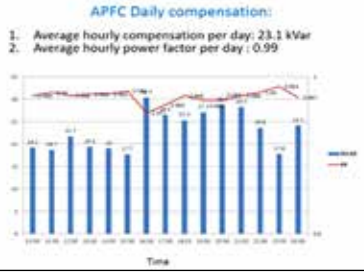
Puducherry- Outage Management System

- ✓ 9 nos. Distribution Transformer Monitoring Systems (DTMS) installed to monitor healthiness of the DTs
  - Oil temperature
  - Oil level
  - Winding Temperature
- ✓ 21 nos. Fault Passage Indicators (FPIs) (communicable / non-communicable) have been installed, receiving alerts at SGCC as well as mobile phones of maintenance crew



Puducherry- Power Quality Management

- ✓ Automatic PFC installed
  - Total VAr compensation: 140kVAr
  - Receiving information at SGCC
  - In steps of (50+50+20+10+10)
  - Built in Capacitor bank controller
- ✓ Active filters installed
  - IGBT based
  - Capacity: 150kVA
  - Smooth control over the rang

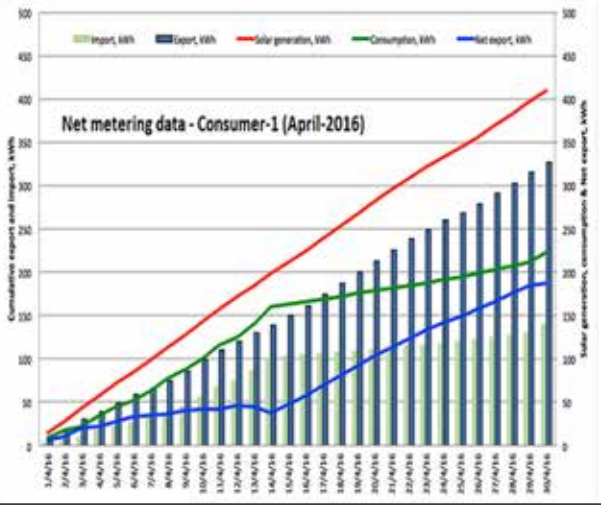


Puducherry- Net Metering

Renewable Energy integration with Net Metering

✓ Smart net meters installed for 2 Roof Top Solar Consumers with commercial mechanism of banking by Puducherry

Energy Exchange from Oct-13 to 24.05.2016 (kWh)	Consumer-1 3 kWp	Consumer-2 2.4 kWp
Total Import from Grid	6419	16063
Total Export to Grid	8651	4808
Net Energy Exchange with Grid	-2232	11255



(Source: POWERGRID)

Annexure-II

Electricity Generation and Consumption Statistics

Table 1 – Electricity Generation, Consumption and losses

Population	1,326,801,576
Total area (in km2)	3.287 million km²
Energy mix (in ton SCE)	Oil, coal, gas, nuclear power, hydro power, rest of energy
1Electricity consumption (in TWh)	1114.41
1Electricity generation capacity (in GW)	326.8*
2Overall network losses (in %)	22.7#

*- upto March2017
#- for the year 2015
1- "All India Installed Capacity (In Mw) Of Power Stations" (Pdf). Central Electricity Authority. 31/03/2017.
2-Ministry of Power, Central Electricity Authority, New Delhi, 31/03/2017.

Table 2 – Electricity mix (April 2016 to February 2017)

(All Figures in MU)

Source- Wise All India Generation from Renewables	For the Month of		Cumulative for the period	
	Feb, 2017	Feb, 2016	Apr, 2016 to Feb, 2017	Apr, 2015 to Feb, 2016
Wind	2485.97	1649.16	43645.88	31136.13
Solar	1355.28	754.22	11855.00	6480.76
Biomass	336.1	342.49	3855.97	3383.71
Bagasse	1192.25	1849.65	8613.54	11408.72
Small Hydro	414.99	372.61	7564.65	7857.72
Others	77.36	25.84	413.89	245.24
Total	**5861.95**	**4993.97**	**75948.93**	**60512.28**

(Source:http://cea.nic.in/reports/monthly/executivesummary/2017/exe_summary-03.pdf)

Table 3 – Smart Meters, Electric Vehicles and Substations (2016)

	Facts and figures
number of smart meters	5.2 million*
number of Electric vehicles	6000**
Number of automated sub-stations	150***

* (Source: http://www.powertoday.in/News/Mission-Metering/83656)
**(Source: https://en.wikipedia.org/wiki/Electric_car_use_by_country#India)
***(Source:POWERGRID)

Annexure-III

Smart Grid Manufacturing / Service Companies

Sl. No.	Company Details
1.	**ABB** is one of the leading power and automation technology company in the world. It's core business lines includes power products, power systems, discrete automation and motion, low voltage products, and process automation. As a leading power sector company, ABB has strong Smart Grid focus and has been actively collaborating with utilities from US, UK, Europe, China, and India. The capacity, reliability, efficiency, and sustainability are the four key aspects of its smart grid vision. First Smart Grid project in India is in Karnataka covering entire state electricity network of generation, transmission & distribution. First SCADA project implementation in India with MFTDMA VSAT Communication, connected to 867 locations across Karnataka through INSAT 3A with communication bandwidth of 11.5 MHz and another 450 locations added subsequently. The project also includes SCADA/EMS/DMS/ Energy Billing, Energy Auditing & ABT Meter Interface, designed to be the largest EMS & DMS data handling SCADA project in the world. Real time data of renewable generation like wind at the injection points in substations. Network visibility of power generation by Independent Power Producers (IPPs) and Open Access.
2.	**Accenture :** As One of the world's top 10 IT consulting firm, Accenture is at the fore-front of the Smart Grid transformation. In a consultative capacity, it is collaborating with organization like World Economic Forum (WEF), Governments, and utility companies to develop road map for Smart Grid evolution. The company offers products, consulting and technology services in AMI, Intelligent Network Data Management, Home Area Network, Distributed Energy Integration, Demand Response, and network application and architecture for technologies like plug-in Electric Vehicle.
3.	Centre for Development of Advanced Computing (C-DAC), Real time Systems Group (RTSSG), Bangalore has developed the COPS SMART ProGate Protocol Converter and currently the recent version of respective technology is available for transfer to manufacturing industries. With the advent of the standard protocol and for coexisting of legacy SCADA System, a multiprotocol gateway is needed. The interoperability issues are of main concern, the ProGate is developed to achieve interoperability by converting standard or proprietary protocol to a suitable standard protocol. The ProGate uses the C-DAC Multi Agent Framework (CMAF) for self-healing from any logical port failures. This product has been developed in adherence to standards and compliance to IEC 60870. The indigenously developed ProGate software has unique feature of the self-healing from logical port failures using agent technology. C-DAC would continue to support with advances in software and develop newer products and versions with the continuing research in the field of real time systems and Smart Grid areas.

4.	Capgemini CapGemini is one of the top 10 largest consulting services company in the world. It has strong presences in energy and utility segment. The company is actively collaborating with utilities in US and Europe for their Smart Grid projects to gain valuable knowledge and experience. It has recently launched Smart Energy Services, a new global service line that will provide full spectrum of smart metering, smart grid, smart home solutions, and smart analytics to utilities across the globe.
5.	CISCO CISCO is the largest supplier of communications products in the world. Cisco considers Smart Grid as the next big thing and visualizes smart grid emergence similar to the emergence of Internet. With its strong networking products portfolio and its deep expertise in IP based products, the company's smart grid vision is to be provider of intelligent, transparent communication between the power producers, the transmission substation, the distribution substation, the residential complex, and the commercial buildings. Through its Smart Grid ecosystem it plans to develop smart grid technologies and standards by collaborating with the smart grid stakeholders. It recently launched Smart Grid products Connected Grid Router (CGR 2010) and Connected Grid Switch (CGS 2520). It has strong presence in emerging country like India, China, and Brazil.
6.	cyan Cyan Holding Plc, founded in 2002 and based out of Cambridge, is a smart energy solution provider. It has two major subsidiaries- Cyan Technologies Ltd working out of Cambridge and a sales and marketing division Cyan Asia Limited working out of Hong Kong. Cyan's flagship product is CyNet- wireless mesh networking protocol for secure communication. Based on this flagship product, it has solutions for three industry sectors- Electricity (Cylec), Lighting (Cylux) and utilities (Cygas). Cyan has shown continuous presence in the Indian market and has been successful in getting orders worth $1m along with a number of pilots with specific utilities around the country including the PGCIL pilot project in Puducherry. Latest of these has been the implementation of a pilot for a North-Indian utility with one of its meter manufacturing partners.
7.	ecolibrium Ecolibrium Energy is India's first Smart Grid startup company focusing on Demand - Response segment. Incubated by Center for Innovation, Incubation, and Entrepreneurship (CIIE) at Indian Institute of Management, Ahmadabad (IIMA) and supported by Ministry of New and Renewable Energy (MNRE), under Renewable Energy Search program. The company is rolling out its first pilot project in Gandhinagar, the capital of Gujarat. The company also focuses on other renewable areas like Bio-fuels and Carbon Advisory Services.
8.	elster Elster is a leading manufacturer in Advanced Metering Infrastructure (AMI) and integrated metering and utilization solutions to the gas, electricity and water industries. Elster is a US based private company that has a 170-year-old history, where a number of times its ownership changed hands. Elster electricity meters are used for residential, commercial and industrial, and interchange metering applications. They support both Automated Meter Reading (AMR) and AMI systems.

9.	e-Meter is one of the leading Meter Data Management System (MDMS) provider company that is serving the utility industry since 1999. Headquartered in California, USA, the company is working with more than 20 utilities in USA, Canada, Europe, Australia, and New Zealand for their Smart Grid deployment projects. Through its leading product EnergyIP, which is open, scalable, and extensible software platform, it provides an important linkage between AMR/AMI and other utility systems like Billing, Outage management systems, Customer portal, Deployment planning, and Asset management. The company was recently named as one of the top 10 Smart Grid company by GreenTech media. It has partnered with companies like IBM, Accenture, Siemens, Trilliant, and Landys+Gyr and is rapidly expanding in other emerging markets like India, Taiwan, and China
10.	General Electric is one of the major players in Smart Grid domain. Through its eco-imagination GE is focusing its research efforts towards clean energy including Smart Grid. It has got US government grant for building Smart Grid training and research infrastructure. GE will leverage its years of vast domain experience to develop various innovative products for the Smart Grid. It has started working with various utilities in US to roll out Smart Meters and related products. In India, GE has collaborated with NDPL for improving energy and transmission efficiency. New Delhi Power Ltd (NDPL) is a joint venture between Tata Power and Delhi Government. NDPL is among the earliest adopter of Smart Grid approach. They have collaborated with GE for using various Smart Grid approaches for efficient distribution of electricity. NDPL serves the National Capital Region(NCR).
11.	HCL InfoSystems Ltd is one of the Top 5 IT company in India providing hardware, software, and system integration services. It offers wide range of ICT products for the computing, storage, networking, security, telecom, imaging, and retail. HCL has partnered with Echelon (A Smart Grid product development company) for providing smart metering and network infrastructure services. It has also roped in Oncor as a client for its Smart Grid infrastructure services. Echelon Corporation (NASDAQ: ELON) is leading the worldwide transformation of the electricity grid into a smart, communicating energy network, connecting utilities to their customers, enabling networking of everyday devices, and providing customers with energy aware homes and businesses that react to conditions on the grid. Echelon's NES System – the backbone for the smart grid – is used by utilities to replace existing stand-alone electricity meters with a network infrastructure that is open, inexpensive, reliable, and proven. The NES System helps utilities compete more effectively, reduce operating costs, provide expanded services and help energy users manage and reduce overall energy use. Echelon's LonWorks® Infrastructure products extend the smart grid, powering tens of millions of energy aware, everyday devices made by thousands of companies – connecting them to each other, to the electricity grid and to the Internet.

12.	IBM nicknamed as the Big Blue is one of the largest technology company in the world. Smart Grid is one of the major component of its Smart Planet initiative. IBM is one of the top 10 Smart Grid companies leading the charge for advancement of this technology. It has setup Global Intelligent Utility Network Coalition (GIUNC) organization to collaborate with utilities of the world. IBM is implementing smart grid project for Oncor, CenterPoint Energy, American Electric Power and Consumers, EDF of France and for Malta.
13.	Infosys, the third largest Indian IT services company is globally engaged with utility companies to meet their IT needs. It has partnered with Itron to provide Itron customers Advance Metering Infrastructure (AMI) and Meter Data Management Services. The company is also part of the Cisco Smart Grid ecosystems and will gain valuable knowledge and experience about Cisco Smart Grid products and related technology. Infosys, along with C-STEP co-developed report "Technology: Enabling Transformation of Power Distribution" for Ministry of Power, India and is associated with India's Smart Grid Development Program. ITRON is the largest manufacturers of smart meters in the world, with a huge market share in its home American market. Itron(NSDQ: ITRI) is one of the biggest independent smart grid companies in the world with 8000 utility customers. It has used its expertise in making meters for gas and water to win large contracts in the electric smart metering market as well. It has won contracts from SCE, DTE Energy,Center Point Energy amongst others. The company sells end-to-end smart grid and smart distribution solutions to electric, gas and water utilities around the globe. Itron is the world's leading provider of smart metering, data collection and utility software systems.
14.	JnJPowercom is providing "Smart Grid" and "Smart Metering" implementation. JnJPowercom offers and "End to End" solution based on its "Smart Meters", Concentrators, and powerful web server. Over the last few years, JnJPowerCom has been successful in implementing an advanced, reliable and secured PLC communication. The breakthrough was achieved by developing a dynamic PLC technology which allows bidirectional data flow over the low voltage grid lines. The technology allows real time readings from any smart meters up to a distance of 2Km, at any world location in seconds. JnJPowercom smart meters enable its customers to implement AMM (Advanced Meter Management) solutions for electric, water, and gas for utilities worldwide. Our team of experts presents experience of over twenty years in the Energy, Control and Electronics sectors.
15.	Kalkitech is a technology based company, which provides products, solutions, and services in the integrated domains of control, communication, and computing of energy industry. The company's main products are SYNC and ELTRIX.SYNC consists of suite of products that enables filed-to-enterprise communication for energy sector whereas ELTRIX is energy optimization solution and is one of the core offering of its optimization verticals. ELTRIX provides overall sustenance of energy eco systems through optimal decision within regulatory, environmental, and reliability constraints.

16.	KEMA is one of the leading authority in energy consultancy and testing & certification at global level. The company is engaged in almost all energy value chain with specialization in business & technical consultancy, operational support, measurement & inspection, and testing & certification. In Smart Grid domain, it has provided its services to various governments, organizations, and companies across the globe. Its notable Smart Grid activities involves partnering with US Department of Energy for Smart Grid and storage report, its CEO's chairmanship of EU Smart Grid Initiative, and report development on Smart Grid impact on Job Creation in US that is drafted in legislation. In India, KEMA is going to serve as knowledge partner to BESCOM (Bangalore Utility) for its Smart Grid project.
17.	Landys+Gyr is the leading provider for total metering solutions in the world with operating presences in more than 30 countries. It provides products and services like Smart Meters, Gas Meters, AMI, Smart Grid, Communication Technology, Heat Meters, Personalized Energy Displays, and IT & MDM services. Based in Zug, Switzerland, the company with 300 million plus installed Smart Meter across the globe is the leader in Smart Meter deployment. In India, it has offices in Kolkata, Bangalore, and Noida. Recently Toshiba acquired Landys+Gyr for $2.3 billion making it one of the largest acquisition in Smart Grid domain
18.	Power System Operation Corporation Limited (POSOCO) is a wholly owned subsidiary of Power Grid Corporation of India Limited (PGCIL). It was formed in March 2010 to handle the power management functions of PGCIL. It is responsible to ensure the integrated operation of the Grid in a reliable, efficient and secure manner. The company is also implementing various projects on Synchrophasors/WAMS in India. Synchrophasors /WAMS is the most essential part of Smart Grid in EHV grid. One pilot project is already operational at National Load Despatch Center, New Delhi.
19.	POWERGRID is one of the largest transmission utilities in the world with 72,000 kms transmission lines in India. A Government of India enterprise has pan India presence and more than 45% power generated in India is transferred through POWERGRID transmission lines. It also has presence in telecommunication sector with more than 19,000 km telecommunication network. Lately the company is focusing its efforts towards Smart Grid. It will be one of the major players in Smart Grid area in India.

20.	Schneider Electric Schneider Electric is a leading organization in power generation, transmission and distribution. It boasts being the leader in Energy Management. It recently acquired the distribution branch of AREVA T&D, another French transmission and distribution Company, along with ALSTOM, a French major in Power Generation and Transport. This recent acquisition has given Schneider a good hold in the global distribution market and enhanced its Smart Grid Vision. It provides solution for power and energy management and has recently launched initiatives like Ecostruxure and MyEnergyUniversity. Ecostruxure, which is an intelligent energy management solution, helps save money and reduce waste by providing compatibility between power management and other essential components of the organization, its agile architecture well fits wider audience and thus saves up-to 30% power for the industries. MyEnergyUniversity provides free online courses on energy management, energy efficiency, smart grid, demand response, and energy audits. The Company has moved from Smarter homes to Wiser homes where it integrates smarter home solution with the multimedia infrastructure in the home. In India, Schneider Electric is headquartered in Gurgaon and has four manufacturing plants and established its first global R&D Center in Bangalore, India. Mahindra Satyam **Mahindra Satyam** is a leading global business and information technology services company that leverages deep industry and functional expertise, leading technology practices, and an advanced, global delivery model to help clients transform their highest-value business processes and improve their business performance. The Group's interests span automotive products, aviation, components, farm equipment, financial services, hospitality, information technology, logistics, real estate and retail. The IT major recently launched Smart Grid Customer Demo Center in collaboration with Schneider Electric to simulate various smart grid technologies.
21.	SIEMENS **SIEMENS** is one of the few companies in the world that provides integrated energy solutions to the entire energy value chain starting from generation and transmission to distribution. Siemens Energy is planning to get engaged in almost all aspect of smart grid businesses. It plans to provide products and services in Smart Distribution, Smart Consumption, Smart Metering, Efficient Network, and e-mobility segment. The company plans to have order worth €6 billion from its present €1 billion in Smart Grid segment. Siemens has partnered with emerging startups e-meter, BPL Global, and Viridity for its Smart Grid offerings and is engaged in various Smart Grid pilots across the world.
22.	TELVENT **Telvent** (NASDAQ: TLVT) is a global IT solutions and business information services provider dedicated to helping improve efficiency and reliability for the world's leading companies. Telvent serves markets that are critical to the sustainability of the planet, including the energy, transportation, agricultural and environmental sectors. Telvent recently announced that it is going to partner with Larsen and Toubro(L&T) for Smart Grid Projects in Maharashtra State Larsen & Toubro is a USD 9.8 billion technology, engineering and construction group, with global operations. It is one of the largest and most respected companies in India's private sector. The company operates in various infrastructure domains and is major player in power infrastructure. It has recently collaborated with Telvent for Smart Grid projects in India.

23.	Tridium is the global leader in open platforms, application software frameworks, automation infrastructure technology, energy management and device-to-enterprise integration solutions. Software frameworks from Tridium extend connectivity, integration and interoperability to the millions of devices deployed in the market today, empowers manufacturers to develop intelligent equipment systems and smart devices that enable collaboration and communication between the enterprise and edge assets.
24.	Wipro has expertise in Smart energy management and developed Smart Meter for house. Wipro provided end-to-end Industrial Product design and development solution that includes designing hardware, firmware and mechanical, prototype, testing, validation and verification within ten months. Wipro adopted reliability centric design approach in designing and development and ensured Standards-driven development. The developed advanced Smart Meter had three-phase Power-line and Wireless communication modes, Tamper detection, Service disconnect, Optimized memory footprint and On-board diagnostics features.

Annexure-IV

Initiatives on Smart Grids

a. Government Ministries / Departments supporting the Smart Grids research:

S. N.	Government Ministry / Department Name	Existing activities
1.	DST- Department of Science and Technology, Government of India	Smart Grid and Energy Storage projects at natural level and with US, UK, Netherlands have been supported.
2.	Science and Engineering research board (SERB)	Supported basic research projects on: (i)Cooperative control of Micro-grid ; (ii) Control and Coordination of micr-ogrid system with multiple renewable energy resources and storage system
3.	Ministry of New and Renewable Energy	The Ministry of New and Renewable Energy (MNRE) is the nodal Ministry of the Government of India for all matters relating to new and renewable energy. The broad aim of the Ministry is to develop and deploy new and renewable energy for supplementing the energy requirements of the country.
4.	Ministry of Power	Ministry of Power setup National Smart Grid Mission in 2015. MoP has supported 12 Smart Grid Pilot projects in State utilities.

b. Utilities supporting the Smart Grids research:

S. N.	Utility Name	Existing activities	Potential future activities
1.	TATA Power Delhi Distribution Limited	Tata Power Delhi Distribution (Tata Power-DDL) is committed to provide value added services to its consumers and with this in mind it has launched a smart grid project involving setting up of radio frequency mesh communication project in its licensed area of 510 sq. km in north and north-west Delhi. The project will help Tata Power-DDL to provide greater service options to customers and accurate information on their energy consumption patterns, helping them to manage their usage more efficiently and improve overall reliability by reducing outage time. The project will also help in enhanced monitoring and control points throughout Tata Power-DDL's network on real time basis and will aid in reduction of commercial losses.	The project will be implemented in partnership with the global energy management pioneer Landis+Gyr. The contract covers the design, supply, installation, testing, commissioning and AMC of a single RF mesh best in class Gridstream network platform that can support multiple applications like AMI (advance metering infrastructure), DA (distribution automation), ADR (automated demand response), distributed energy resources (solar), street light management, grid substation automation solution (GSAS) backup communication. The collaboration also includes deployment of 20 lakh endpoints, comprised of communication card for smart meters and automation of operational applications and integration with current and future applications like advanced distribution management System (ADMS), SCADA and SAP, etc.
2.	Bangalore Electricity Distribution Company Ltd	A smart grid is an electricity network based on digital technology that is used to supply electricity to consumers via two-way digital communication. This system allows for monitoring, analysis, control and communication within the supply chain to help improve efficiency, reduce energy consumption and cost, and maximize the transparency and reliability of the energy supply chain. Smart Grid enables monitor and measure all power flow across the system continuously.	The deployment of smart grid technology will result in transforming of present grid into a marvel with many benefits as indicated and there will be improvement in two way interaction between consumer-utility. he Smart grid pilot would provide opportunity to consumers to use the electricity in an efficient way, participate and avail incentives that would come along, be power source by opting to install roof top solar. The SG technologies do not pose health hazards.
3.	Reliance Power	Reliance Energy has been consistently striving to conserve and use electricity efficiently. Reliance Energy sources 9% of its requirement through Renewable Energy. Reliance Energy's distribution network is one of the most reliable and efficient in the country with approx9.5% losses.	Reliance Energy has prepared a roadmap to adopt smart grid technologies in near future

S. N.	Utility Name	Existing activities	Potential future activities
4.	Haryana Vidyut Prasaran Nigam Limited	To take all necessary steps to improve power situation in Gurugram primarily with the two objectives in mind to start with. One, to provide 24x7 uninterrupted electricity to all the consumers and two, to make Gurugram Diesel Generator free town in a year and to scale up the infrastructure further to make it a Smart Grid. The smart grid has been prioritized for Strengthening / Up-gradation / Modernization of Power Transmission, Sub-transmission & Distribution infrastructure to assure 24x7 uninterrupted Power Supply to all the categories of consumers and to make Gurugram Diesel Generator Set Free within next one year.	To eliminate need of Diesel Generator Set in Gurugram within next one year.
5.	BSES Yamuna Power Ltd and BSES Rajdhani Power Ltd	Power major BSES has embarked on a drive to promote 'net metering' in the national capital as a part of which six roof-top solar panels with a capacity of producing 88 KW have been installed across the city.	BSES companies in the capital had installed 185 rooftop solar 'net metering' connections (smart meters measuring net consumption from the grid after selling surplus solar power from rooftop panels to the grid). These installations have a sanctioned load of 6.6MW. The companies are installing 30 more with a sanctioned load of 1.37MW. Around 40 schools and educational institutes have opted for 'net metering' connections from BSES. The savings consumers make range from Rs.1,800 a month to around Rs.10 lakh a month depending on the sanctioned load. Around 110-120 sq. ft. is required for each kilowatt of capacity

c. Universities working on Smart Grids

University	Area of Research
IIT-Roorkee	Smart Grid-DC grids
IIT-Delhi	Prevention of blackouts, control of micro-grids
IIT-Kanpur	Smart grid- micro-grids
IIT-Kharagpur	Protection and Renewable Energy integration to grid
IIT-Bombay	Power electronic interfaces for non-conventional energy sources.

d. Research institutions/laboratories working on Smart Grids

S. N.	R&D laboratories	Area of Research
1.	Central Power Research Institute (CPRI)	CPRI functions as a centre for applied research in electrical power engineering assisting the electrical industry in product development and quality assurance. CPRI also serves as an independent authority for testing and certification of power equipment. The major thrust areas of research include Solar wind integration and micro grids; AC / DC Micro-grid demonstration project by deploying various distributed energy resources, energy storage systems, communication systems, AMR, VSC, DVR, STATCOM, etc. for improving reliability and power quality. Study of Smart Grid & Impact of Renewable Integration has been completed. Currently a project to improve Reliability Assessment in Power Distribution System is under progress.
2.	The Energy and Resources Institute (TERI)	TERI has developed a Smart Mini-Grid (SMG), or Micro-Grid, is an intelligent electricity distribution network, operating at or below 11 KV, in order to provide electricity to a community. Smart Mini-Grids use advanced sensing, communication, and control technologies to generate, manage, distribute, and utilize electricity more intelligently and effectively. The electricity is supplied by a diverserange of Distributed Energy Resources (DERs), which typically include small conventional generators such as diesel gensets, and a range of renewablegenerators such as solar PV, micro-hydro power plants, wind turbines, biomass, and so on, in combination with each other. Smart Mini-Grids can either be connected to the conventional utility grid or be isolated, providing electricity for localized loads only.
3.	Centre for Development of Advanced Computing (C-DAC), Bengaluru	Real time Systems Group (RTSSG) of C-DAC, Bangalore has developed the COPS SMART ProGate Protocol Converter and currently the recent version of respective technology is available for transfer to manufacturing industries. With the advent of the standard protocol and for coexisting of legacy SCADA System, a multiprotocol gateway is needed. The interoperability issues are of main concern, the ProGate is developed to achieve interoperability by converting standard or proprietary protocol to a suitable standard protocol. The ProGate uses the C-DAC Multi Agent Framework (CMAF) for self-healing from any logical port failures. This product has been developed in adherence to standards and compliance to IEC 60870. The indigenously developed ProGate software has unique feature of the self-healing from logical port failures using agent technology. C-DAC would continue to support with advances in software and develop newer products and versions with the continuing research in the field of real time systems and Smart Grid areas.

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