Smart Grid Initiatives in India

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Abstract: **The growing demand of electricity with the requirement of latest developments in the grids of power network proposes the need for the creation of smart grids. A smart grid is the integration of information and communication technology with the existing power network making the two way communication possible in the generation, transmission & distribution sectors between the utilities and customers by employing the use of smart devices. This paper presents a vision of smart grid development in India. The road map, highlights and development plans envisaged by the India Smart Grid Task Force for smart grid in India are discussed in the paper.**

Every power grid has three functional components generation, transmission & distribution. A smart grid should employ smart control centers, smart transmission network and smart distribution systems. The paper discusses the chronological development in these functional areas. The development is based on the optimal use of natural resources, integration of grids, creating and enhancing smart infrastructure of generation, transmission & distribution technology. This work is an effort to investigate all the developments related to smart grid in reference to India. The developments for creating smart grid in India are multifactorial in nature but major concerns are to electrify rural sector of India which is yet deprived from electrification.

Keywords: **Smart Grid (SG), Smart Metering, Demand side management (DSM), Advanced Metering Infrastructure (AMI), Demand Response (DR), short-term load forecasting, short-term price forecasting, CEA (Central Electricity Authority), Supervisory Control and Data Acquisition (SCADA), Extra High voltage (EHV), Flexible AC Transmission System (FACTS), Intelligent Multi Agent System (IMAS), Bureau of Energy Efficiency (BEE).**

1. INTRODUCTION

A Smart Grid is a very responsible denominator used for the future grid which should be highly reliable, secure, clean and capable of providing high power quality. At the same time it should be eco-friendly, energy conservation oriented and assure the best utilization of existing resources. For this purpose, almost every developed/developing country is giving a special attention in the development of these grids. The emphasis is on the extension and restructuring of conventional grids [1-5] in conjunction with the penetration of smart devices in every layer of the power network.

The conventional grids even in developed countries are fairly old, inefficient, unreliable, polluting, incompatible with renewable energy sources and vulnerable to cyber attack. At the transmission level, the existing grid is efficient, smart and intelligent, but at the distribution level and customer level, there are possibilities of automation, advanced data collection and intelligent appliance control which improve energy efficiency and better integration of distributed generation including renewable sources of power to reduce carbon emission.

The following important aspects of smart grid with reference to India are discussed in the following sections

i. Basic composition of Smart Grid
ii. CO_2 Emission Policies
iii. Integration & enhancement of generating plants (thermal, hydro and nuclear power plants) and incorporation of renewable energy sources, various policies and issues.
iv. Innovative technologies (Communication system working in smart grid)
v. Demand side management which includes the transparent market customer satisfaction and two way fair communication.
vi. Reduction in aggregate technical and commercial losses.
vii. Prevention of power theft.
viii. Integration of large captive power plants.
ix. Absorption of surplus power from individual customers.
x. Introduction of dynamic pricing system.

SG development in India brings new challenges and thus arises the need for pre-estimation of power system planning and operation.

Following are the main technologies and issues which are needed to be brought into consideration with respect to the Indian scenario.

i. Increased load demand is putting a pressure on supply system. Planning is to be done to avoid frequent power cuts and black-outs.
ii. Electrification of a large segment of rural population which is yet deprived from electricity supply.
iii. Optimized usage of electricity by managing loads and mitigate operating inefficiencies.

2. THE MAIN FEATURES OF SMART GRID

SG not only provides efficient demand side management by integration of conventional and renewable energy sources but also helps us make the environment pollution free by utilization of renewable energy sources, thus reducing greenhouse gas emissions. A Smart Grid is reliable, efficient, economical, possesses operational flexibility, integrates different types of power plants, and helps in efficient management of resources [6]. The main features of SG are :

A. Resiliency

SG increases the reliability of power supply to an area even if other areas suffer from power outage due to large disturbance, faults, blackouts etc.

Digitalization : SG provides a digital platform to control operation in a better way by using digital measuring devices, digital communication and digital monitoring.

B. Flexibility

SG provides flexibility whether it is in reference to control scheme of power supply or in reference to increase in power generating capacity.

C. Intelligence

The intelligent operation by self awareness and self-healing is present in SG to give better automatic control under any abnormal condition.

D. Sustainability

In SG the overall power network efficiency is sustained by employing smart devices. Though conventional power plants can not be made non-polluting, but emphasis is laid on installation and sustenance of renewable energy sources to a particular extent which doesn't deteriorate power system stability beyond certain limits.

E. Customization

SG provides user friendly environment creating transparency in operation, and thus, liberalizing the power market.

3. MAJOR CHALLENGES IN THE DESIGN OF SMART GRID

Due to debundling of the existing power systems, numerous private power companies with variety of generating systems came into existence. These private players are selling power to customers utilizing the existing transmission and distribution network. Due to this, a number of weaknesses have emerged such as congestion of transmission lines, rerouting of flow of power in the lines to reduce congestion, determination of appropriate transmission charges to be recovered from private power companies etc. Outages are often recognized only after customers report. Matching of generation to demand is challenging because utilities do not have clear cut methods to predict demand and to request demand reduction (load shedding). As a consequence, they need to over-generate power for peak demand which is not only expensive but contributes to degradation of environment & resources. Difficulties also arise to incorporate variable generation using solar and wind energy due to their intermittent nature and imprecise prediction. Last, there is a dearth of information available for customers to determine how and when to use energy intelligently for cost reduction. The main challenges before the Indian power sector are summarized below :

i. Power Shortage : Among BRICS (Brazil, Russia, India, China, South Africa) countries, India is the only country, which has positive growth. In the current financial year i.e. 2014-15, it is 5.7 % and may rise in the years to come. Despite this fact, the power system continues to be riddled with power shortages and inefficiencies. The challenge before power sector policy makers is to overcome power shortages by rapid electrification while preserving the environment.

ii. Large growth in population : India is one of the most densely populated country. It's total population is about 1.3 billion and is growing rapidly. About 60 per cent of the population live in villages and many of them do not have access to electricity. They use non commercial form of energy which pollutes the environment. It is thus, a big challenge to supply clean and sustainable energy to all villagers to empower them.

iii. Uneven distribution of energy resources : The distribution of primary commercial energy resources is uneven. India's 70 per cent of total coal reserves are located in the eastern region, nearly 80 per cent of the total liquid and gaseous hydrocarbons are located in the western region and more than 75 per cent of hydro-potential is located in the northern and the north eastern region. Sometimes, land strips are not available to lay new transmission lines for evacuating bulk power from far flung areas.

iv. High energy losses : The Aggregate Technical & Commercial (AT&C) losses in our country are the highest in the world. During the year 2011-12 these losses were reported to be about 27 per cent.

4. STRATEGIC PLANNING OF SMART GRID

For establishing a smart grid, each participating device must be a smart device capable of two way communication. The penetration of smart devices into each layer can be achieved by planning strategically, considering every possible constraint. Without implementation of strategically planned development of smart grid, it will suffer from high revenue loss, less-than optimal service delivery, and long-term excessive IT costs, which will affect both the customers and utilities. This planning for development of SG is based upon bottom-up approach of realizing different layers, as shown in Fig.1 [7]. The various layers are discussed briefly in the following paragraphs.

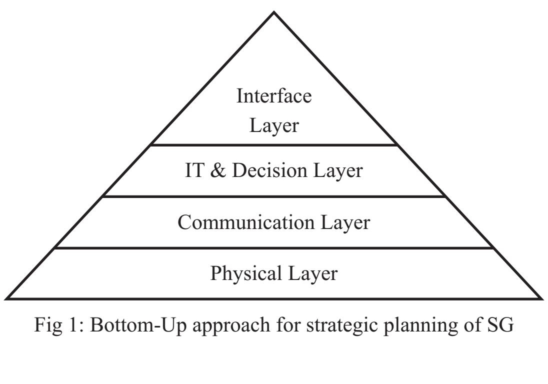

Fig 1: Bottom-Up approach for strategic planning of SG

A. Physical layer

It is the base layer for development of SG. This layer basically involves the installation and control of hardware devices like PMUs (Phasor Measurement Units) / PDCs (Phasor Data Concentrator), IEDs (Intelligent Electronic Devices), smart Switchgear, Sensors/Transducers, Data Acquisition Devices, Condition Monitoring Equipments, SCADA/Automation, GPS (Global Positioning System), FACTS (Flexible AC Transmission System) devices, EHV/UHV Transmission Lines, Asset Mapping, Intelligent Metering etc. Thus, the physical layer of the SG constitutes the construction of the smart network.

B. Communication layer

To upgrade the conventional power grid to smart power grid, we require a lot of research in the field of design of communication system which is used between different components of smart grid because communication in the grid is related to the transfer of information from one end to another. In SG the communication between the components must be able to carry information from both the sides. But in the present grid system we use Supervisory Control and Data Acquisition (SCADA) system and it doesn't allow the flow of information on both sides.

The two way communication network will not only provide advanced monitoring and control, but will also support efficient generation, transmission and distribution of power.

The new intelligent communication technique to obtain two way communication in smart grid is the machine-to -machine (M2M) communication. The M2M communication facilitates load demand management according to utility constraints.

The M2M communication generally involves different types of electronic devices and various softwares and communication technologies. The basic building architecture of M2M communication is shown in Fig.2. The M2M system provides communication network between M2M area network and M2M application. The M2M network can be as small as a home or it can occupy a large area comparable to that of a huge industrial plant. Communication between area network and application can be provided by a satellite or by a power line [8].

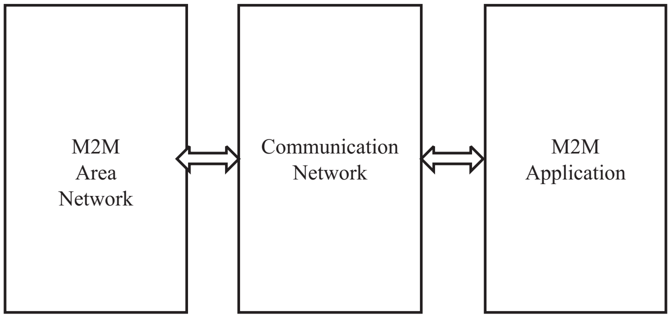

Fig 2: Framework of M2M communication system

C. IT and decision support layer

This layer forms the monitoring and control system of SG. It involves devices and softwares like Servers, Computers, Printers, Ethernet Switches, Network Management Software(s), Decision Support System, Network Control Centers, Forecasting softwares etc.

D. Interface layer

Interface layer integrates information and power supply from different sources. It involves Seamless Integration and Information Exchange with other Stakeholders i.e. Generators, DISCOMs, Prosumers etc.

5. SMART GRID ROAD MAP FOR INDIA

The Indian Power Ministry released Smart Grid Vision and Road map for India on Sept. 10, 2013. The Road map was drafted by the India Smart Grid Task Force with the assistance of India Smart Grid Forum, and spreads over the 12^{th}, 13^{th} and 14^{th} five-year plan periods from 2012 to 2027. The vision behind the road map is to transform the Indian power system into a secure, adaptive, sustainable and digitally enabled eco-system that provides reliable and quality energy for all with active participation of stakeholders.

The key targets and highlights of the five-year plan periods of SG road map are as follows:

A. 12th Plan (2012 – 2017)

- Completion of ongoing smart grid pilot projects.
- Augmentation of data centres and communication network for AMI (Advanced Metering Infrastructure) roll out
- Distribution Automation & Geographic Information System (GIS)/Automated distribution systems.
- Development of indigenous smart meter
- Dynamic tariffs, Sustainability Initiatives –promoting distributed generation

B. 13th Plan (2017 – 2022):

- Nationwide AMI roll out for customers grater than10KW load
- Mandatory Roof Top Installation of Solar generating capacity for large establishments
- Total Renewable integration of 80GW;
- Electric Vehicle (EV) charging infrastructure
- Development of micro grids in total 10000 villages
- Distribution Automation

C. 14th Plan (2022 – 2027):

- Development of 50 Smart cities.
- Mandatory installation of roof top solar generating capacity
- Total Renewable integration of 130 GW; 10% EV penetration
- Nationwide AMI roll out for customers
- Continuous Research &Development
- Choice of electricity supplier

6. SMART GRID DEVELOPMENT POLICIES FOR INDIA

This section discusses the various policies developed for the implementation of SG in India.

A. Carbon emission policies

Nearly 70 per cent of electricity in the country is being generated by burning fossil fuel, mainly coal. The coal dominant scenario projects nearly a fourfold increase in the requirement of coal by 2030 as compared to coal consumption of 650 million tonnes in the year 2010. This will increase the emission of greenhouse gases into the atmosphere many times. Still, India's per capita carbon emission level will be much less compared to per capita emission levels of developed countries. Even then, India made a declaration voluntarily that it will aim to reduce emissions' intensity of its GDP by 20-25 per cent by 2020 in comparison with the 2005 level. This declaration will require actions to be taken in certain specific sectors along with a large scale power generation using renewable energy sources such as solar and wind. It is expected that a capacity addition of 45000 MW of wind power and an equal amount of solar capacity addition by 2030 can be achieved. These sources would replace generation from coal power plants by an amount equal to 160 bkWh and thus contribute in reducing carbon footprint. By taking appropriate measures such as enhancing energy efficiency through demand side management, designing commercial buildings more energy efficient, promoting energy efficient lighting, appliances & equipment along with increasing the share of renewable sources of energy, it is possible to achieve the target as announced.

B. Policies on tariffs during 12^{th}, 13^{th} and 14^{th} plans[16]

i. Policies during 12^{th} plan will be based on the following initiatives :

a. Implementation of Dynamic Tariffs
b. Mandatory Demand Response programs for selected categories of customers
c. Tariff mechanism for roof top solar PV's – Net Metering/Feed in Tariffs

ii. Policies during 13^{th} plan will address the following issues :

a. Choice of electricity supplier (open access) to customers in metros and select urban areas
b. Mandatory Demand Response programs for larger sections of customers

iii. During the 14^{th} plan the main focus will be on - Choice of electricity supplier (open access) to all customers

C. Other Policies for the Smart Grid development will focus on the following objectives from 2012-2027 [16]

i. Enable access and availability of quality power for all
ii. Loss reduction
iii. Smart Grid Rollouts including Automation, Microgrids and other improvements
iv. Green Power and Energy Efficiency
v. Electric Vehicles and Energy Storage
vi. Enablers and Other Initiatives

7. SMART GRID DEVELOPMENT IN INDIA

A. Expansion of Grid utility and current position of Generation and Demand in India

India is trying to expand electric power generation capacity, as current generation is seriously below peak demand. Although about 80% of the population has access to electricity, power outages are common, and the unreliability of electricity supplies is severe enough to constitute a constraint on the country's overall economic development. The government had targeted capacity increase of 100,000 megawatts (MW) over the next ten years. As of July 2014, total installed Indian power generating capacity was 250256.98 MW. Table 1 shows the all India region wise generating installed capacity as of June 2014, Table 2 shows the all India region wise generating installed capacity as of December 2013 and Table 3 shows the data for May 2012. Further Fig 6 gives the basic distribution of the Generating capacity in different consumption sectors. All the data are based on CEA reports [18,19]. The following four are the main observations in context with Indian scenario.

1. *Supply shortfalls :* Demand, especially peak demand, continues to outpace India's power supply. To understand the gap between demand and supply yearly data of supply and demand is taken from CEA, for 2013-14 and is shown in Table 4 [20]. From the data it can be observed that our country isn't able to meet the demand yet. Managing growth and ensuring supply is a major driver for all programs of the Indian power sector.
2. *Loss reduction :* India's aggregate technical and commercial losses are thought to be about 25-30%, but could be higher given the substantial fraction of the population that is not metered and the lack of transparency. While a smart grid is not the only means of reducing losses, it could make a substantial contribution.
3. *Peak load management :* India's supply shortfalls are expected to persist for many years, as per the data of Table-4. A smart grid is needed to match this difference between peak demand and peak met. Further smart grid allows "intelligent" load control which would help to mitigate the supply-and demand gap.
4. *Renewable energy :* India has supported the implementation of renewable energy. Historically, much of its support was for wind power, but the newly announced National Solar Mission and its goal to add 20,000 MW of solar energy by 2020 should be an accelerant.
5. *Growth in power generation :* From the data of Tables 1 to 3, chronological growth is observed in all the regions, however the generation growth is almost constant in Islands. Similar growth is observed in thermal power generation and renewable energy sources. However nuclear plants didn't grow and hydro power plants show very poor growth.

6. *HVDC link development :* Construction of a smart grid primarily depends upon the strong and reliable power grid. India is coming ahead with the construction of HV grids in many places.
   India is one of the few countries having a large number of HVDC schemes in operation; under commissioning, construction and planning.
7. *Generation link :* The power generation link includes distributed generation, renewable energy generation, generator and power system coordinated operation, energy-saving oriented dispatch technology and auto-generation control etc for the expansion of which new policies and schemes are in progress.
8. *Distribution and supply link :* The power distribution and supply link include distribution automation system, feeder
9. Automation system, custom power, auto-metering etc. Smart metering is about to be implemented in India for small scale solar plants. Recently, Tamil Nadu, Andhra Pradesh, Delhi, Kerala, Punjab, Maharashtra and Uttarakhand issued guidelines for net-metering of solar small scale projects [21]

Table 1: All India Region wise Generating installed Capacity June 2014(All data are in MW)
RES -Renewable Energy Sources include Small Hydro Project (SHP), Biomass Gas (BG), Biomass Power (BP), Urban & Industrial waste power (U&I), Wind Power and Solar Power [19]
Source : Central Electricity Authority (CEA), India

S.No.	Region	Thermal				Nuclear	Hydro	R.E.S.	Total
		COAL	GAS	DSL	TOTAL				
1.	Northern	36793.5	5331.26	12.99	42137.75	1620.00	16529.44	5935.77	66222.96
2.	Western	59114.51	10915.41	17.48	70047.40	1840.00	7447.50	11271.07	900605.97
3.	Southern	26582.5	4962.78	939.32	32484.6	1320.00	11398.03	13784.67	58987.3
4.	Eastern	25927.88	190.00	17.20	26135.08	0.00	4113.12	432.86	30681.06
5.	N.Eastern	60.00	1208.50	142.74	1411.24	0.00	1242.00	256.67	2909.91
6.	Islands	0.00	0.00	70.02	70.02	0.00	0.00	11.10	81.12
7.	All India	148478.39	22607.95	1199.75	172286.09	4780.00	40730.09	31692.14	249488.31

Table 2: All India Region wise Generating installed Capacity December 2013 (All data are in MW)
RES -Renewable Energy Sources include Small Hydro Project (SHP), Biomass Gas (BG), Biomass Power (BP), Urban & Industrial waste power (U&I), Wind Power and Solar Power [19]
Source : Central Electricity Authority (CEA), India

S.No.	Region	Thermal				Nuclear	Hydro	R.E.S.	Total
		COAL	GAS	DSL	TOTAL				
1.	Northern	34583.50	5031.26	12.99	39627.75	1620.00	15692.75	5729.62	62670.12
2.	Western	52899.51	8988.31	17.48	61905.3	1840.00	7447.50	9925.19	81117.99
3.	Southern	25932.5	4962.78	939.32	31834.6	1320.00	11398.03	13127.33	57679.96
4.	Eastern	24737.88	190.00	17.20	24945.08	0.00	4113.12	417.41	29475.61
5.	N.Eastern	60.00	1208.5	142.74	1411.24	0.00	1242.00	252.65	2905.89
6.	Islands	0.00	0.00	70.02	70.02	0.00	0.00	10.35	80.37
7.	All India	138213.39	20380.85	1199.75	159793.99	4780.00	39893.40	29462.55	233929.94

Table 3: All India Region wise Generating installed Capacity May 2012(All data are in MW)
RES -Renewable Energy Sources include Small Hydro Project (SHP), Biomass Gas (BG), Biomass Power (BP), Urban & Industrial waste power (U&I), Wind Power and Solar Power [19]
Source : Central Electricity Authority (CEA), India

S.No.	Region	Thermal				Nuclear	Hydro	R.E.S.	Total
		COAL	GAS	DSL	TOTAL				
1.	Northern	30017.50	4421.26	12.99	344517.5	1620.00	15192.75	4391.40	55655.90
2.	Western	39484.50	8354.81	17.48	47756.79	1840.00	7447.50	7909.95	64954.24
3.	Southern	22882.50	4962.78	939.32	287784.60	1320.00	11338.03	11569.30	53011.93
4.	Eastern	22337.88	190.00	17.20	22545.08	0.00	3882.12	398.71	26825.91
5.	N.Eastern	60.00	824.20	142.74	1026.94	0.00	1200.00	228.00	2454.94
6.	Islands	0	0	70.02	70.02	0	0	6.10	76.12
7.	All India	114782.38	18653.05	1199.75	134635.18	4780.00	39060.40	24503.45	202979.03

Table 4: Demand distribution region wise. All data are in MW (2013-14) CEA Report

Region	Requirement	Availability	Surplus / Deficit		Demand	Met	Surplus / Deficit	
	MW	MW	MW	%	(MW)	(MW)	MW	%
Northern	309,463	290,880	-18,583	-6	45,934	42,774	-3,160	-6.9
Western	294,659	291,856	-2,803	-1	41,335	40,331	-1,004	-2.4
Southern	277,245	258,444	-18,801	-6.8	39,015	36,048	-2,967	-7.6
Eastern	108,203	106,783	-1,420	-1.3	15,888	15,598	-290	-1.8
North-Eastern	12,687	11,866	-821	-6.5	2,164	2,048	-116	-5.4

B. Demand side management (DSM) in India

SG uses intelligent and two way communication which provides better awareness to utility companies regarding the state of the grid. With the help of information systems, it is possible to predict the periods when less power is available from solar and wind resources. With the help of new storage technologies, it is possible for utility companies to keep a balance between generation and demand. By installing smart meters at the customer's premises and by implementing dynamic pricing system it is possible to reduce peak demand significantly. This will reduce the cost of generation and also benefit the customers by reducing their electricity bills. Fig. 3 shows how to use electricity during off peak periods when the price is low.

On the other hand, Fig.4 shows load shedding during peak period when the price is high and utilization of energy storage to meet customer demand. The effect of reduction in peak demand by implementing demand side management is shown in Fig. 5. Disconnecting non-essential appliances based on price information can cut electricity bills for customers by 10 to 15 per cent without causing any discomfort.

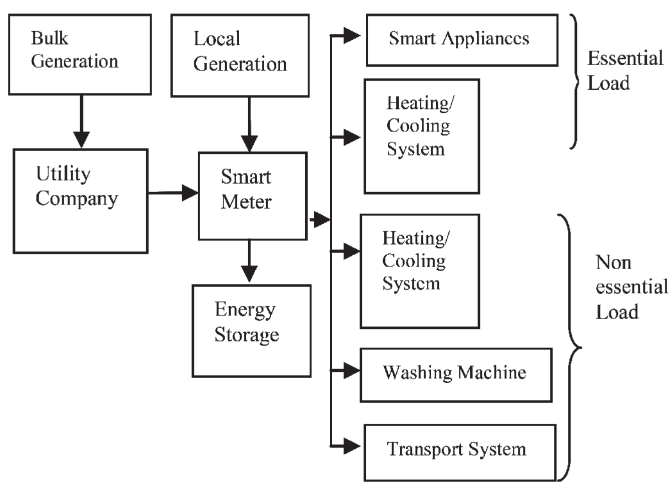

Fig 3: Utilization of electricity during off-peak periods

Due to reduction in peak demand the utility companies are spared from running expensive additional generating units during peak demand. This will not only benefit utility companies economically but also reduce carbon footprints.

Electricity plays an important role to economic growth of any country. India suffers from power shortages and therefore, our country needs to establish more power plants which will incur huge capital cost and will result in large increase in CO_2 emissions. Demand side management (DSM) provides the solution for these problems.

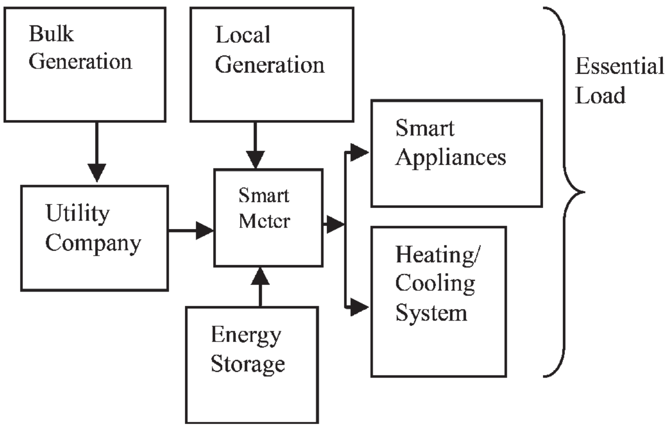

Fig 4: Load Shedding during peak period

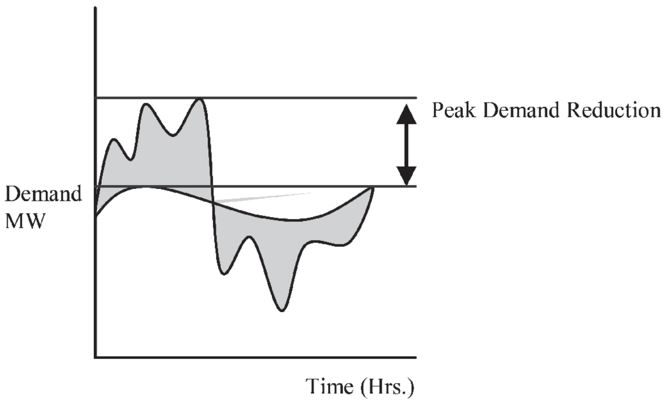

Fig 5: Peak demand reduction by implementing demand side management

Fig 6 represents the percentage electricity consumption in different comsumable sectors. According to this figure, the industrial sector of India is the topmost energy consumable sector and consumes electricity of about 44.87 % of total energy generation.

By effectively managing the electricity consumption from the demand side we can manage the consumption in various sectors according to the total generation and priority-wise need of electricity requirement in each sector. This is achieved by using energy efficient motors, variable speed drives, waste heat recovery, efficient lighting system etc. [14-15].

We have been doing DSM in agricultural sector because the power wastage mostly is observed in this area. Till 2012 the consumption of electricity was 22 % in this area which is reduced to 17.95 % in 2013 [18]. In many states of India it has been observed that the actual electricity consumption is 35-40%, but the revenue received by the electricity board is only 5-10%. There are many reasons for the theft. So management of this sector is necessary to promote agriculture as the nation's progress mainly depends on this sector, and at the same time it is necessary to control the theft of electricity.

The installed generation capacity of each state is increasing as the demand is increasing each year. The Tables 1 to 3 show the data of the installed capacity of all 5 regions & Islands in India, with respect to the contribution by each type of power plant [19]. The capacity of nuclear plants has remained the same but others have magnified their capacity with the increase in population to meet the requirement of electricity consumption.

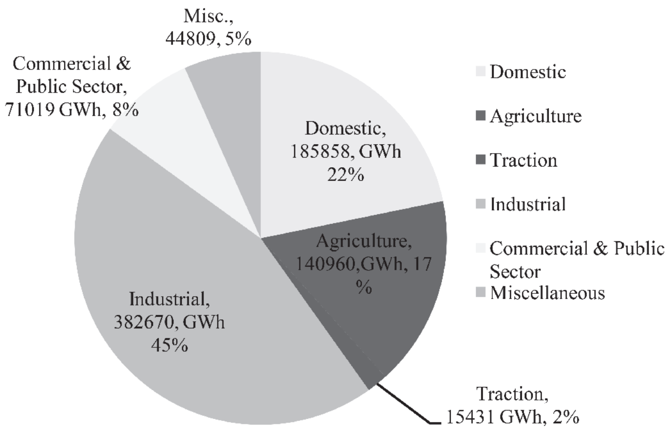

Fig 6: Percentage Electricity Consumption in different Sectors (31.3.2013) [18]
Source : Central Electricity Authority (CEA), India

5. CONCLUSION

The electricity requirements of India have grown tremendously and the demand has been running ahead of supply. The large disparity between electricity demand and availability continues to grow and so does the shortage with regard to peak demand. The country's plan to provide reliable and affordable power supply to all by rapid electrification while keeping carbon emission within control will put tremendous challenges before the Indian power industry. To meet these challenges with limited conventional energy resources, India needs to put forward efforts in research and development to find renewable substitutes particularly solar and wind. It is also necessary to modernize the existing grid and make it smarter. This will not only reduce the technical and commercial losses but will also reduce carbon footprint. There are many aspects of smartness and each aspect meets only a particular objective. The cost involved in making the grid smarter is very high and hence priorities based on relative importance of various aspects of smart grid will have to be decided to achieve them. Installation of smart meters and by pushing demand side management will reduce peak demand & energy losses and hence should be given top priority.

REFERENCES

[1] Office of Electric Transmission and Distribution, U.S. Dept. of Energy, "Grid 2030 : A national version for electricity's second 100 years", July 2003.

[2] John J. Simmins, A PowerPoint Presentation on "EPRI Smart Grid Demonstration and CIM Standard Development", EPRI Inc., 2009. Available Online : cimug.ucaiug.org/Meetings/Charlotte2009/Presentations/epri_simmins.ppt

[3] O'neill R., "Smart grid sound transmission investments", IEEE Power and Energy Magazine. Sep./Oct. 2007, pp. 100-102.

[4] Tai H., Hogain E O., "Behind the Buzz . Eight smart-grid trends shaping the industry", IEEE Power & Energy, 2009. 7(2) pp. 96-97.

[5] John D. McDonald, “The next generation grid : Energy infrastructure of the future”, Guest Editorial, IEEE Power & Energy Magazine, March/April 2009.

[6] Fangxing Li, Wei Qiao, Hongbin Sun, Hui Wan, Jianhui Wang, Yan Xia, Zhao Xu and Pei Zhang, “Smart Transmission Grid: Vision and Framework”, IEEE Transactions on Smart Grid, Vol. 1, No. 2, September 2010.

[7] An Oracle White Paper, “Smart Grids: Strategic Planning and Development”, September 2009.

[8] Siok Kheng Tan, Mahesh Sooriyabandara, and Zhong Fan, “M2M Communications in the Smart Grid: Applications, Standards, Enabling Technologies, and Research Challenges ”, International Journal of Digital Multimedia Broadcasting, 2011, Article ID - 289015, DOI : 10.11.2011.

[9] “McKinsey on Smart Grid”, No.1, Summer 2010, McKinsey & Co. Available Online : http://sedc-coalition.eu/wp-content/uploads/2011/06/McKinsey-10-08-05-Smart-Grid-Benefits.pdf.

[10] “National Energy map for India : Technology Vision 2030”, TERI Press, India, ISBN : 81-7993-099-8.

[11] Articles on Carbon footprint, The Economic Times. Available Online : http://articles.economictimes.indiatimes.com/keyword/carbon-footprint.

[12] “Low carbon development in China and India : Issues and Strategies”, The Energy and Resources Institute, National Centre for Climate Change Strategy and International Cooperation (NCSC), Central University of Finance and Economics (CUFE), Zhejiang University and the United Nations Development Programme (UNDP), Teri Press, 2014.

[13] Liu Chuanjiang, Feng Ya, “Low-carbon Economy: Theoretical Study and Development Path Choice in China”, Energy Procedia, Issue 5 (2011), pp. 487–493.

[14] S. Padmanaban & Ashok Sarkar, “Electricity Demand Side Management (DSM) In India –A Strategic And Policy Perspective”, Office of Environment, Energy And Enterprise, US Agency for International Development, New Delhi, India. . Available Online : http://www.energymanagertraining.com/DSM/ElectricityDemandSideManagement.doc.

[15] “Energy Efficiency Technologies-World Energy Council (WEC)”, World Energy Council 2014. Available Online on official website of WEC : www.worldenergy.org.

[16] India's Road map for smart grid from 2012 to 2027. Available Online : http://smartgridinsights.com/news/indias-smart-grid-roadmap-2012-2027.

[17] Whitepaper on Net-Metering in India (provided by IET India Solar Panel). Available Online : http://goo.gl/lzo85n.

[18] Central Electricity Authority (CEA), India, PDF document on link - “Growth of Electicity Sector in India from 1947-2013”, Available Online : http://www.cea.nic.in/planning_wing.html

[19] Monthly All India Generation Capacity Report, May 2012, December 2013 and June 2014. Available Online : http://www.cea.nic.in/installed_capacity.html.

[20] Load Generation Balance Report for the year 2014-15. Available Online : http://www.cea.nic.in/yearly_report.html

[21] News Article, March 16, 2014, “IET India Solar Panel releases first whitepaper on Net-Metering in India”. Last accessed on Aug 14, 2014. Available Online : http://panchabuta.com/2014/03/16/iet-india-solar-panel-releases-first-whitepaper-on-net-metering-in-india/

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