



# Transmission and Distribution in India

A report



A joint initiative of WEC-IMC and Power Grid Corporation of India Limited

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# Chapter-1

## Generation Demand Scenario

### 1.1 Energy Resources in India

The natural resources for electricity generation in India are unevenly dispersed and concentrated in a few pockets. Hydro resources are located in the Himalayan foothills and in the north-eastern region (NER). Coal reserves are concentrated in Jharkhand, Orissa, West Bengal, Chhattisgarh, parts of Madhya Pradesh, whereas lignite is located in Tamil Nadu and Gujarat. North Eastern Region, Sikkim and Bhutan have vast untapped hydro potential estimated to be about 35000 MW in NER, about 8000 MW in Sikkim and about 15000 MW in Bhutan. Energy resource map in India is shown at Fig. 1.1.

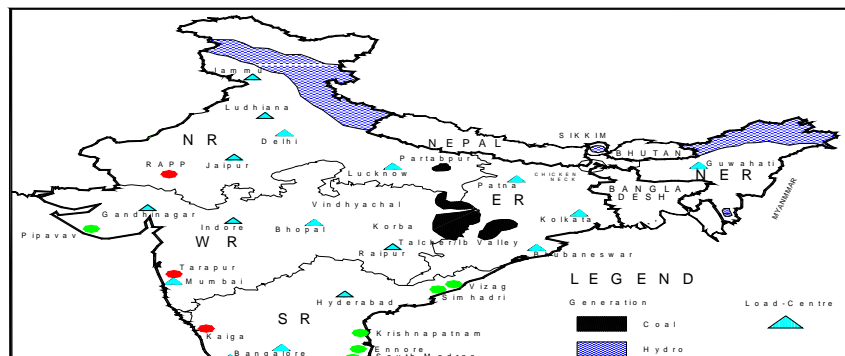


Fig 1.1: Energy resource map for electricity generation in India.

The distribution of energy resources and consumption centres are extremely unbalanced. The load centres are scattered at far-off places away from resource rich areas. Recent government initiatives for establishment of special economic zones have also given rise to new potential load centres. Projects are proposed to be located mostly at pit head/resource areas with each location having capacities in the range of 5,000-10,000 MW.

### 1.2 Growth of Installed Capacity

The power sector as a whole has shown significant progress in physical terms and to meet the ever-growing demand is leading way to more encouragement to private sector participation since 90's.

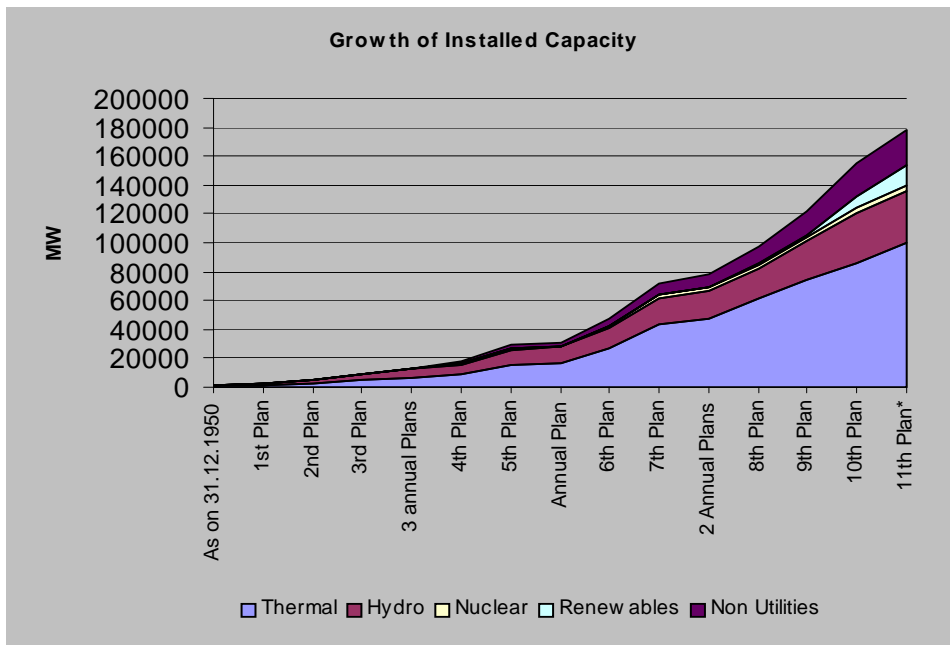


Fig 1.2: Growth of Installed Capacity in India.

### 1.3 Feasible Capacity Addition during XI Plan and XII Plan

As against the 11th Plan(2007-2012) target of 78700 MW set by the Planning Commission, the CEA has, on the basis of preparedness of the projects, revised the feasible capacity addition target for the 11th Plan to 80010 MW as shown below-

Status	Central sector	State sector	Private sector	Total(MW)
Commissioned	3990	7094	1633	12717
Under Construction	29540	18269	19484	67293
Total	33530	25363	21117	80010

Table-1.1: Capacity Addition in 11<sup>th</sup> Plan

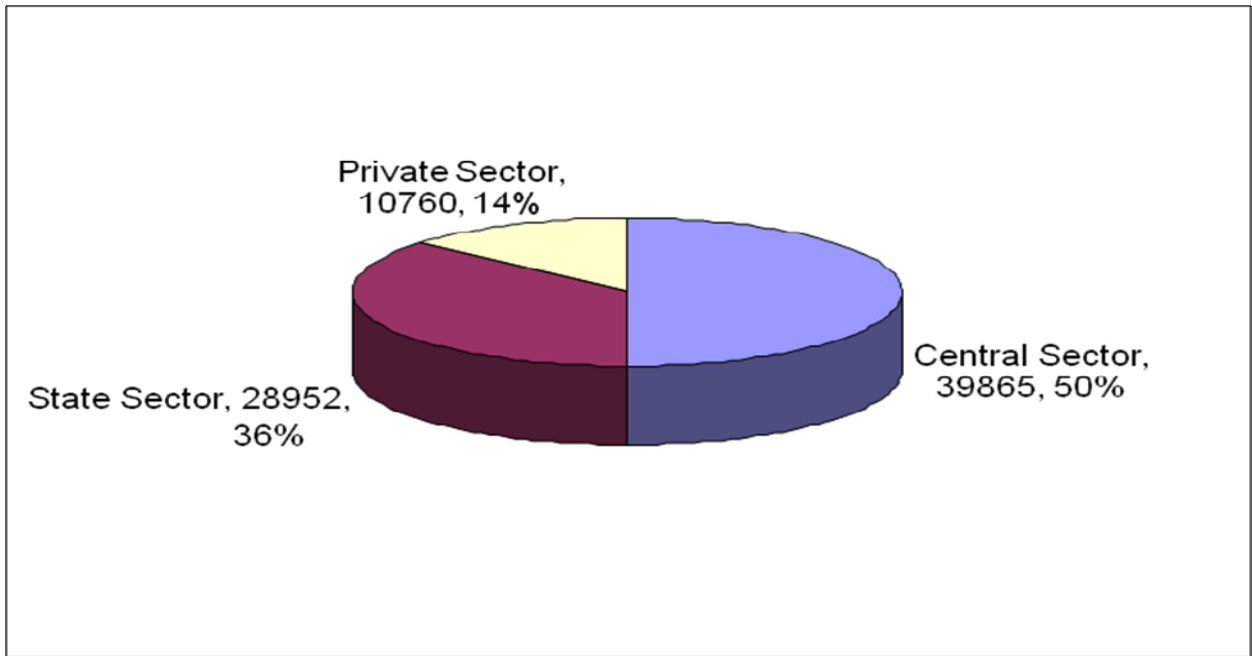


Fig 1.3: Capacity addition target of 78,700MW by 2012

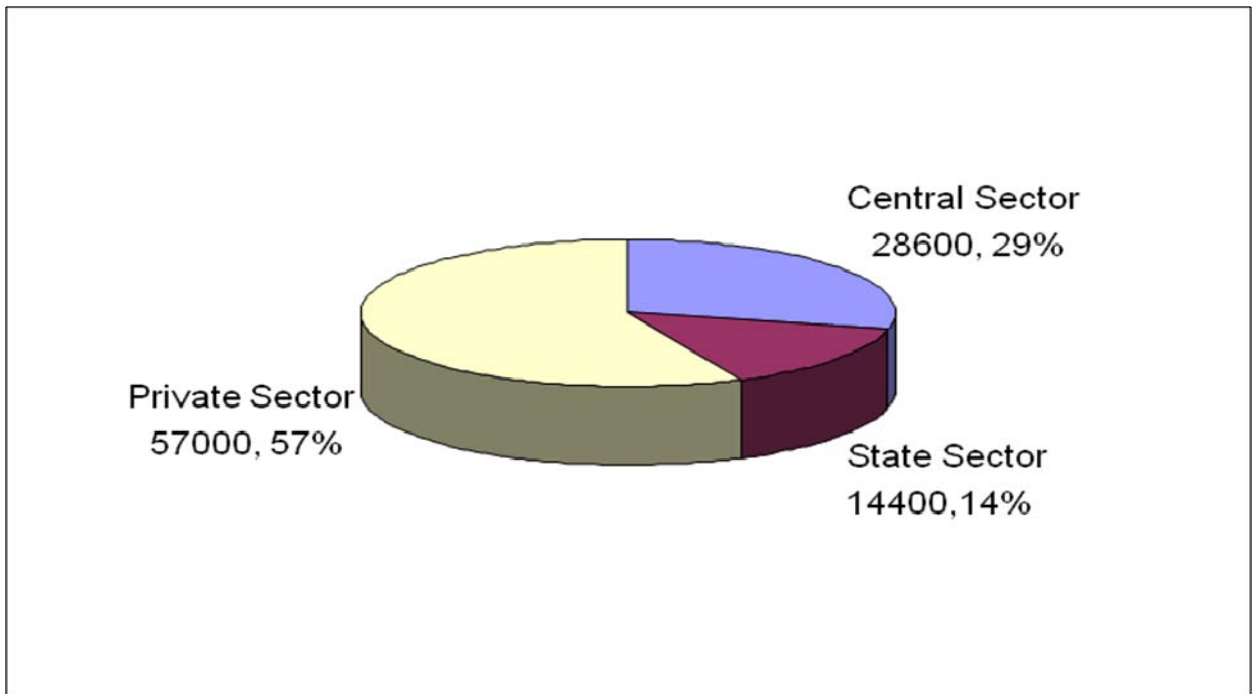


Fig 1.4: Capacity addition target of 1,00,000MW by 2017

In addition, large generation capacity addition of the order to about 198,000MW has been proposed through private sector on long-term open access route.

### 1.3 Demand

Electricity sector in India is growing at rapid pace. The present Peak Demand is about 1,15,000 MW and the Installed Capacity is 1,52,380 MW with generation mix is thermal (63%), hydro (25%), Nuclear (9%) and renewables (9%).

The projected Peak Demand in 2012 is about 150 GW and in 2017 is more than 200 GW. The corresponding Installed capacity requirement in 2012 is about 220 GW and in 2017 is more than 300 GW. The projected Peak Demand and the Installed Capacity Requirement in next 15 years is shown in Fig.1.5 and 1.6 respectively.

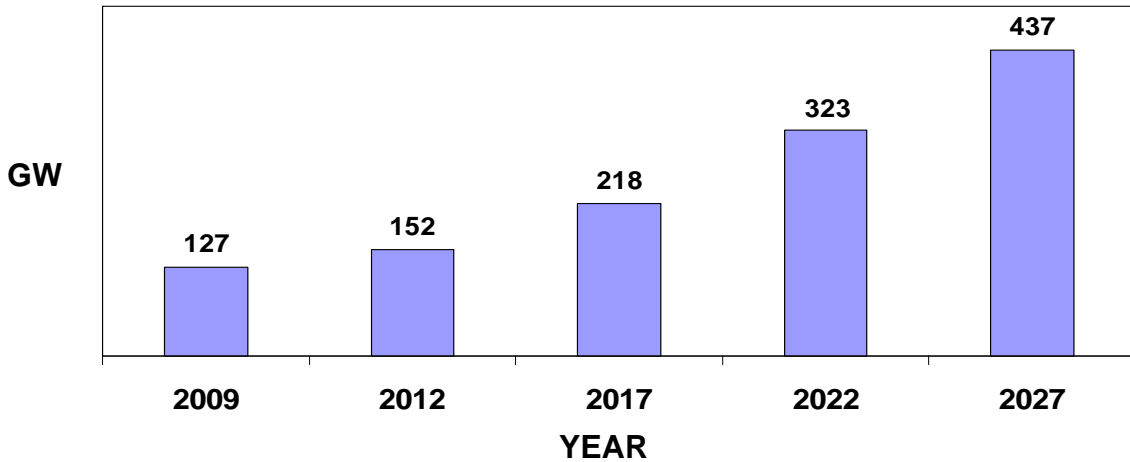


Fig. 1.5: Projected peak demand in India

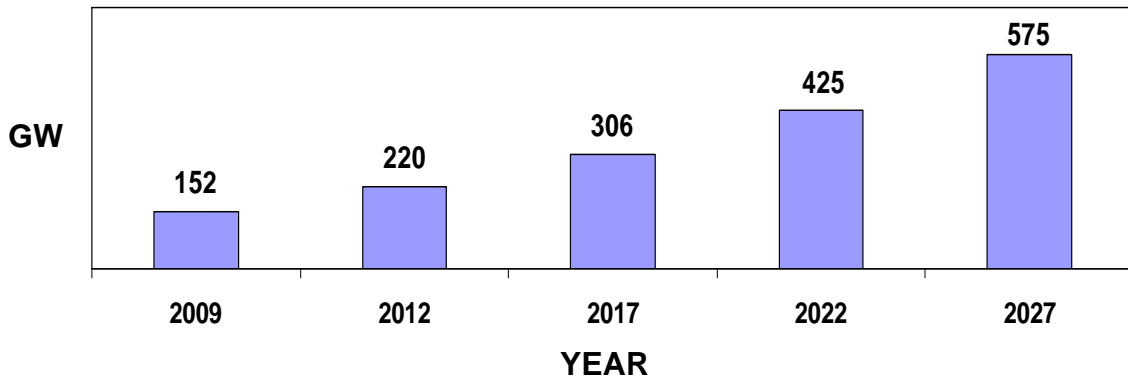


Fig 1.6: Projected Installed Capacity Requirement

## Chapter-2

### Transmission

#### 2.1 Present Transmission System of India- An Overview

Electricity is a concurrent subject in India i.e, both the central and state governments are responsible for the development of the electricity sector. NTPC, NHPC, THDC, NEEPCO, SJVNL, NLC etc. are the central generation utilities and POWERGRID is the Central Transmission Utility. At the State level, there are Gencos and Transco in the respective States.

The country has been demarcated into five electrical Regions viz. Northern (NR), Eastern (ER), Western (WR), Southern(SR) and North Eastern (NER). However, NR, ER, WR and NER have been synchronously interconnected and operating as single grid – Central Grid (capacity about 110,000MW). The Southern region is asynchronously connected to the Central Grid through HVDC links.

Power map showing present National Grid is given at Fig.2.1.

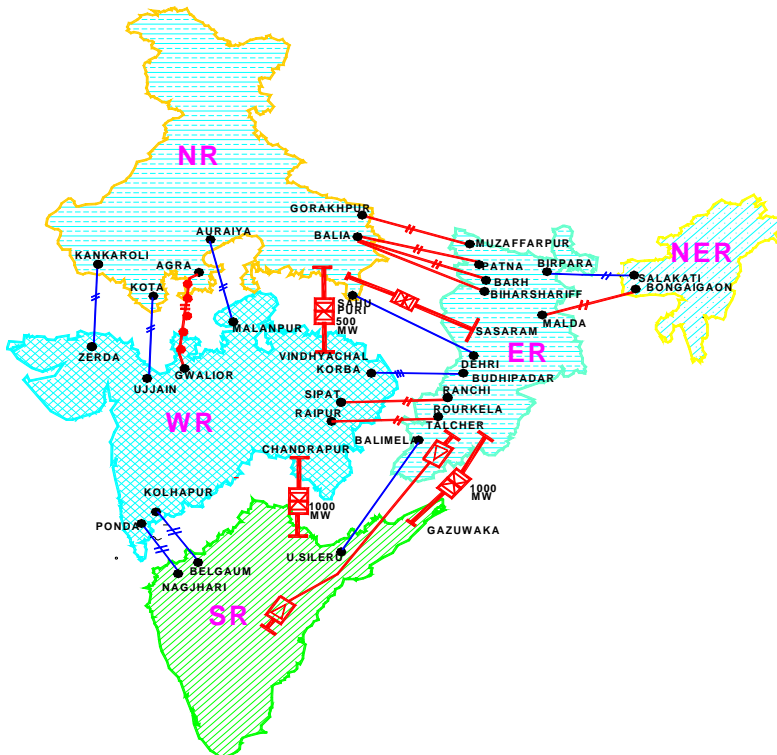


Fig. 2.1: Power map showing National Grid at present

The backbone transmission system in India is mainly through 400 kV AC network with approximately 90,000 circuit kilometers (ckm.(=2xroute km)) of line length. Highest

transmission voltage level is 765kV with line length of approximately 3120 ckm. There are about 7,200 ckm of 400 kV system, 5500 MW, +/- 500 kV long distance HVDC system, an HVDC Monopole of 200 MW and four HVDC Back-to-Back links of 3000MW capacity. These are supported by about 1,23,000 ckm. of 220kV transmission network. As mentioned above, all the five regions are interconnected through National Grid comprising hybrid AC/HVDC system. Present inter-regional transmission capacity of the National Grid is about 20,800 MW.

The details of the existing transmission system in India are given in Table 2.1.

<b>Transmission Lines</b>	<b>Unit</b>	<b>As on March 2009</b>
765 kV	ckm	3118
HVDC+/- 500 kV	ckm	7172
400 kV	ckm	89496
220 kV	ckm	122960
<b>Total- Transmission Lines</b>	<b>ckm</b>	<b>222746</b>
<b>Substations</b>		
HVDC Terminal Capacity	MW	8700
765 kV	MVA	4500
400kV	MVA	111202
220 kV	MVA	177190
<b>Total-AC Substation Capacity</b>	<b>MVA</b>	<b>292892</b>

**Table-2.1: Present Transmission network**

The present transmission system has to meet the firm transmission needs as well as Open Access requirements. The Long term Access (LTA) gives the transmission system strengthening required for future generation additions and the Short Term Open Access (STOA) facilitates increased real time trading in electricity, utilizing the inherent margins provided for required redundancies as per planning criteria. The STOA leads to market determined generation dispatches resulting in supply at reduced prices to the distribution utilities and ultimately to the consumers. In the year 2008-09, the volume of energy traded under Short term open access was about 31 Billion units.

Electricity is a regulated sector in India with Central Electricity Regulatory Commission at the central level and State Electricity Regulatory Commission in each of the states. Power grid Corporation of India Limited (POWERGRID), the Central Transmission utility (CTU) is responsible for wheeling power of central generating utilities and inter-state Mega IPPs, while State Transmission Utilities are responsible for wheeling of power from State generating units and State level IPPs. The CTU, plays an important role in the planning of new transmission systems as well as strengthening of existing networks at the Central level.

As per the Electricity Act, 2003 the functions of the Central Transmission Utility are to-

- Undertake transmission of energy through inter-State transmission system

- Discharge all functions of planning & co-ordination for inter-state transmission system with state transmission utilities, Central Govt., State Govt., Generating companies, Authority, Licensees etc
- Ensure development of an efficient, coordinated and economical system of inter-state transmission lines for smooth flow of electricity from generating stations to load centers
- Exercise supervision & control over the inter-state transmission system
- Ensure integrated operation of the regional grids through RLDCs

Similarly, the State Transmission Utilities are responsible for the development of transmission networks at the state level.

## 2.2 Transmission System Development - Issues

As mentioned above, in order to meet growing requirement, development of strong transmission system between pit-head/resource generation complex and bulk consumption centres are required. However, development of transmission system involves following issues:

- ❖ Minimization of Right of Way
- ❖ Protection of flora & fauna, wild life
- ❖ Creation of long distance high capacity transmission corridors to enable minimum cost per MW transfer as well as Optimal Transmission losses
- ❖ Minimal Impact on Environment
- ❖ Strengthening of National Grid

## 2.3 Future Plan In Transmission

In order to address above issues, high capacity transmission corridors comprising 765kV AC and  $\pm 800$ kV 6000MW HVDC system along with 400kV AC and  $\pm 500$ kV/600kV 2500Mw/6000MW have been planned to facilitate transfer of power from remotely located generation complexes to bulk load centres. This shall also facilitate strengthening of National Grid capacity to more than 37,000MW by 2012. The details of the transmission addition programme for the country are given below.

**Table 2.2: Transmission Addition Programme in India**

<b>Transmission Lines</b>	<b>Addition by 2012 (Ckm)</b>	<b>Addition by 2017 (Ckm)</b>
765 kV	7,612	25000-30000
HVDC Bipole	11,078	4000 - 6000
400 kV	1,25,000	50000
220 kV	1,50,000	40000
Total	2,93,852	119,000 – 126,000
<b>Substations</b>	<b>Addition by 2012</b>	<b>Addition by 2017</b>
HVDC	14,700 MW	16,000 -22,000 MW
765 kV	53,000 MVA	1,10,000 MVA
400kV	1,45,000 MVA	80,000 MVA
220 kV	2,30,000 MVA	95,000 MVA
Total Capacity	4,28,000MVA	2,85,000MVA
<b>Inter Regional Transfer Capacity</b>	38,000 MW	75,000 MW

Power map showing proposed high capacity transmission corridors is shown at Fig. 2.2.

Figure 2.2: Proposed High Capacity Transmission Corridors under Various IPPs

The intra state transmission and distribution at 220 kV, 132 kV, 66 kV, 33 kV, 11 kV, etc. would need to be planned and built by the state transmission and distribution utilities.

## **2.4 Integration of Emerging Technology**

To meet the growing power demand of various regions, power transfer capacity of the inter-regional links is being enhanced continuously. However a variety of issues and challenges need due emphasis in expansions to the desired level, some which are as under:

**Right Of Way:** The most notable and challenging issue the transmission sector is facing today is the Right of Way (ROW). It is the need of the hour to develop high intensity transmission corridor (MW per meter ROW) in an environmental friendly manner including protection of flora and fauna.

**Regulation of Power:** Another important aspect is the need towards regulation of power flow due to wide variation in demand on day as well as seasonal basis and change in the drawl pattern/shares of the utilities from time to time.

**Flexibility in Line Loading:** To handle more power as well as to optimize the use of transmission corridor it is important to load the different lines in the corridor more or less equally. To achieve this use of power electronic control devices like Fixed and Thyristor Controlled Series Capacitors(TCSC) and similar other means is an effective method.

**Improvement of Operational Efficiency:** Power system is required to be operated at the rated capacity with security, reliability and high availability. This can only be achieved through reliability based on-line condition monitoring, repair and maintenance in advance and making forced outage as zero.

In view of the above, key technological requirements for development of future power system are upgrading/uprating of existing transmission system, technology suitable for bulk power transfer over long distances like high capacity EHV/UHV AC system, HVDC system, compact tower/substation, mitigating devices to address high short circuit level, intelligent grid etc. POWERGRID, the Central Transmission Utility in its continuous endeavour has already integrated many of the above technologies in its power transmission system and many more are in pipe line/being explored for implementation. Brief description of new technologies implemented/being implemented is as under:

## 2.5 High Density Transmission Corridor

### 2.5.1 Increase in voltage

In order to optimize right-of-way, high density transmission corridors (MW per metre ROW) either by increasing voltage level or current order or both i.e. increase in voltage and current are need to be developed. Power intensity at different voltage level is tabulated in Table-2.3 below:

**Table-2.3 Power intensity in MW/meter at different voltage level.**

Voltage	132 kV	220 kV	400 kV	765 kV	±500 kV	±800 kV (approx.)	1200 kV (approx.)
ROW Meters(M)	27	35	46	64	52	70	90
Capacity (MW)	Upto 70-80	Upto 160-170	Upto 600-700	Upto 2500-3000	Upto 2000-2500	Upto 6000-6400	Upto 6000-8000
MW/m	3	5	15	45	48	90	90

It may be seen from the above Table-4 that power intensity at 132kV and 220kV corridors are 3 MW/meter and 5 MW/meter respectively, which is highly inefficient. With the increasing voltage, power intensity can be increased and transmission voltage upto 765kV level already operating. Towards development of high intensity

transmission corridor, there is a plan to develop  $\pm 800$  kV, 6000 MW HVDC system as a part of evacuation of bulk power from North Eastern Region (NER) to Northern Region (NR) over a distance of around 2000 kms. In addition, increasing the AC voltage level at 1200kV level has been planned. It is to mention that we are aiming towards use of 1100kV equipments for 1200kV operation by optimizing their protective level with the help of high energy level Surge arrester so as to achieve economy in respect of 1200kV UHV system development. Research work for 1000kV HVDC system has also been commenced.

### **2.5.2 Upgradation of transmission line**

POWERGRID has successfully implemented upgrading of 220kV D/C Kishenpur-Kishtwar line in J&K to 400 kV S/c first time in India. It has resulted in increase of power transfer intensity of the transmission corridor with marginal increase in ROW (from 35m to 37m) but far less than standard 400kV line (46 m). Upgradation of 400kV D/C lines to 400/ $\pm$ 500kV HVDC bipoles are also under exploration.

### **2.5.3 Upgradation of HVDC Terminal**

POWERGRID has been seamlessly upgraded  $\pm$ 500kV Talcher(ER) – Kolar(SR) HVDC terminal from 2000MW to 2500MW without changing of any equipment. That has been achieved with enhanced cooling of transformer and smoothing reactor with meager cost. The pay back period is about 2-3 years.

### **2.5.4 High capacity 400kV multi-circuit/bundle conductor lines**

POWERGRID has designed & developed multi circuit towers (4 Circuits on one tower with twin conductors) in-house and the same are implemented in many transmission system, which are passing through forest and RoW congested areas. POWERGRID has also designed and implemented multi circuit towers for use in Kudankulam & RAPP-C transmission system. This has effectively reduced the ROW to half and there by saving in cutting of trees and impact on environment. Typically for 400 kV Multi circuit lines the power intensity increases to about 30-60MW/m. Further, POWERGRID is extensively using four(4) conductors per phase in place of conventional twin to increase the power carrying capacity to two times through increase in current. This methodology has tremendous potential in sub-transmission system in urban/city areas.

### **2.5.5 High Surge Impedance Loading(HSIL) Line**

In order to increase the loadability of lines, development of HSIL technology is gaining momentum. By suitably spacing the bundle conductor, surge impedance can be reduced. POWERGRID is building up one HSIL line viz. 400kV Meerut – Kaithal D/c where SIL is about 750 MW as against nominal 650MW for a normal quad bundle conductor line.

### **2.5.6 $\pm 800$ kV, 6000MW High Capacity HVDC system**

POWERGRID has developed in-house expertise in implementation of HVDC systems. We have commissioned  $\pm 500$ kV 2000 MW HVDC bipole between Talcher & Kolar, Asia's longest HVDC bipole (about 1400 kms). Further  $\pm 500$ kV, 2500MW Balia-Bhiwadi HVDC Bi-pole is under advance stage of implementation. POWERGRID now is in the process of implementing  $\pm 800$ kV, 6000 MW HVDC Bi-pole line from North Eastern region (Biswanath Chariali) to Northern Region (Agra). This shall be the first  $\pm 800$ kV HVDC line in the world having largest power carrying capacity of the order of 6000MW and transferring power over more than 2000 Kms.

### **2.5.7 Compact towers**

In special areas, compact towers like delta configuration, narrow based tower etc. which reduce the space occupied by the tower base are being used. In this direction, 765kV tower with delta configuration has been designed and implemented, which reduces the Right-of-Way requirement of 765kV lines from 85m to 64m (approx. 33% less) resulting in forest & environmental conservation. First 765kV Sipat – Seoni 2xS/c line with delta configuration tower is under operation since 2007.

Further, 400kV Pole structure is also being used especially in areas of high population density and for aesthetic integration of transmission line to surrounding environment. Pole type structures with about 1.85 m base width as against 12-15m base width of a conventional tower were used in transmission line approaching Maharani Bagh, Delhi substation to address Right-of-way problem in densely populated urban area.

### **2.5.8 Increase in current: High Temperature Low Sag (HTLS) conductor line**

Efforts to reduce right-of-way are complemented with the use of high temperature endurance conductor for select transmission corridor to increase the current rating. Presently the technology to use high temperature and low sag conductor is becoming more important. Maximum temperature limit of the Aluminium Conductor Steel Reinforced (ACSR) conductors is about 100°C and it may not be possible to go beyond this limit as galvanization of the wire would be tampered and secondly there may be a creep in the conductor. However, in special situations we can use high temperature endurance conductors which can withstand temperature upto 230°C like Invar. This type of conductor is designed with max. operating temperature of 210°C against 85-95°C for ACSR conductor. It gives matching thermal rating and also has been found to be economical due to considerable savings on structure. POWERGRID has already implemented twin INVAR conductor line for LILO portion (15kms stretch) of 400kV Dadri-Ballabgarh quad conductor line at Maharani Bagh substation. Apart from increasing the power flow capacity, there was considerable reduction in special pile foundations in the river Yamuna. Further, after implementation of Tala transmission system, two nos. of 400kV D/c lines between Siliguri and Purnea, one with twin Moose conductor and other with quad Moose conductor are running in parallel. This not only creates unbalanced power flow condition but also restricts total transfer capacity of the corridor. In order to address above issues, Siliguri – Purnea, twin Moose conductor line is being re-conducted with high temperature low sag

(HTLS) conductor. This type of conductor also has high potential in urban/city areas which is being implemented in metros like Mumbai.

### **2.5.9 Fixed and Thyristor Controlled Series Compensation (TCSC)**

Series compensation on the transmission line enhances power handling capability depending on the amount of compensation provided. Series capacitors in the form of fixed and variable compensation (TCSC), increases the power transfer capability as well as enables damping of power oscillations to improve system stability. POWERGRID already implemented 24 nos. fixed series capacitors and 6 nos. TCSC on 400kV lines resulting in increase of power transfer capability of these lines by 30-40% and 22 nos. fixed series capacitors installations are in pipe line.

### **2.5.10 Reduction in land for substation**

#### **3.4.1 Gas Insulated Substations (GIS)**

With scarce land availability there is a growing need for reduction of land use for setting up of transmission systems, particularly in Metros, hilly and other urban areas. POWERGRID has established State-of-the-art Gas Insulated Substations (GIS), which requires less space (about 80% reduction) i.e. 5-6 acres as compared to conventional substation which generally requires 30-40 acres area. POWERGRID has already commissioned 400/220kV GIS at Maharaniabagh in Delhi, Kayankulam in Kerala. Presently GIS are being implemented at many such locations (Gurgaon, Navi Mumbai, Koteswar etc). The performance is very satisfactory.

#### **3.4.2 Substation Automation and Remote Operation**

There is a growing need for judicious use of skilled manpower and their redeployment in areas requiring more attention. Towards achieving this goal, POWERGRID established its first remote controlled 400kV substation at Bhiwadi, remotely controlled from Ballabgargh substation. This was the first remotely controlled substation in India. Later 3 more substations were implemented with remote operation as part of pilot projects in SR and WR for continued improvement in operational efficiency and reduction in operational cost. Presently all new substations are being provided with-automation.

### **3.5 Regulation in Power Flow/ FACTS devices**

With electricity market opening up further, more and more need has been felt to utilize the existing assets to the fullest extent as well as regulate the power in a particular direction which may not be possible only through ac network. This could be possible through use of power electronics in electricity network. Further, integration of renewable resources such as wind, solar etc. need usage of more power electronic devices for smooth and reliable operation. A lot of work is being done in this area by POWERGRID and other utilities/agencies.

### **3.6 Improvement of operational efficiency**

In order to improve operational efficiency of transmission system, many new technologies have been implemented by POWERGRID to ensure preventive maintenance and quick restoration of faulty system. Some of the major technologies are as under:

#### **3.6.1 Emergency Restoration Systems (ERS)**

Natural calamities, cyclonic storms etc. uproot the transmission line towers interrupting power flow and sometimes cause system disturbances. Restoration of transmission lines with the conventional system takes very long time. POWERGRID is using Emergency Restoration System(ERS) which helps in restoration of lines in shortest possible time within few days, which otherwise normally takes longer times.

#### **3.6.2 Hotline maintenance**

Highly skilled manpower work on live lines for planned maintenance activities such as replacement of insulator, spacer dampers, hardware etc and thereby avoiding outages.

#### **3.6.3 Live Line insulator washing:**

Recently POWERGRID has adopted helicopter based live line washing of insulators in heavily polluted areas (in NCR) and thereby reducing unwanted tripping during winter season. This technique requires highly skilled personnels, who uses water jets with precision maneuvering of the helicopter to wash the insulators on charged lines.

#### **3.6.4 Condition Based Monitoring**

POWERGRID has adopted many state of the art condition monitoring & diagnostic techniques such as DGA, FRA, PDC, RVM etc. for transformers, DCRM for CBs, Third Harmonic Resistive current measurement for Surge Arrestors etc. to improve Reliability, Availability & Life Extension. Further, on-line monitoring systems for transformers have been implemented to detect faults at incipient stage and provide alarms in advance in case of fault in the transformers. These systems will also provide the dynamic overload capacity of the transformers and will improve reliability & availability of the transformers. More and more condition based technology need to be used to avoid forced outage and reduce the maintenance requirement.

#### **3.6.5 Preventive Maintenance**

Preventive State-of-the-art maintenance techniques for various equipment applied in our system include On line monitoring of various components of transformers and reactors, Circuit Breakers, Instrument transformers, Lightning arrester etc.

### **2.7 Emerging technology in Grid Management**

Indian power system is characterized by continuous expansion of the grid, expanding in the range of 35-40% per year. Increasing grid connectivity is accompanied with various factors viz. spread of the grid geographically, wide variation in generation as well as loads on daily/seasonal basis, multi direction flow of power, open access, unscheduled interchange (UI) and the need for economic dispatch. It necessitates

reliable and secure grid with quality power supply. Under these circumstances, it is important to know the dynamic state of the grid on real-time basis in terms of

- i) Angular and voltage stability
- ii) Level of increase in transfer capacity of various transmission elements at different instances
- iii) Control and regulation of power flow to maintain grid parameters
- iv) Remedial Action Scheme (RAS) and System Integrated Protection Scheme (SIPS) in the event of severe contingency in the grid

Today RLDCs have been modernized and we are getting analog and digital data from the field at a regular interval of 15 seconds and 4 seconds respectively. These are steady state values. However to get the same under dynamic condition we need to have new technology called Smart/Intelligent Grid. Major features of Smart Grid is that it continuously monitors the grid state, say phase angle separation and alerts the operator to take corrective action in real time. So, we need to develop Smart Grid with the following State-of-art features like: a) Integrated energy and Communication system architect; b) Phasor measurement technique; c) Wide area measurement; d) Adaptive islanding; e) Self healing grid and f) Probabilistic assessment, Dynamic stability assessment and Voltage stability assessment techniques etc.

For the Smart Grid to function properly a strong and reliable communication system is very much essential because we need data samples at a very fast interval. We have already started working towards development of Smart Grid and very soon we may install Phasor Measurement Units (PMUs) at the critical nodes in the grid and shall be equipped with Wide Area Measurement System (WAMS).

POWERGRID has already taken up pilot project for certain critical area before it is implemented countrywide. This would support utilities in making optimal usage of the transmission grid capacity and in preventing the spreading of disturbances. By providing on-line information on stability and safety margins for dynamic condition monitoring, it would serve as an early warning system in case of potential power system disturbances.

Another area where research is on is towards low cost energy storage system such as large batteries, fly wheels, compressed air etc. so that in case of contingency, these systems may pump energy into the system.

## **2.8 1200kV Test Station**

In order to increase the power density of the corridor, development of 1200kV AC system as next higher AC voltage level has been decided. However, 1200kV AC technology is relatively a new one in the world. Therefore, to develop this technology indigenously, a unique effort has been made by POWERGRID through a collaborative research between POWERGRID and Indian manufacturers to establish a 1200kV UHVAC Test Station. This endeavour shall benefit the Indian Power sector and manufacturers as availability of 1200KV class equipment within country will not only enable optimisation of transmission cost, but also help in during O&M phase. In this direction, POWERGRID along with Indian manufacturers is establishing a 1200kV

UHVAC Test Station at Binalin the State of M.P) where a 1200KV test line (S/c+D/c) is being constructed along with two nos. 1200KV test bays in which the leading manufacturers are providing main equipment like transformers, surge arresters, circuit breakers, CTs, CVTs and transmission line hardware etc. POWERGRID shall provide space, civil foundation, 1200kV line, control & protection system, various testing equipment, auxiliaries & fire protection system, 1200kV bushing etc. These test bays and test line shall be used by the manufacturers and POWERGRID for various field tests so that the results and feedback can be used for developing field proven equipment of 1200KV system in India as well as gain initial operational experience. Development of this test station is in advance stage and likely to be commissioned by 2010.

## **2.9 Investment in Transmission**

The Estimated total fund requirement for transmission by 12<sup>th</sup> Plan i.e. 2016-17 has been assessed as USD 42 Billion.

Inter-State Sector	USD 21 Billion
State Sector	USD 21 Billion

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## **Chapter-3**

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### **Distribution**

#### **3.1 Introduction**

Power distribution is the final and most crucial link in the electricity supply chain and, unfortunately, the weakest one in the country. It assumes great significance as the segment has a direct impact on the sector's commercial viability, and ultimately on the consumers who pay for power services. The sector has been plagued by high distribution losses (30% overall) coupled with theft of electricity, low metering levels and poor financial health of utilities with low cost recovery. Due to the above, the distribution companies have not been able to undertake corresponding investments in infrastructure augmentation.

The sector has started receiving greater attention and investment with the restructuring of the state electricity boards (SEBs). Several new initiatives have been introduced to reduce aggregate technical and commercial (AT&C) losses along with a definitive regulatory framework. Electricity Act 2003, National Electricity Policy 2005 and National Tariff Policy 2006 are important regulations governing the sector today with an aim to bring competition in the sector and improve the services to the end consumers.

The Govt. has also made heavy investments in the distribution sector through the Rajiv Gandhi Grameen Vidyutikaran Yojna (RGGVY) and Accelerated Power Development and Reforms Programme (APDRP) during the Tenth Plan and has continued to extend the same in the Eleventh Plan as well. The aim of these programs is to provide access of electricity to all and bring down the AT&C losses to a level of around 15% across the country. The various policies and regulations introduced by the government are set to increase competition and bring about commercial viability.

Participation of private players into the Distribution Sector has also been encouraged through various models such as Public Private Participation as in case of Delhi and Orissa and more recently through input based distribution franchisee models in Maharashtra, Madhya Pradesh and Uttar Pradesh.

#### **3.2 Overview of the Existing System**

The distribution segment continues to carry electricity from the point where transmission leaves off, that is, at the 66/33 kV level. The standard voltages on the distribution side are therefore 66kV, 33 kV, 22 kV, 11 kV and 400/230 volts, besides 6.6 kV, 3.3 kV and 2.2 kV. Depending upon the quantum of power and the distance involved, lines of appropriate voltages are laid. The main distribution equipment comprises HT and LT lines, transformers, substations, switchgears, capacitors, conductors and meters. HT lines supply electricity to industrial consumers while LT lines carry it to residential and commercial consumers.

In the Tenth Plan, the state utilities added 855,059 ct. km of distribution lines' infrastructure. The number of step-down and distribution transformers also increased by 13,961 and 1,250,038 respectively. This represented a capacity addition of 192,369 MVA and 86,512 MVA respectively during the Tenth Plan, at the end of which (March 2007), distribution infrastructure stood at 6,580,949 ckt. km of line network and a transformer capacity of 863,462 MVA.

**Table 3.1: Capacity Addition in the X Plan**

<b>Voltage Level</b>	<b>Capacity Addition (ckm)</b>
<b>33/22 kV</b>	26312
<b>15/11 kV</b>	356726
<b>6.6/3.3/2.2 kV</b>	1694
<b>Upto 500 V</b>	470327
<b>Total</b>	<b>855059</b>

*Source: CEA General Review 2008*

### **3.3 Future Requirement**

The government has set an ambitious target for system augmentation in the distribution segment. It plans to quadruple the distribution network by adding 3.2 million ct. km of distribution lines in the Eleventh Plan. Another 4.2 million ct. km is planned to be added in the Twelfth Plan. Thus by the end of the Twelfth Plan, the total distribution network in the country would have doubled, thus greatly facilitating delivery of power to the expanding base of end-use customers. Further, it plans to bring about 214,000 MVA of transformer capacity in the Eleventh Plan and another 270,000 MVA in the Twelfth Plan. Of these, the distribution transformers for the Eleventh and Twelfth Plans will be 128,000 MVA and 162,000 MVA respectively.

**Table 3.2 : System Augmentation Eleventh and Twelfth Plan**

<b>Particular</b>	<b>11<sup>th</sup> Plan</b>	<b>12<sup>th</sup> Plan</b>
<b>Lines (ct km)</b>		
<b>66 kv overhead</b>	23335	30546
<b>33 kv overhead</b>	113936	149142
<b>6.6/11/22 kv overhead</b>	1036396	1356638
<b>LT lines</b>	2080106	2722857
<b>Total</b>	<b>3253773</b>	<b>4259183</b>
<b>Transformer capacity (MVA)</b>		
<b>Power Transformer</b>	86000	108000
<b>Distribution Transformer</b>	128000	162000
<b>Total</b>	<b>214000</b>	<b>270000</b>

*Source: Working Group on Power for 11<sup>th</sup> plan*

As per the CEA's 17s Electric Power Survey (EPS), the all India energy requirement is expected to grow at an annual rate of 6.8 per cent during 2007-08 to 2011-12 to reach 968,659 GWh in 2011- 12. The total energy requirement takes into account transmission and distribution losses of approximately 22 per cent, and hence the energy consumption is expected to be around 755,847 million kWh. The energy

consumption is expected to be drawn equally amongst rural and urban consumers throughout the Eleventh Plan (2007-12), although the share of rural consumers will decline marginally from 50.08 per cent of total consumption in 2007-08 to 49.89 per cent of total consumption in 2011-12.

	<b>2007-08</b>	<b>2008-09</b>	<b>2009-10</b>	<b>2010-11</b>	<b>2011-12</b>	<b>CAGR(%)</b>
<b>All India-Rural</b>	255899	281853	310257	341924	377141	<b>10.18</b>
<b>All India-Urban</b>	255000	281035	309994	342400	378706	<b>10.39</b>

Amongst the consumer categories, domestic consumers are expected to grow at the fastest rate 13.04 per cent during the Eleventh Plan. This category of consumers is expected to be followed by commercial consumers, LT industries, public lighting and public water works' consumers. Growth in the number of agricultural/irrigation consumers is expected to be at 7.95 per cent.

Category	<b>2007-08</b>	<b>2008-09</b>	<b>2009-10</b>	<b>2010-11</b>	<b>2011-12</b>	<b>CAGR(%)</b>
<b>Domestic</b>	134962	152653	172443	194937	220372	<b>13.04</b>
<b>Commercial &amp; Miscellaneous</b>	42596	47305	52663	58755	65666	<b>11.43</b>
<b>Public Lighting</b>	5984	6674	7397	8184	9043	<b>10.87</b>
<b>Public water works</b>	13093	17393	15845	17468	19281	<b>10.16</b>
<b>Irrigation</b>	112626	121658	131357	141775	152931	<b>7.95</b>
<b>LT Industries</b>	44200	49086	54643	60944	68135	<b>11.43</b>
<b>HT Industries</b>	136712	148876	161999	176522	192614	<b>8.95</b>
<b>Railway Traction</b>	12455	13381	14404	15569	16913	<b>7.95</b>
<b>Non-Industrial</b>	8270	8865	9500	10170	10893	<b>7.13</b>
<b>Total</b>	<b>510899</b>	<b>562889</b>	<b>620251</b>	<b>684324</b>	<b>755847</b>	<b>10.29</b>

### 3.4 Key Drivers of the Distribution Sector

Several drivers will shape the outlook of the Indian power distribution sector in the coming years. A few among these are:

- **Continued demand for power:** The Integrated Energy Policy predicts that in order to eradicate poverty, the country's economic growth needs to be at least 8 per cent annually until 2032 and in that time frame, the power capacity needs to rise to as high as around 800 GW.
- **Distribution Reforms:** Unbundling of the vertically integrated SEBs into functional entities is a key requirement of the EA 2003. While most of the

States as depicted above have unbundled their utilities into Generation, Transmission and Distribution Companies, the real benefit of unbundling can be derived only through bringing in best practices and professional management through Privatization or PPP models. Given the political sensitivity and issues on valuation of assets on transfer together with employee reservations, States are looking at the Distribution Franchisee as a middle path for securing efficiencies while addressing the above political/social issues. However, in the long run, privatization seems to be a sustainable solution. The PPP model in Delhi has been successful in curbing AT&C losses from a level of greater than 55% to a level of around 20% in a span of 7 years. NDPL has invested more than Rs. 2000 Crs in the network over the past 7 years and an equivalent amount has been put up by other discoms.

- **Supply codes and Performance Standards:** Supply Code lays down standards and procedures for recovery of electricity charges, billing cycles, disconnections, and restoration of service and metering among other things. To protect consumer interests, the EA2003 requires the SERCs to specify standards of performance for distribution licensees. The commissions also have to specify the penalty and compensation to be paid by the licensees to the affected parties if the former fails to meet the standards. The licensees also have to furnish information regarding the level of performance achieved, the number of cases in which compensation was made along with the aggregate amount of compensation, to the SERCs.

Both supply codes and standards of performance help in improving efficiency in power distribution operations and consumer service. All functional SERCs have notified the standards of performance regulations, and 21 SERCS have issued electricity supply code regulations as of December 2008. Sooner than later when open access in distribution becomes a reality, the importance of adhering to supply codes would become visible as the choice of supplier would depend on this.

- **Growing consumer awareness:** For both SEBs and private companies, consumer interest is becoming a high priority. Connections are far easier to come by, bill payments are being streamlined, and complaints are addressed more promptly and effectively. Utilities in Andhra Pradesh and Delhi have proved to be frontrunners in establishing high standards of customer service. For instance, North Delhi Power Limited (NDPL) has received accolades for providing better customer service through several measures including implementing a customized CRM package. Every customer at NDPL is segmented based on their sanctioned load, and NDPL has appointed dedicated client managers to cater to the specific needs and requirements of certain key consumer groups. This is in addition to the consumer relationship cell and consumer grievance redressal groups set up for addressing grievances of consumers. Further, call centers have been set up to address supply and billing complaints. It has put in place a short messaging service (SMS) based-fault management system whereby complaints are addressed through SMS. This

has resulted in increased customer satisfaction across all segments, especially among urban domestic consumers, thereby improving the customer's willingness to pay for better services. A virtuous cycle of better customer satisfaction resulting in more revenues for the discoms, who in turn are investing in better services, seems to be finally coming into play.

- **Focus on IT:** IT is increasingly playing a prominent role in making the transition. More and more discoms are adopting IT systems and practices to improve operations and customer service. Supervisory Control and Data Acquisition (SCADA) is being used for better management of distribution networks. Spot billing, call centers, remote meter reading, automated billing, and energy accounting are some of the IT mechanisms being incorporated. Advanced technologies are being deployed particularly in billing, fault reporting, remote metering and substation operations, enterprise solutions involving employees and commerce, consumer servicing through the Internet and telephones (call centres), and management information systems (MIS). Energy auditing and accounting are also being taken up assiduously.
- **Move towards demand side management (DSM):** Realizing the benefits of introducing DSM measures in reducing overall electricity demand, several state regulators are encouraging DSMs in their states. Many SERCs have introduced time-of-day with differential tariffs for usage in different times, particularly for high tension (HT) consumers. Discoms and regulators are also encouraging the use of energy efficient devices, including efficient pumpsets in agriculture, and efficient lighting and appliances. Farmers are being encouraged to use electricity in non-peak hours. They are also encouraging the use of energy efficient devices, including efficient pumpsets in agriculture, and efficient lighting and appliances.
- **Environmental and social pressures:** As a result of increasing environmental pressures, both local and global, the country's power mix is increasingly becoming green. The National Action Plan for Climate Change calls for about 5 per cent of the national generation to be based on renewable sources. Since power from renewable energy is infirm (though not unpredictable), these require a well interconnected grid with adequate spinning reserves and transfer capabilities. Further, as per policy objectives, discoms have to procure a certain percentage of their power requirement through renewable (**The Jawaharlal Nehru National Solar Mission has envisaged an RPO mandate increasing from 0.25% to 3% of energy purchased by 2022**). The government is also proposing to set up trading in renewable energy certificates which will help create a vibrant market for renewable energy and go a long way in converting the potential for renewable energy into a reality.
- **Tariff rationalization:** As per policy objectives, rationalisation of electricity tariffs and reduction of cross-subsidies will take place within a band of +/- 20 per cent by the end of year 2010-11. However, the consumers below the poverty line (BPL) and who consume a small quantity of electricity shall continue to receive special support through cross-subsidised tariffs. The tariff rationalisation will result in commercial viability of the discoms and hence lead

to corresponding investments in related infrastructure. With tariff rationalisation, the HT consumer, who currently bears the burden of higher tariffs, will increasingly find it competitive to buy power from the grid rather than through captive generation. This will further help the discoms in improving their consumer mix, and hence their financials.

- **Improving grid standards:** Just about five years ago, Indian grids were both unsafe and unreliable with voltages and frequencies fluctuating way beyond stated or permissible parameters resulting in frequent grid disturbance and collapses, equipment damages and/or operations at much lower efficiencies. This in turn resulted in the inability to enforce merit order despatch, and operational and commercial disputes ruled. The regulatory mechanisms of the availability based tariff (ABT) and unscheduled interchange (UI) have created a solid base for maintaining grid standards. These should improve further with the newly notified draft for the amendment of the Indian Electricity Grid Code by the Central Electricity Regulatory Commission (CERC). Thus the utilities will have to focus on demand forecasting, and predict their long term requirement of power in order to benefit from the ABT regime.

These drivers along with the government's focused interest in the distribution segment as illustrated through the institutionalisation of the Restructured-APDRP will shape the outlook for the sector in the coming years.

### **3.5 Status of Implementation of Distribution Projects**

#### **3.5.1 Accelerated Power Development Reforms Programme**

The scheme was launched in 2002-03 as Additional Central Assistance to the States for strengthening and up-gradation of sub-Transmission and Distribution systems. 50% incentives were given to SEBs / Utilities to reduce their financial losses for actual cash loss reduction.

Achievements:

- 571 projects were sanctioned under APDRP covering Distribution network of approx. 906 towns in the country. AT&C losses have been brought down below 20% in 215 APDRP towns in the country, of which 163 towns have been brought below 15%.
- The billing efficiency at national level has improved from 68.37% during 2002-03 to 71.04% during 2006-07. The national average collection efficiency has also improved from 92.68% during 2002-03 to 94.02 % during 2006-07. With this improvement in billing and collection efficiency, the national average AT&C loss of the distribution companies have reduced from 36.64% in the year 2002-03 to 33.07% in year 2006-07.
- 100% feeder metering has been completed in 23 states. Overall 98% feeder metering and 88% consumer metering has been achieved at national level.

- The overall commercial loss (without subsidy) of the utilities has reduced from Rs. 29,331 Crores during 2001-02 to Rs. 27,446 Crores during 2006-07.
- Loss of utilities with respect to turnover has reduced from 36.55% in year 2001-02 to 16.45% in year 2005-06.

### **3.5.2 Restructured APDRP (Eleventh Plan)**

The focus of recently approved Restructured APDRP (R-APDRP) in 11th Plan and beyond is on actual, demonstrable performance in terms of loss reduction. State Power Utilities are expected to reduce AT&C losses to 15%. The Utilities are also to achieve the following target of AT&C loss reduction for the Utility as a whole:

- Utilities having AT&C loss above 30%: Reduction by 3% per year
- Utilities having AT&C loss below 30%: Reduction by 1.5% per year

Projects under the scheme are proposed to be taken up in **Two Parts**.

#### **Part – A**

- Preparation of Base-line data for the project area covering Consumer Indexing, GIS Mapping, Metering of Distribution Transformers and Feeders, and Automatic Data Logging for all Distribution Transformers and Feeders and SCADA / DMS system for big cities only. Expected investment shall be Rs. 10,000 crores.

#### **Part – B**

- Renovation, Modernization and strengthening of 11 kV level Substations, Transformers /Transformer Centers, Re-conductoring of lines at 11kV level and below, Load Bifurcation, Load Balancing, HVDS, installation of capacitor banks and mobile service centers etc. In exceptional cases, where sub-Transmission system is weak, strengthening at 33 kV or 66 kV levels may also be considered. Expected investment shall be Rs. 40,000 crores.

### **3.5.3 Rajiv Gandhi Grameen Vidyutikaran Yojna (RGGVY)**

RGGVY aims at electrification of 125,000 un-electrified villages and un-electrified hamlets and electrification of 7.8 crore households. The estimated cost of the scheme (including 11th Plan) was Rs.16,000 crores approximately and Rs.5000 crores were earmarked for capital subsidy in phase- I during the 10th Plan Period.

Electrification of un-electrified Below Poverty Line (BPL) households will be financed with 100% capital subsidy as per norms of Kutir Jyoti Programme in all rural habitations. Households above poverty line will be paying for their connections at prescribed connection charges and no subsidy will be available for this purpose. 10% of the project cost will be provided by REC as soft loan @ 5%.

#### **Present Status:**

558 projects have been sanctioned with an outlay of Rs. 25,679.64 crores for providing electricity to 1,16,124 un-electrified villages, intensive electrification of 3,49,853 already electrified villages, releasing electricity connections to 4.09 crore rural households including 2.43 crore Below Poverty Line (BPL) households. The

cumulative achievement is the electrification of 53,048 hitherto un-electrified villages, intensive electrification of 66,808 already electrified villages and provision of electricity connections to 48.18 lakh rural households including 40.76 lakh BPL households. Govt. of India has approved the continuation of the scheme in 11th Plan for attaining the goal for providing access to electricity to all households by 2009 with a capital subsidy of Rs. 28000 crores. Under the scheme, Ninety per cent capital subsidy would be provided towards overall cost of the projects under the scheme.

### **3.6 Key Issues**

- **AT&C losses remain woefully high though the Restructured APDRP is aiming to bring it to 15 per cent by 2012:** AT&C losses are coming down only in the case of a few reforming. Utilities/SEBs while the national average continues to remain high. There are several Pockets of excellence but overall state wide reduction in AT&C loss remains and a consistent downward trend is not yet visible. AT&C losses which were 32.54 per cent in 2002-03 still hover around 30 per cent as of 2008-09. Power theft is rampant in some of these states and some also have a high rate of equipment theft, particularly in the rural areas. This has resulted in high non-technical losses. Other causes include faulty meters and unmetered supply. Greater influx of professional services within the limitations of state owned discoms would go a long way in improving system wide AT&C losses.
- **Poor recoveries hamper:** Another problem is poor billing and collection. Of the total electricity generated, less than 50 per cent is paid for. Electricity is stolen or not billed or electricity bills are not paid at all or not paid on time. The anti-theft legislation passed by the Parliament in June 2007 provides a more stringent framework to check electricity theft and non-payment of bills. Further, a Y-o-Y revenue gap in tariffs further hamper the financial state of the utilities
- **Tariffs continue to suffer from lack of commercial principles in most cases:** Most of the problems arise from incorrect pricing of power whereby there are large cross subsidies built into tariff structures which provide incorrect economic signals to the consumers. While the Act provides for reduction in cross subsidy to +/-20%, given the political and socioeconomic structure of the country, not much has been done by the regulators in reducing the cross subsidies or in laying down a framework for reduction of the same.. Populist policies such as free power have proved to be a big dampener with the state governments unwilling or unable to compensate the discoms for the additional costs they have to bear as a result of these measures. Not only do these populist measures put an additional financial burden on the discoms but they also lead to wastage of power by the farmers. Water-tables in a number of states have been pushed down, which has led to a serious water crisis.
- **Investment in distribution infrastructure remains lower than what is**

**desirable:** Investment in the distribution sector has not kept pace with investment in generation, which has led to high transmission and distribution (T&D) losses, poor networks, and delays in projects. Due to distribution network constraints, power cannot be fully transported from surplus to deficit areas, and open access transactions cannot be effectively facilitated.

- **Distribution Open Access Still in Nascent Stages:** According to the mandate of the EA2003, open access in transmission was operationalised with immediate effect, and that in distribution was to be implemented in phases. All the 23 SERCs have passed final regulations for implementation of open access in distribution in phases (1 MW and above by Dec 2008), however, the actual implementation of open access is still very nascent. Until the issues in open access are resolved, the intent of competition in the retail segment shall never materialize. Open Access in concept is welcome for the distribution sector; however, the same shall only take off when there is adequate power in the country and the cross subsidies are reduced to reasonable levels so as to provide a level playing field to incumbent utility and open access provider.

### **3.7 Role of Information Technology and Automation**

A number of utilities have now started focusing on IT based applications to bring about efficiency in distribution. Moreover, the Restructured APDRP encourages IT enabled applications and automation for reduction of energy losses as well as energy accounting and auditing. Some of the automation and IT enablement in the Power Distribution Sector and their role in improving the commercial viability and service standards are:

- **Customer indexing & GIS based Database:** Consumer indexing based on GIS applications needs to be given priority in the Eleventh Plan to enable the respective utilities to increase their customer coverage, regularize unregistered/unauthorized connections, conduct audits at the feeder level by comparison of 'energy sent out' on a 11 kV feeder with total energy meter readings of all HT/LT customers in that particular feeder
- **Energy Accounting and Auditing:** A robust Energy Accounting and Auditing framework shall help the utilities in prioritization of loss reduction measures and bringing about aggressive reduction in loss levels.
- **Reliability Monitoring of Power Distribution Systems:** There are a number of reliability indices which measure the outage in terms of, consumer hours and number of consumer interruptions etc. Reliability monitoring will become more fruitful once 'Consumer Indexing' is completed and will provide a direct index for customer satisfaction.

- **Supervisory Control and Data Acquisition (SCADA):** A well planned and implemented SCADA system not only helps utilities deliver power reliably and safely to their customers but it also helps to lower the costs and achieve higher customer satisfaction and retention.

SCADA Operation	Analog Values Archiving	Message Archiving	Tagging	Load Shedding	Load Forecasting	ABT
<ul style="list-style-type: none"> <li>• Perform data consistency checking. Determine data that is not available. Identify anomalous measurements in the network. Verify overloads and alarms on monitored equipment.</li> </ul>	<ul style="list-style-type: none"> <li>• Power Flow performs power flow studies that include loss of power system equipment, changes in generation, changes in bus load, and any other changes in system or area quantities</li> </ul>	<ul style="list-style-type: none"> <li>• Contingency Analysis function is used to analyse the real-time power system security under pre-defined contingency conditions such as loss of an equipment or feeder.</li> </ul>	<ul style="list-style-type: none"> <li>• Safety being the prime concern, tagging is available in SCADA, wherein tags such as PTW, Caution Order, Control Inhibit etc. can be used to increase operational safety</li> </ul>	<ul style="list-style-type: none"> <li>• Load Shedding module has been customized to suit NDPL requirements, block Load Shedding, Under-Frequency, ISLS, Distress Load Shedding as well</li> </ul>	<ul style="list-style-type: none"> <li>• Load Forecasting can be done based on temperature, humidity, historical load and day type (for e.g holidays)</li> </ul>	<ul style="list-style-type: none"> <li>• A tentative ABT UI can be calculated based on the Sanction Schedule given by DTL and actual load</li> </ul>

- **Distribution and Grid Station Automation:** Distribution automation (DA) optimizes a utility's operations and directly improves the reliability of their distribution power system. Adding targeted distribution automation capabilities can be economical when they are an extension of your existing SCADA investments and the communication infrastructure. The success or failure of an automation program hinges on proper selection of equipment and communications to seamlessly integrate data into the utility control room. The key is to choose equipment that leverages your current assets wherever possible. With the latest in high speed communication technology, there has never been a better time for utilities to extend their automation beyond the substation. Substation automation is a rapidly increasing area of interest and benefit to utilities. Substation automation goes beyond traditional SCADA to provide added capability and information that can further improve operations and maintenance, increase system and staff efficiencies, and leverage and defer major capital investments.
- **Outage Management Systems:** An Outage Management System (OMS) provides the capability to efficiently identify and resolve outages and to generate and report valuable historical information. It also helps the utility inform the customer of the outage situation and restoration status (rather than the customer informing the utility first). An OMS typically works in conjunction with a GIS, the utility's CIS, and automated call handling systems, such as an Interactive Voice Response (IVR) system.
- **Distribution Network Planning:** Inadequate network planning is one of the reasons for haphazard and scientific development of the distribution system.

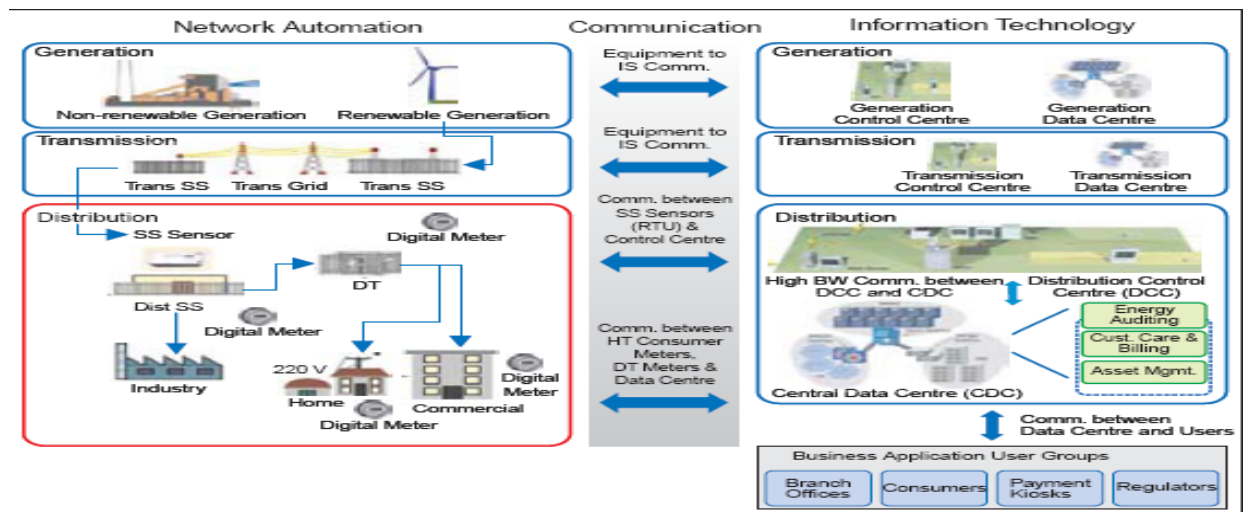
The utility should move to proper distribution network planning both for demand forecasting on a medium and long term basis, and for determining the need for system expansion and improvement to meet load growth. This will help in reducing the short term power purchase costs, particularly as short term prices have been high in the near future. Utilities should prepare a perspective network plan for a 10 year period, and this should become part of the conditionality's for sanction of grants under various programmes.

- **Automated Meter Reading/ Advanced Metering Infrastructure:** Another area gaining prominence is the Automated Meter Reading of high revenue consumers which help the utilities protect their revenues and keep a continuous track of any anomalies at the consumer premises through a remote location. GPRS, GSM and CDMA are being used as the communication medium for these technologies. NDPL has undertaken Automated Meter Reading for more than 30000 consumers (highest in India so far) and this has ensured revenue protection to the tune of 60%. Advanced metering infrastructure (AMI) is defined as the communications hardware and software, and associated system and data management software that creates a network between advanced meters and utility business systems, and which allows collection and distribution of information to customers and other parties such as competitive retail providers, in addition to providing it to the utility itself. AMI is the wave of the future in distribution sector as more and more focus is laid on demand side management.
- **Prepaid Metering:** Pre-paid meters enable efficient use of power for agricultural use and also eliminate adverse impact on the water table due to excessive exploitation of ground water. Though it involves huge capital costs, the gains from the system can offset such costs in the long run. It is aimed; expected that large scale use will bring down the cost of the technologies. Further, prepaid metering can act as an effective tool against defaulters and those found involved in dishonest abstraction of energy. Further, these meters find a prominent use in Govt. accommodations.
- **HVDS Systems:** The advantages of HVDS systems are well known, particularly in containing theft of electricity. Besides, it improves the quality of power significantly and thereby improves customer satisfaction. HVDS systems should be given a special focus to get immediate results in loss reduction. Efforts also need to be made to bring down the HT/LT ratio during the 11th Plan. The investment on conversions from conventional systems to HVDS is recovered by way of loss reduction within a period of 3 to 5 years in most cases.

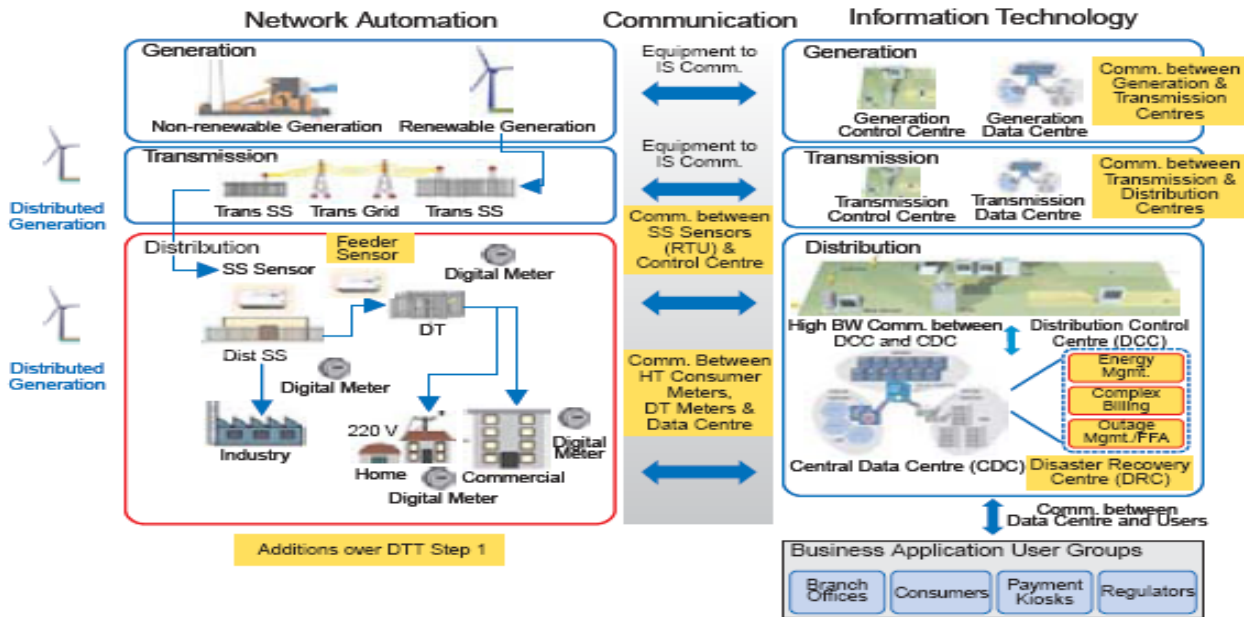
- **Enterprise Resource Planning:** Employing an enterprise asset management solution will help utilities free work management from tedious and manual data entry and streamline new service initiation through improved dispatch, scheduling and tracking. The utilities can also improve management and tracking of capital invested and reduce spares inventory. NDPL implemented an ERP solution for its business, and benefits out of this implementation can be measured in terms of improvement in quality, reduction in cycle time, speedy decision making and decrease in expenses.
- **Smart Grid:** A smart grid delivers electricity from suppliers to consumers using two-way digital technology to control appliances at consumers' homes to save energy, reduce cost and increase reliability and transparency. Such a modernized electricity network is being promoted by many governments as a way of addressing energy independence, global warming and emergency resilience issues. Smart meters may be part of a smart grid, but alone do not constitute a smart grid. A smart grid includes an intelligent monitoring system that keeps track of all electricity flowing in the system. It also incorporates the use of superconductive transmission lines for less power loss, as well as the capability of integrating alternative sources of electricity such as solar and wind. When power is least expensive a smart grid could turn on selected home appliances such as washing machines or factory processes that can run at arbitrary hours. At peak times it could turn off selected appliances to reduce demand. Smart Grid can be seen as the convergence of three industries/sectors: Electric Power/ Telecommunications Infrastructure and Information Technology.

A phased approach for distribution sector is depicted below:

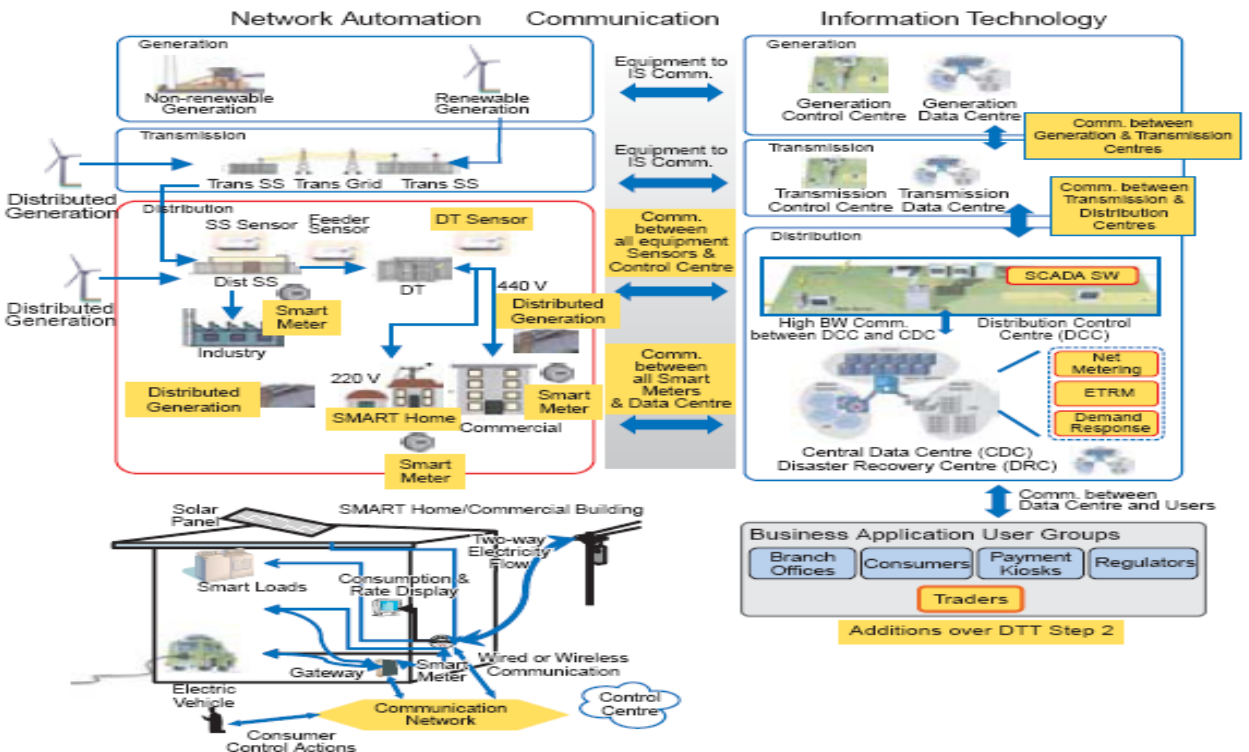
Phase 1: Curtailing AT&C Losses



Phase 2— Focus on operational efficiency and customer service excellence



Phase 3—Focus on Smart Grid development.



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## Chapter-4

# Grid Operation and Management

### 4.1 Introduction

The Indian Power sector, classically driven by technical considerations, is now subject to various market forces. This has resulted in power systems being operated closer to the edge. Under these conditions operating and maintaining the grid within acceptable parameters is a challenge. Deficit conditions prevailing in the country are a well known fact. Stress on quality supply is increasing day by day. Here starts the role of Grid Management. Grid Management effectively means managing supply and demand to maintain frequency, voltage and stability of the network. It essentially requires taking care of the over all reliability, security, economy and efficiency of the power system.

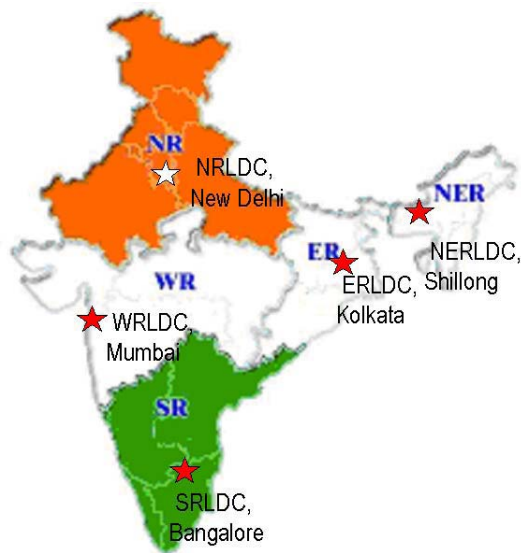


Figure 4.1: The Five Electrical Grids in India.

In India Grid management on regional basis started in sixties. Over a period of time, State grids were inter-connected to form regional self sufficient grid. Whole of the India was demarcated into 5 regions namely Northern, Eastern, Western, North Eastern and Southern region. In order to harness the diversity in terms of time, availability of resources, seasonal crops, industrialization, the need of grid interconnection was felt. At present out of 5 regional grids Northern, Eastern, Western and North Eastern grids are synchronously connected forming central grid operating at one frequency. The North Eastern and Eastern grids were connected in October 1991 followed by East and West grids in March 2003 and North and East grids in August 2006. Southern grid operates at different frequency and is asynchronously connected to central grid

through HVDC link to facilitate the transfer of power from central grid to southern grid and vice-versa.

## 4.2 Load Despatch Centers

Operation of each of these regional grids is handled by the regional load dispatch centers, RLDC's. The state grids are managed and operated by state load dispatch centre (SLDC). National Load Despatch Centre (**NLDC**) is for scheduling and despatch of electricity across various regions and also coordinating cross border energy exchanges in real time. Power System Operation (PSO) in India is being coordinated through five regional and more than thirty state control centers. These control centers owned by different utilities collaborate with each other for executing their statutory responsibility of ensuring a secure, reliable, efficient and economic power system operation. Behavior of electricity deficit such a large interconnected power system gives rise to a dynamically varying system states. These states are normal, alert, emergency and restorative. The operator has to quickly asses the contingencies and maintains the system to normal state under all situations and at all time.

In order to accomplish the objectives of security and economy, Indian system operators have at their disposal a number of tools to manage the system in real time. These tools range from Supervisory Control and Data Acquisition (SCADA) systems, sophisticated state estimators to safety schemes.

## 4.3 Safety Schemes

System security is achieved by making system operation tolerant of the outage of any component. Following safety net are available at present in Indian grid to achieve system security.

### 4.3.1 Under Frequency Relay (UFR) Load Shedding

Under frequency relay, rate of change of frequency load shedding and islanding schemes are strength of grid defense plans. With the increase in grid size the settings of under frequency relays and quantum of load shedding have been modified over a period of time. The present settings are shown in Table 1:

	Stage	Initiating Frequency(Hz)	Time delay	Load Relief(MW)	
				NR	WR
Northern and Western Grid	1st	48.8	Instantaneous	800	960
	2nd	48.6	Instantaneous	1000	960
	3rd	48.2	Instantaneous	1250	1280
Eastern Grid	1st	48.5	Instantaneous	300	
	2nd	48.2	Instantaneous	300	
	3rd	48.0	Instantaneous	410	

Table 4.1: Settings Of Under Frequency Relays and Quantum Of Load Shedding

### **4.3.2 Rate of change of frequency [df/dt]**

With the interconnection of 4 grids the rate of change of frequency is not very steep as the inertia of grid has increased. 1st stage df/dt is at 0.1 Hz. /sec (freq. 49.9 Hz.). This has saved the integrated NEW grid at least on two occasions 1) Total loss of generation at Vidhyachal 2) Loss of generation at Korba complex (about 3000 MW).

1st stage of df/dt takes care of large contingencies even when network is integrated and plays an important protective role when the networks are islanded.

### **4.3.3 Islanding schemes**

Various islanding schemes are also operational in different region for survival of smaller islands during contingencies. These islanding schemes are mostly for metro cities and sensitive nuclear generation.

### **4.3.4 Special protection schemes**

Control strategies are very important for emergency control of the system. The SPS concept is designed to detect a particular system condition that is known to cause unusual stress to the power system and to take some type of predetermined action to counteract the observed condition in a controlled manner. It uses modern means of communication and automation system for reliable and quick operation. These special control schemes have been provided at few places in Indian grid. This scheme is in place at Talcher-Kolar and Rihand-Dadri HVDC link to take care of the contingency of tripping of Single pole/Bi pole.

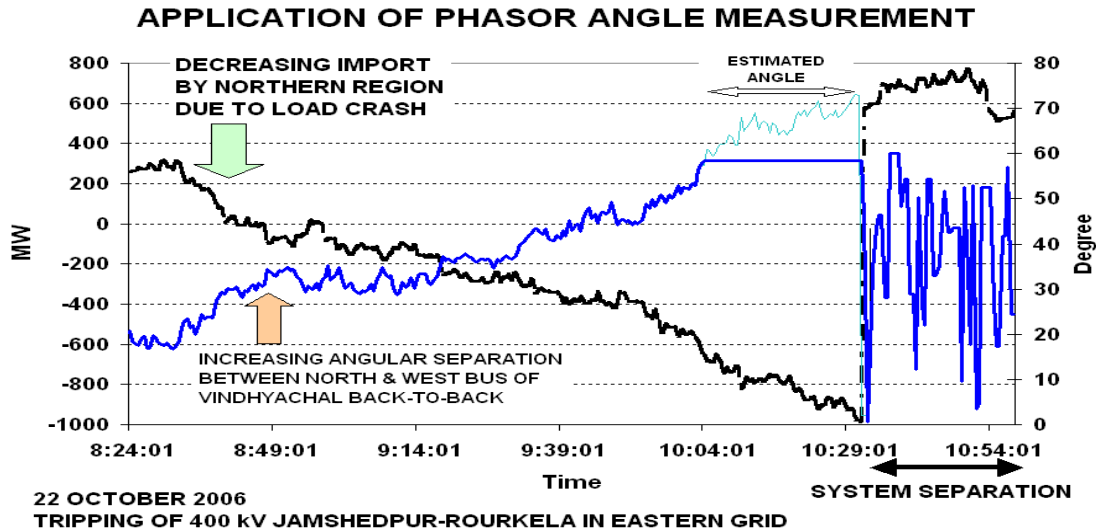
### **4.3.5 State-Of-The-Art SCADA/EMS System**

SCADA system which is the sensory organ of grid operator measures vital system variables through RTU (Remote terminal Unit) or SAS (Substation automation system) installed at all the important locations in the grid. The recorded data is transmitted through modern communication channels and displayed in the operator consoles in load despatch centers. It provides real time control and monitoring of energy management facilities to optimize system reliability, load dispatch, voltage control, system restoration, switching operations, planned maintenance outage, data recording, load flow, analyses of existing & future system conditions and thereby optimize operation to each constituent in particular and the Region as a whole.

Effective visualization techniques and tools are used to empower the system operator in facilitating quick response under critical conditions. Techniques used by the Indian grid operators are Tabular presentation, Bus Diagrams, Flowgate Illustration, Control Area – Tie Line Representation, Geographical Displays, Contouring, Three Dimensional Representations, and Animation.

### 4.3.6 Angle measurement

With the integration of regional grids there has been a paradigm shift in the operation of power system in India. Knowledge of neighboring system has become essential for real time security assessments of the integrated system. Phase angles are measured at strategic locations in the network. The assessment of system state using phase angle measurement not only gives system behavior at low frequency oscillations but is also a good visualization tool to monitor the health of integrated power system.



On one of the incident of system separation due to the tripping of Jamshedpur - Rourkela line of eastern region it was observed that angular difference continued to increase between Vindhyachal North and West bus prior to tripping giving precise information about the system state.

### 4.4 Smart Grid

The complexity of Grid is increasing continuously due to Growing number of interconnections within and across the regions. The real time information available today through conventional SCADA/EMS system is limited to analog and status data from the remote terminal units. Information, such as indications of protective control actions, event/fault records, device settings are not available. System dynamics are not taken in real time evaluations. Emergency controls such as load shedding do not consider system-wide conditions. Protective relay settings are static – no intelligence is embedded to allow adaptation to the changing system conditions

To take care of above complexities and to ensure safe, secure and reliable operation of large interconnected Indian Grid, system operation in future would be equipped with an Intelligent/Smart Grid with placement of Phasor Measurement Unit, Wide Area Monitoring, Self Healing, and adaptive islanding features etc with an intent to quickly evaluate system vulnerability with respect to cascaded events involving faults, device malfunctions and provide remedial action.

Initiatives have been taken to implement Smart Grid pilot projects for grid security of Indian grid.

- (a) Implementation of Pilot project for installation of PMUs (Phasor Measurement Units) in Northern Region
- (b) Implementation of CSIR approved Project “Intelligent Monitoring & Control of the Interconnected Electric Power Grid using WAMS.

To keep track of new technology & development POWERGRID is also a member of International group VLPGO (Very Large Power Grid Operators) with other international utilities .VLPGO is a common platform where world wide large Grid Operators come together for mutual benefit, sharing common problems and solution.

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## **Chapter-5**

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# **Regulatory Functions**

### **5.1 Creation of Regulatory Commissions**

The Electricity Regulatory Commission Act, 1998 paved the way for creation of the Regulatory Commissions at the Centre and in the States. The 1998 Act was enacted with the objective of distancing the Government from tariff regulation. The Act provided for Electricity Regulatory Commissions at the Centre and in the States for rationalization of electricity tariff, transparent policies regarding subsidies etc. Accordingly, the Central Government constituted the Central Electricity Regulatory Commission (CERC) in July, 1998. The new legislation on electricity, the Electricity Act, 2003 which addressed the larger issue of reforms and restructuring, further enhanced the powers and the scope of Regulatory Commissions.

### **5.2 Electricity Act, 2003**

The Electricity Act, 2003 consolidates laws relating to regulation of generation, transmission, distribution, trading and use of electricity and generally for taking measures conducive to development of electricity industry, promoting competition therein, protecting interest of consumers and supply of electricity to all areas, rationalization of electricity tariff, promotion of efficiency and environmental benign policies and provides for the establishment of appellate tribunal in addition to regulatory commissions. The Electricity Act, 2003 encourages the participation of the private sector in generation, transmission, distribution and trading of electricity.

### **5.3 Creation of Central And State Transmission Utilities**

The Act has created a Central Transmission Utility (CTU) and State Transmission Utilities (STUs) and these have the responsibility of ensuring that the transmission network is developed in a planned and coordinated manner. For the present, the load dispatch function has been kept with the transmission utility but it can be subsequently separated and given to another Government company/organization. POWERGRID has been notified as the Central Transmission Utility.

### **5.4 Transmission Planning**

The Central Government has notified a National Electricity Policy and Tariff Policy as provided in the Electricity Act. In accordance with the National Electricity Policy the Central Electricity Authority (CEA) prepares a perspective National Electricity Plan based on optimal utilization of resources. It also includes a perspective national transmission plan based on demand forecast and identified generation projects. The

National Electricity Plan prepared by CEA serves as a guiding document in the development of transmission system by the CTU and STUs. The transmission plan is prepared to meet the objective of reliable evacuation of power in an optimum manner conserving the right-of-way, providing for delivery points near load centres, having adequate margins for trading of electricity and using the best technological options. The transmission plans are prepared on the basis of power flow studies, contingency studies, short circuit, dynamic stability and voltage stability studies and techno-economic analysis.

## **5.5 Licensing Requirement**

Transmission, Distribution And Trading Of Electricity Are Licensed Activities. However, the CTU and STUs are deemed to be transmission licensee under the law. In case a person intends to generate and distribute electricity in a rural area to be notified by the State, such person does not require any license for generation and distribution of electricity. The basic procedure for grant of license is laid down in the law and detailed regulations have been issued by the Regulatory Commissions. The tenure of license is 25 years unless revoked earlier. In case of a distribution agency the Regulatory Commission has the powers to suspend the distribution license in public interest and appoint an administrator to discharge the function of distribution licensee.

## **5.6 Functions Of Grid Entities**

### **5.6.1 Load Dispatch Centres**

The Regional Load Dispatch Centres fall under the domain of the Central Commission and State Load Dispatch Centres fall under the domain of the State Commissions. Their fee and charges are approved by the appropriate Commission. The Load Dispatch Centres are responsible for optimum scheduling and dispatch of electricity, real time grid operation and energy accounting. The load dispatch centres have been given powers to give directions and exercise control for ensuring grid stability and every licensee generating company and substation has to comply with its direction. In case of dispute over compliance of direction of load dispatch centre, the matter can be referred to the appropriate Commission but pending the decision the direction of the load dispatch centre has to be complied. The Load Dispatch Centres and transmission licensees are not allowed to trade in the electricity.

### **5.6.2 CTU and STUs**

The functions of the Central Transmission Utility include transmission of electricity through inter-State transmission system, planning and coordination of inter-State transmission system, to ensure development of an efficient coordinated inter-State transmission system and to provide non-discriminatory open access. The State Transmission Utility performs similar functions in respect of intra-State transmission system. The transmission licensee can engage in other business such as communication with prior intimation to the Regulatory Commission. The transmission

licensee has to maintain separate account for each business undertaking and ensure that transmission business neither subsidizes nor encumbers its transmission assets in any manner. The regulatory commission lays down revenue sharing methodology from such business in which transmission assets are utilized.

### **5.6.3 Distribution Licensee**

It is the duty of a distribution licensee to develop and maintain an efficient, coordinated and economical distribution system in his area of supply and to supply electricity to consumers of its area. Every distribution licensee has to establish a forum for redressal of consumer grievances in accordance with the SERC guidelines. Any consumer, who is aggrieved by the non-redressal of his grievances, can make a representation to the Ombudsman to be designated by the State Commission. Under normal circumstances the distribution licensee has to provide supply to a new consumer within one month of receipt of application. The charges for supply of electricity by a distribution licensee are fixed in accordance with the methods and principles specified by the concerned State Commission. The distribution licensee is empowered to collect reasonable money as security from its consumers as approved by the State Commission. A distribution licensee may engage in any other business for optimum utilization of its assets provided that a proportion of the revenue derived from such business, as specified by the State Commission, is utilized for reducing its charges for wheeling.

### **5.6.4 Regulatory Commissions**

The functions of the Central Commission include regulation of inter-State transmission, determination of tariff for inter-State transmission, grant of license for inter-state transmission, to specify grid code having regard to grid standards and to specify and enforce standards with respect to quality, continuity and reliability of service by licensee and to adjudicate upon disputes involving generating companies or transmission licensees falling in its domain. The State Regulatory Commissions are responsible for determination of wholesale and retail tariff for generation within State and to regulate the distribution of electricity by the licensee. They are also responsible for regulating intra-State transmission. Each regulatory commission is a judicial body and functions according to the conduct of business regulations specified by it.

### **5.7 Tariff Regulations**

While laying down tariff regulations the State Regulatory Commissions have to be guided by the principles and methodology specified by the Central Commission for determination of tariff applicable to generating companies and transmission licensees and the regulations have to encourage competition, efficiency, safeguard consumers interest, follow principle of rewarding of efficiency in performance and promoting co-generation and generation of electricity from renewable sources of energy.

### **5.7.1 Tariff determination**

The tariff of transmission lines and substations is determined by the Regulatory Commissions considering return on equity, interest charges, depreciation, operation and maintenance expenses and interest on working capital. The Regulatory Commissions also lay down the performance benchmark of transmission system in terms of its availability and the recovery of annual charges and incentives is linked to the achievement and actual availability with respect to the benchmark of availability. The transmission services charges are shared on the basis of transmission capacity created for each beneficiary. Most of the transmission system is being built by the Central and State Transmission Utilities. However, a few transmission systems have been built by the generating companies as dedicated lines, some through the joint venture route and a few by private sector through tariff based competitive bidding. There is also a provision in the law for discovery of generation and transmission tariff through a process of competitive bidding.

### **5.8 Grid Code**

The Indian Electricity Grid Code (IEGC) was first issued in January, 2000 under the direction of CERC. The IEGC brings out a single set of rules encompassing all utilities connected with the inter-state transmission system. It documents the principles and procedure which define the relationship between various users of inter-state transmission system as well as with regional and state load dispatch centres. It contains the procedure for connection to the ISTS; operating code for regional grids covering system security; demand management; operational liaison; outage planning and recovery procedures; scheduling and dispatch code including day ahead time line and reactive energy management. SERCs have specified State grid codes on a similar pattern.

### **5.9 Transmission Access**

Access to inter-State transmission system is governed by the regulations of the Central Commission. The Central Transmission Utility is the nodal agency for providing medium term (3 months to 3 years) and long term access (up to 25 years), typically required by a generating station or a trader on its behalf. The nodal agency for grant of short term open access (up to one month) is the regional load dispatch centre. The nodal agency for providing transmission access to the power exchanges is the National Load Dispatch Centre.

### **5.10 Transmission Losses**

In the Indian grid transmission losses are applied in kind based on average transmission losses of a regional grid or a state grid as the case may be. Typically for a bilateral transaction the schedule at the point of withdrawal is less than the schedule at the point of injection. The Central Commission has commissioned a study for application of inter-State transmission losses based on power flow tracing studies.

## **5.11 Distance & Direction Sensitive Transmission Tariff**

The Tariff Policy of the central Government has mandated the introduction of distance and direction sensitive national transmission tariff framework which gives appropriate signal for locating new loads and generating stations. The Central Commission has commissioned a study for this purpose and the initial proposal is to develop a point of connection tariff matrix based on marginal participation method and selection of slack bus by average participation method. The new template is under development and it would eventually replace the existing postage stamp method of sharing transmission charges. The new method is more appropriate for a market scenario.

## **5.12 Conclusion**

The regulatory environment is steadily moving towards increasing competition in the electricity market allowing several new players in addition to traditional utilities and independent power producers such as captive power producers, merchant power producers, renewable energy generators, etc., on the one hand and customers requiring access to the grid on a non discriminatory basis on the other. With full open access in the distribution segment, the consumer will no longer be captive to one discom but will have greater choice in getting power from any of the new entities connected to the grid. The regulatory environment too has now become stable with multi-year tariffs becoming a norm in states.

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## Chapter-6

# Benchmarking of Best Practices

### 6.1 Benchmarking In Transmission

The focus of benchmarking of best practices in transmission is to identify technologies leading to greater efficiency in the bulk power system, an increase in system utilization and a reduction in system losses that would otherwise flow to the end user. Reducing T&D losses will allow utilities to generate less power and thereby lower the industry's carbon footprint.

POWERGRID, India is taking a leading position in the utilization of the most up-to-date transmission technologies including HVDC/HVAC transmission, FACTS device, integration standards and advanced system planning tools.

Some comparison has been done amongst a group of developing countries such as India, China, Brazil and South Africa.

#### 6.1.1 Existing maximum voltage level in transmission

##### HVAC

**POWERGRID, India:** 765kV

**China:** 1000kV

**South Africa:** 765kV

**Brazil:** 765kV

##### HVDC

**POWERGRID, India:** +/-500 kV

**China:** +/-800 kV

**South Africa:** 533kV (Monopolar)

**Brazil:** +/-600

#### 6.1.2 Substation automation

**POWERGRID, India:** Yes

**China:** Yes

**South Africa:** Yes

**Brazil:** Yes

#### 6.1.3 FACTS Devices

**POWERGRID, India:** SVC, FSC, TCSC

**China:** FSC, TCSC

**South Africa:** SVC

**Brazil:** SVC, FSC, TCSC

