Indian Power Sector

By
Ghanshyam Prasad
Director, Ministry of Power
Government of India

Lahore
September 30 – October 1, 2015
Players In The Indian Power Sector

Central Electricity Authority
Perspective Planning & National Electricity Plan

Generators
Central/State GENCOs, IPPs, Captive

CTU
Inter-State Trans. System, Open Access

STU
Intra-State Trans./Sub-Trans. System

DISCOMs

Consumers
Industries, Household, Agriculture

System Operator (POSOCO)

Power Exchange

Traders

Power Exchange
Generation
Electricity Generation & Growth over the years

Highest Generation Growth of 8.43% in last two decades
# Fuelwise Generation Installed Capacity in India

(As on 31-August-2015)

<table>
<thead>
<tr>
<th>Fuel</th>
<th>Installed Capacity (MW)</th>
<th>% Share in Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>THERMAL</td>
<td>192,535</td>
<td>69.6%</td>
</tr>
<tr>
<td>Coal</td>
<td>168,208</td>
<td>60.8%</td>
</tr>
<tr>
<td>Gas</td>
<td>23,333</td>
<td>8.4%</td>
</tr>
<tr>
<td>Diesel</td>
<td>994</td>
<td>0.4%</td>
</tr>
<tr>
<td>HYDRO</td>
<td>41,997</td>
<td>15.2%</td>
</tr>
<tr>
<td>NUCLEAR</td>
<td>5,780</td>
<td>2.1%</td>
</tr>
<tr>
<td>RES</td>
<td>36,471</td>
<td>13.2%</td>
</tr>
<tr>
<td><strong>TOTAL</strong></td>
<td><strong>276,783</strong></td>
<td></td>
</tr>
<tr>
<td>Sector</td>
<td>Installed Capacity (MW)</td>
<td>% Share in Total</td>
</tr>
<tr>
<td>-----------------</td>
<td>-------------------------</td>
<td>------------------</td>
</tr>
<tr>
<td>Central Sector</td>
<td>74,171</td>
<td>26.8%</td>
</tr>
<tr>
<td>State Sector</td>
<td>96,015</td>
<td>34.7%</td>
</tr>
<tr>
<td>Private Sector</td>
<td>106,597</td>
<td>38.5%</td>
</tr>
<tr>
<td><strong>TOTAL</strong></td>
<td><strong>276,783</strong></td>
<td></td>
</tr>
</tbody>
</table>

(As on 31-August-2015)
Electricity Generation: Fuelwise & Sectorwise during 2014-15

**Generation (BU) during 2014-15 (Fuel wise)**

- **Coal**: 800.33 BU (76%)
- **Hydro**: 129.24 BU (12%)
- **Gas**: 41.08 BU (4%)
- **Lignite**: 35.5 BU (3%)
- **Diesel**: 1.41 BU (0%)
- **Nuclear**: 36.1 BU (4%)
- **Bhutan Import**: 5.01 BU (1%)

Total 1048.6 BU

**Generation (BU) during 2014-15 (Sector wise)**

- **Central**: 400.1 BU (38%)
- **State**: 366.8 BU (35%)
- **Private**: 281.8 BU (27%)

Total 1048.6 BU
Electricity Generation: Fuelwise & Sectorwise during 2015-16 (Upto Aug’15)

**Fuelwise Generation (BU) during 2015-16 (upto Aug' 15):**
- Coal: 340.3 BU, 74%
- Hydro: 67.5 BU, 15%
- Nuclear: 16.3 BU, 3%
- Gas: 17.8 BU, 4%
- Lignite: 14.8 BU, 3%
- Diesel: 0.2 BU, 0%
- Bhutan Import: 3.3 BU, 1%
- Total: 460.0 BU

**Sectorwise Generation (BU) during 2015-16 (upto Aug' 15):**
- Central: 181.0 BU, 39%
- State: 143.3 BU, 31%
- Private: 135.7 BU, 30%
- Total: 460.0 BU
Future Scenario

Capacity requirement to be doubled by next decade and quadrupled in next two decades

Ambitious Plan to establish 100 GW Solar including 20 GW through Ultra Mega Solar Power Parks
Renewable Potential

• Solar Potential in India: about 20-30 MW/sq km, about 5000 trillion units annually (about 2800 GW)
  
  ➢ 12th Plan envisaged Solar Capacity addition: 10 GW (As per data during GEC Study)

• Solar UMPP being envisaged to set up in deserts of Thar, Rann of Kutch, Lauhal & Spiti valley and Ladakh
  
  ➢ Solar Generation Potential utilizing 5-15% of wasteland area in deserts about 300 GW

• Researchers Claim more than 1000GW Wind Generation Potential
  
  ➢ 12th Plan envisaged Wind Capacity addition: 20 GW (As per data during GEC Study)
Transmission
## Total Transmission Lines (cKm) & Transformation Capacity (MVA)
### As on 31-August-2015

<table>
<thead>
<tr>
<th>Voltage</th>
<th>Total Transmission Lines (cKm)</th>
<th>% Share in Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>765 kV</td>
<td>20,792</td>
<td>6.45</td>
</tr>
<tr>
<td>400 kV</td>
<td>1,40,083</td>
<td>43.43</td>
</tr>
<tr>
<td>220 kV</td>
<td>1,52,247</td>
<td>47.20</td>
</tr>
<tr>
<td>HVDC</td>
<td>9,432</td>
<td>2.92</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>3,22,554</strong></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Voltage</th>
<th>Total Transformation Capacity (MVA)</th>
<th>% Share in Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>765 kV</td>
<td>1,33,500</td>
<td>21.51</td>
</tr>
<tr>
<td>400 kV</td>
<td>1,96,362</td>
<td>31.64</td>
</tr>
<tr>
<td>220 kV</td>
<td>2,77,218</td>
<td>44.67</td>
</tr>
<tr>
<td>HVDC</td>
<td>13,500</td>
<td>2.18</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>6,20,580</strong></td>
<td></td>
</tr>
</tbody>
</table>
## Growth of Transmission System

### Transmission Lines (400kV and above system) (values in ckm)

<table>
<thead>
<tr>
<th></th>
<th>11th Plan (2011-12)</th>
<th>Existing as on 30-04-15</th>
<th>12th Plan (2016-17)</th>
<th>13th Plan (2021-22)</th>
</tr>
</thead>
<tbody>
<tr>
<td>HVDC Bipole lines</td>
<td>9432</td>
<td>9432</td>
<td>16872</td>
<td>27472</td>
</tr>
<tr>
<td>765 kV</td>
<td>5250</td>
<td>18650</td>
<td>32250</td>
<td>54450</td>
</tr>
<tr>
<td>400 kV</td>
<td>106819</td>
<td>136264</td>
<td>144819</td>
<td>174819</td>
</tr>
<tr>
<td>Total</td>
<td>121501</td>
<td>164346</td>
<td>193941</td>
<td>256741</td>
</tr>
</tbody>
</table>

### Substations (AC & HVDC) (400kV and above) (values in MVA / MW)

**HVDC Terminals:**

<table>
<thead>
<tr>
<th></th>
<th>11th Plan (2011-12)</th>
<th>Existing as on 30-04-15</th>
<th>12th Plan (2016-17)</th>
<th>13th Plan (2021-22)</th>
</tr>
</thead>
<tbody>
<tr>
<td>HVDC back-to-back</td>
<td>3000</td>
<td>3000</td>
<td>3000</td>
<td>3000</td>
</tr>
<tr>
<td>HVDC Bipole terminals</td>
<td>6750</td>
<td>10500</td>
<td>19500</td>
<td>34500</td>
</tr>
<tr>
<td><strong>Total- HVDC Terminal Capacity, MW</strong></td>
<td><strong>9750</strong></td>
<td><strong>13500</strong></td>
<td><strong>22500</strong></td>
<td><strong>37500</strong></td>
</tr>
</tbody>
</table>

**AC Substations**

<table>
<thead>
<tr>
<th></th>
<th>11th Plan (2011-12)</th>
<th>Existing as on 30-04-15</th>
<th>12th Plan (2016-17)</th>
<th>13th Plan (2021-22)</th>
</tr>
</thead>
<tbody>
<tr>
<td>765 kV</td>
<td>25000</td>
<td>121600</td>
<td>174000</td>
<td>253000</td>
</tr>
<tr>
<td>400 kV</td>
<td>151027</td>
<td>192997</td>
<td>196027</td>
<td>245027</td>
</tr>
<tr>
<td><strong>Total- AC Substation capacity, MVA</strong></td>
<td><strong>176027</strong></td>
<td><strong>314597</strong></td>
<td><strong>370027</strong></td>
<td><strong>498027</strong></td>
</tr>
</tbody>
</table>

**Total Fund requirement would be about Rs 2,60,000 Crore**

(assuming about Rs. 100,000 crore for 220kV and below systems)
Transmission Planning - Consideration

- It is directional and to be known in advance.
- System to be planned for peak power transfer
- (N-1-1) reliability criteria
- Conservation of Right of Way
- To fit into long term perspective
- The transmission system should have enough ‘controllability’ features (in addition to wires)
Transmission System – As of Today

• Strong back bone of 400 kV – Overlay of 765 kV & high capacity HVDC under Implementation

• All India synchronous grid – One of the largest in the World

• Thriving Pan-India Single Market enabled

• Under new concept of planning, 10 nos. of high capacity corridors evolved - to reduce the dependency on a particular generation

• These corridors shall facilitate about 40,000MW power transfer
HIGH CAPACITY CORRIDORS
Evolving Voltage Landscape

POWER MAP OF INDIA

POWER GRID LINES

[Map of India showing power grid lines with cities such as Delhi, Jaipur, Bishwanath Chariali, Agra, Gwalior, Mumbai, Hyderabad, Chennai, Ahmadabad, Bangalore, Thiruvananthapuram, and Andaman & Nicobar Islands.]
Green Energy Corridor: Integration of Renewables

- About 33GW capacity addition envisaged through wind & solar in next 4-5 years

- The Plan includes
  - Transmission strengthening(s)
  - Dynamic reactive compensation,
  - Energy Storage,
  - Smart grid applications,
  - Establishment of Renewable Energy Management Centre enabling forecasting of renewable generation, real time monitoring, etc.
National Grid
Potential being harnessed to meet demand in next 7-8 years

**Coal – In Central India**
- Chhattisgarh: 58,000 MW
- Orissa: 30,000 MW
- Jharkhand: 15,000 MW
- Madhya Pradesh: 16,000 MW

**Hydro – In North Eastern & Northern Himalayan region**

**Coastal based**
- Andhra Pradesh: 24,000 MW
- Tamil Nadu: 10,000 MW
- Gujarat: 11,000 MW

Energy resources (Coal, Water etc.) unevenly distributed
Transmission System Requirement

Cluster of Concentrated Demand pockets

Cluster of Generation pockets
Evolution of National Grid

State → Region → Nation: A Paradigm Shift

Self Sufficiency at State Level

Self Sufficiency at Regional level

Optimal Utilization of Resources at National level

1950s
• Local

1950s-60s
• State Grid by SEBs

1970s-80s
• Regional Grids with Trans. Systems of Central Gen. Stations

1990s
• Interconnecting Regional Grids with HVDC

2000s-2010s
• National Grid

Installed Capacity
Aug-15: 277 GW

1947: 1,362MW
Development of Synchronous National Grid

Strengthening of National Grid –
A Continuous Process
(to match upcoming generation and increasing demand)

- National Grid started through HVDC Inter-Regional links
- Regional grids synchronised progressively through EHVAC links
- Synchronous National Grid established in Dec., 2013
Development of Synchronous National Grid

- One of the largest Electricity Grids operating at single frequency in the world

- March 2003: West synchronized with East & North-East
- August 2006: North synchronized with Central Grid
- December 2013: South synchronized with NEW Grid

- Existing I-R Capacity: 51,650MW

- 5 Grids, 5 Frequencies

- Central Grid
- South Grid
- North East West
- NEW* Grid

- Inter-Regional (I-R) Capacity (MW, as at the end of)
  - IX Plan: 5,050
  - X Plan: 14,050
  - XI Plan: 27,750
  - Aug-15: 51,650
  - XII Plan(*): 72,250
Inter-Regional Transmission Links
Optimal Utilization of Resources both Generation & transmission

- I-R Transfer has grown 83 times since 1992-93
- Substantial increase in STOA utilizing margins in ISTS network
- Reduction in per unit energy charges

Benefits of National Grid: Development of Vibrant Electricity Market

Movement of Weighted Average Prices

Through Traders  | Power Exchange (IEX)  | Deviation Price

Source: CERC, BMRC Data
Interconnection with SAARC Countries
India & Bangladesh Interconnection

• **Existing Interconnection:**
  – Baharampur (India) - Bheramara (Bangladesh) 400kV D/c line (100 km) and 500MW HVDC back-to-back Station at Bheramara

• **Ongoing:**
  – Surjyamaninagar (Tripura) – South Comilla D/C line (400kV upto North Comilla) via North Comilla (58km long) to be operated at 132kV voltage. [expected by Dec. 2015]
  – Upgradation of the existing Baharampur (India) - Bheramara (Bangladesh) interconnection with additional 500 MW HVDC back-to-back converter unit (2\textsuperscript{nd} module) at Bheramara [June 2017]

• **Future:**
  – ±800 KV, 7000MW HVDC multi-terminal bipole line from Rangia (NER, India) to Muzaffarnagar (NR, India) through Bangladesh with 500/1000MW HVDC terminal in Bangladesh
INTERCONNECTION BETWEEN INDIA AND BANGLADESH GRIDS

LEGEND
- THE PROJECT
- 400 kV
- 230 kV
- 132 kV
- Existing
- Under Constr. / Future
Benefits of Interconnection for Bangladesh

• In Bangladesh, low frequency operation below 48.9 Hz reduced by 60% post interconnection with India

• East to West transfers in Bangladesh reduced significantly leading to reduction in transmission losses

• Voltage profile in West zone of Bangladesh improved by 15-20 kV at 230 kV level

• Reduced dependence on expensive gas and oil resources
Benefits of Interconnection for Bangladesh

- Reduced dependence on expensive oil and gas
India - Bhutan : Interconnections

• **Existing Interconnection** :
  
  *For Import from Tala-1000 MW, Chukha-336MW & Kurichu-60MW]*
  
  – Tala – Siliguri 400kV 2x D/c line
  – Chukha – Birpara 220kV 3 ckts
  – Kuruchu - Geylegphug(Bhutan) – Salakati(NER) 132 kV

• **On-going Interconnection** :
  
  *For Import from Punatsangchu-I:1200MW, Punatsangchu-II: 990MW and Mangdechu-720 MW]*
  
  – Punatsangchu-I – Alipurduar 400kV D/c line (Bhutan portion 2xD/c and Indian portion D/c quad line]
  – Jigmelling – Alipurduar 400kV D/c line (quad)

• **Future Interconnection** :
  
  *For Import from 14 HEP, 11,784 MW by 2020 and 75 HEP, 26,504 MW by 2030]*
  
  – Total 5(five) no 800kV, 6000-7000MW HVDC high capacity corridors (2 nos. by 2020 & balance 3 nos by 2030) required for transfer of power to Indian Grid.
India - Nepal : Interconnections

• Existing Interconnection :
  – There are about 12 cross border interconnections at 11kV, 33kV and 132 kV level through which Nepal draws power upto 200MW.

• On-going Interconnection :
  – Muzaffarpur(India) – Dhalkhebar(Nepal) 400kV D/c line (to be operated at 220kV) [Dec. 2015]

• Future Interconnection :
  – Planning for cross border interconnection under progress for import of power from various hydro power projects to be developed in Nepal
India - Nepal: Future Plan

Future Hydro Projects:
- Karnali - 10,800 MW
- (Upper Karnali - 900 MW)
- Tamakoshi III - 880 MW
- U. Marsyangdi – 2 - 600 MW
- Pancheshwar HEP - 5,600 MW
- Sapta Koshi - 3,300 MW
- Arun HEP - 1,100 MW
- West Seti HEP - 750 MW
- Lower Marsyangdih - 300 MW

- **East-West High capacity transmission Corridor** to be planned in Nepal
- This is to be **connected with hydro projects in Nepal** and **Load centres in India**
Feasibility study carried out for the following interconnection:

- 2x500MW HVDC bipole line from Madurai (India) to Anuradhapura-New (Sri Lanka): 360km
  - Overhead Line (India): Madurai to Panaikulam: 130km
  - Submarine Cable: Panaikulam (India) to Thirukketiswaram (Sri Lanka): 120km
  - Overhead Line (Sri Lanka): Thirukketiswaram to Anuradhapura (New): 110km

- 2x500MW HVDC terminal stations each at India (Madurai) to Sri Lanka (Anuradhapura-New): 360km
India – Sri Lanka Interconnection

Proposed Route for Interconnection

Madurai – Madurai-New – Panaikulam – Thirukketiswaram (*)

110 Kms

130 Kms

48 Kms
Suitability of HVDC for interconnections
Benefits of HVDC

- Greater power density in a given corridor
- Higher efficiency
- Environmental advantages (lesser RoW requirement)
- Improved real time power flow control – Power flows where you want it to
- Increased power system reliability and security
- Improved power system transient and dynamic stability
- Only possible solution for interconnecting AC networks of different frequencies
Distance Break-even points - AC vs DC

Distance break-even point (HVDC versus HVAC)
- Underground or submarine cables > 50 km
- Transmission lines > 700 km

500 – 700 km

Cost of AC Line
Cost of DC Line

Cost of DC terminal
Cost of AC terminal

Break even distance

Distance in km
HVDC Configurations

- **Bipole HVDC** for Bulk Power transmission to Long distances
  - Inverter & Rectifier placed at two different locations
  - Interconnection by DC overhead line

- **Back to Back HVDC** for coupling of electricity grids of different frequencies.
  - No DC Line
  - Rectifier & Inverter at the same station
Applications of HVDC in inter-connection

- In initial stages of interconnection, it is desirable to wholly isolate/insulate the interconnected grids from AC induced grid disturbances by DC back to back interconnection and to gain operational experience of interconnected operation
- For under sea (submarine) connection
- If the volume of power to be transacted is very large and meant for a long distance transfer
- Integration of Renewable energy sources in the Grid
- To re-distribute power in congested load centres
Inter-regional links through HVDC back-to-back
HVDC interconnections – Indian Experience

Northern Region

Eastern Region

North-eastern Region

Western Region

Southern Region

Phase-3

Hybrid interconnections – AC and HVDC
HVDC SYSTEMS IN INDIA

- 4 back to back HVDCs
- 5 bipole HVDC links
- 2 bipoles under construction
- 1 MTDC under construction

With Neighbouring Countries
- Back-to-back with Bangladesh
Existing HVDC interconnections in India

1 – Rihand-Dadri (1500MW) Bipole
2 - Vindyachal (500MW) B-t-B
3 - Chandrapur-Padghe (1500 MW) (MSEB) Bipole
4 - Chandrapur-Ramagundam (1000MW) B-t-B
5 – Barsoor-Lower Sileru (100MW)
6 – Gajuwaka 1 & 2(500MW each) B-t-B
7 - Sasaram (500MW) B-t-B
8 - Talcher-Kolar (2500MW) Bipole
9 – Balia – Bhiwadi (2500 MW) Bipole
10- Mundra-Mahendragarh ( 2500 MW) (Adani Power) Bipole
HVDC interconnections in India – Under Implementation

- ±800 kV, 6000 MW Multi-terminal NER/ER-NR/WR Interconnector – I HVDC Project
- ±800 kV, 3000 + 3000 MW Champa - Kurukshetra HVDC Project
- ±800 kV, 6000 MW Raigarh - Pugalur HVDC Project
POWERGRID is installing +/-800 kV, 6000 MW HVDC multi-terminal system of approx length of 1750 km.

- One Rectifier station in Biswanath Chariali (in North Eastern Region), second one in Alipurduar (in Eastern Region) and Inverter station at Agra (in Northern Region)

- First ±800 KV Multi-Terminal HVDC project in the world.
HVDC Worldwide - 2015

Total: 196254MW
Evolution of HVDC Transmission Voltage

- 100kV (1972)
- 270kV (1986)
- 500kV (1992)
- 285kV (2005)
- 660kV (2009)
- 800kV (2012)

- Multiple 12-pulse bridges per pole
- Single 12-pulse bridge per pole

500kV becomes de facto standard for single 12-pulse bridge

Projects:
- Cahora-Bassa 533kV
- Itaipu 600kV
- Xiangshaba-Shanghai; Yunnan-Guangdong
- Champa
- Ningdong-Shandong

1100kV DC in
Recently introduced (first commercial scheme commissioned in 1999)

- Uses IGBT, IGCT or similar device

- Ratings
  - Typically ± 320 kV dc at 1000MW
  - ± 500 kV dc at 1400 MW

- Reduced overall site footprint

- Easier construction

- Simultaneous control of MW and Mvars

- Faster response to events

- Can “black start” a network

- Enables use of lower cost XLPE cable
HVDC to re-distribute Renewable Energy

- Renewable energy is not evenly distributed
  - Solar power in N Africa and S Europe
  - Wind power in NW Europe
  - Hydro power (can be used for storage) in mountainous areas

- HVDC is the most efficient way of transporting energy over such long distances

- HVDC also gives great benefits of controllability, “firewall” functionality etc
Offshore HVDC

- LOCATION: German North Sea, 83 km North of Germany
- Offshore ±320 kV, 900 MW HVDC VSC converter
Thank You

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