Welcome

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Ministry of Power
India
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Outline of Presentation

➢ Brief of Power Sector in India

➢ Prevailing Practices pertaining to Generation Planning
Power Sector Structure

- **Centre**
  - MOP
  - CEA
  - CERC/CEA
  - Central Generating Units
  - CTU
  - NLDC
  - RLDC
  - Trading Licencee
  - Appellate Tribunal

- **State**
  - State Government
  - SERC
  - GENCOs
  - IPPs
  - STU
  - SLDC
  - Distribution Licencee
  - Trading Licencee
  - Appellate Tribunal

- **Some Private Players in Generation & Distribution**
Power Sector-an Overview

- Electricity - ‘Concurrent Subject’ : joint responsibility of State and Central Governments.
- Distribution and supply of electricity to end consumers lies with State Utilities.
- Conventional Generation - blend of thermal, hydro and nuclear sources.
- Coal based thermal power plants and in some states hydro power plants - mainstay of electricity generation.
- Natural gas and nuclear power accounts for smaller proportion of power.
- Thrust is being given to electricity generation from non-conventional energy sources i.e. solar, wind etc.
Installed Electricity Generating Capacity as on July 2017

- **Thermal**, 220,456 MW, 67%
- **Hydro**, 44,614 MW, 13%
- **Nuclear**, 6,780 MW, 2%
- **RES**, 58,303 MW, 18%

Total Installed Electricity Generation Capacity: 330,000 MW
Electricity Generation during the year 2016-17

- Thermal, 994 BU, 80%
- Hydro, 128 BU, 10%
- Nuclear, 38 BU, 3%
- RES, 82 BU, 7%

Total Electricity Generation: 1,242 BU

1 BU = 10^9 kWh
### Length of Transmission lines & Sub-station Capacity (as on July, 2017)

#### Length of Transmission lines

<table>
<thead>
<tr>
<th>Voltage level</th>
<th>Length (Ckm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>765 kV AC</td>
<td>32,572</td>
</tr>
<tr>
<td>400 kV AC</td>
<td>163,630</td>
</tr>
<tr>
<td>220 kV AC</td>
<td>164,459</td>
</tr>
<tr>
<td>+/- 500 kV HVDC</td>
<td>9,432</td>
</tr>
<tr>
<td>+/- 800 kV HVDC</td>
<td>6,124</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>376,217</strong></td>
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</tbody>
</table>

#### Sub-stations

<table>
<thead>
<tr>
<th>Voltage level</th>
<th>MVA/MW</th>
</tr>
</thead>
<tbody>
<tr>
<td>765 kV AC</td>
<td>174,500</td>
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<tr>
<td>400 kV AC</td>
<td>255,347</td>
</tr>
<tr>
<td>220 kV AC</td>
<td>319,968</td>
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<tr>
<td>+/- 500 kV HVDC</td>
<td>13,500</td>
</tr>
<tr>
<td>+/- 800 kV HVDC</td>
<td>7,500</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>770,815</strong></td>
</tr>
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</table>
Per Capita Consumption of Electricity

<table>
<thead>
<tr>
<th>Year</th>
<th>Per Capita Consumption (kWh)</th>
</tr>
</thead>
<tbody>
<tr>
<td>2011-12</td>
<td>884</td>
</tr>
<tr>
<td>2012-13</td>
<td>914</td>
</tr>
<tr>
<td>2013-14</td>
<td>957</td>
</tr>
<tr>
<td>2014-15</td>
<td>1010</td>
</tr>
<tr>
<td>2015-16</td>
<td>1075</td>
</tr>
<tr>
<td>2016-17</td>
<td>1120</td>
</tr>
</tbody>
</table>
Electricity Exchange with neighbouring countries

- Nepal
- Bhutan
- Bangladesh
- Myanmar

- 430 MW export
- 1400 MW import
- 650 MW export
- 3 MW export
As the electricity demand increases, generating capacity is required to be added in the system.

Generation capacity is also required to be added to cater to retirement of existing generating units.

Generation expansion planning is concerned with:
- when to add the generating units (time)
- the type of generating units to add (base load, peak load etc.)
- location at which the generating units are to be added (spatial distribution)

Operational constraints of generating units is not considered in traditional generation expansion planning models.

Transmission network is also generally not considered.
## Traditional Generation Expansion Planning Model (Single Node)

- All the generating units & loads concentrated on a single bus
- No consideration of transmission lines

## Generation Expansion Planning Model considering spatial distribution of generating stations

- Fuel transportation may or may not be modelled
- Power flow modelled considering only flow conservation at each node

## Generation Planning Models with high RES penetration (mix of Expansion Planning + Operation Planning Models)

- Operational constraints of Generating units
- Power flow modelled considering DC/AC load flow
Generation Planning with high penetration of Renewable Energy (wind& solar)

- World wide thrust is being accorded to electricity generation from RES.
- RES Installed Capacity by the year 2022 in India ~ 175,000 MW
- RES being intermittent in nature, electricity generated from RES (wind/solar), shows variation throughout the day and through the seasons.
- There are periods/seasons of very low electricity generation/no electricity generation from RES
The objective of installing RE generators in the grid is its maximum utilization.

As the power output of RE generators increases, conventional generators (non RE) would have to reduce their power output and as the power output of RE generators decreases, other generators would have to increase their power output ~ determined by the ramp rate of generators.

To what extent a conventional generating unit can ramp down ~ depends on its minimum operating limit.

If a generating unit needs to be shut down to accommodate the power output of RE generators ~ does it meet the minimum up time criteria and if it meets the minimum up time criteria, it can be shut down only if it is not required for the duration of its minimum down time.

Generation Planning with high penetration of Renewable Energy (wind& solar)
Operational Parameters of Conventional (non-RE) Generators affecting utilization of RE Sources

- The capacity of RE generators to be installed and utilization depends upon:
  - Ramp-Up/Ramp-Down Rate of conventional generators
  - Minimum operating limit of conventional generators
  - Minimum up-time/down-time of conventional generators

- In a system dominated by non-flexible coal based or CCGT generating units, penetration of wind/solar will be limited, and generation from wind/solar would have to be curtailed.
High penetration of wind/solar power may change the capacity mix in the system in terms of requirement of more flexible generating units and it may also result in change in operational strategy of coal based generating units, increasing the need of cycling them.

With high penetration of RES, operational constraints of conventional generating units need to be considered in Generation Planning~ the planned system must be feasible from operational aspects
Generation Planning with high penetration of Renewable Energy (wind & solar)

- RE generators are concentrated in specific areas. Electricity generated by RE generators needs to be transmitted to other areas, if it cannot be consumed locally.
- Further, gestation period of RE generators is small as compared to the gestation period of transmission lines.
- With high RE penetration in the grid, planning of conventional generators, RE generators, flexible generators and transmission lines must be coordinated; otherwise it will lead to curtailment of wind power due to transmission constraints or operational issues and advantage of RE generators may not be realised.
With high RES penetration, reserve requirement in the system increases.

In addition to the reserve required to take care of unpredicted increase in electricity demand or forced outage of generating units, reserve is also required to cater to unpredicted increase/decrease in RE generation.

A system with high RE penetration must plan for both
- Up Spinning Reserve (USR)-to cater to unpredicted decrease in RE generation
- Down Spinning Reserve (DSR)- to cater to unpredicted increase in RE generation
Generation Planning with high penetration of Renewable Energy (wind & solar)

There may be negative co-relation between electricity demand and power output from RE generators ~ high electricity generation during period of low electricity demand.

- Problematic as most of the coal based (base load) electricity generating units may be operating near/at their minimum operating limit during period of low electricity demand and some of these may be required to shut-down in the event of increase in RE power.

- There would be insufficient DSR in the system during low load condition~ a generating unit has to be in operation to provide DSR

- To provide DSR, commitment of generating units may be required to be changed~ commit flexible generating units during period of low electricity demand
Generation Planning with high penetration of Renewable Energy (wind & solar)

• In big power systems involving fuel transportation over long distance, fuel transportation network along with associated constraints must be modelled in generation expansion planning exercise.

• Planning of transmission lines also needs to be integrated in the generation planning model. At least, the base transmission network must be modelled.

• Strengthening of transmission network from system security point of view, design of suitable compensation schemes etc. would be taken up at the time of detailed transmission network planning.

• Instead of sequential approach of first planning generation expansion and then planning the transmission network, integrated approach must be followed in the planning process.
Generation Planning for the year 2021-22
### Installed Capacity of Renewables in the year 2022

<table>
<thead>
<tr>
<th></th>
<th>Installed Capacity (MW)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Solar</td>
<td>100,000</td>
</tr>
<tr>
<td>Wind</td>
<td>60,000</td>
</tr>
<tr>
<td>Small Hydro</td>
<td>5,000</td>
</tr>
<tr>
<td>Biomass</td>
<td>10,000</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>175,000</strong></td>
</tr>
</tbody>
</table>

Installed RES based Capacity in July 2017: 58,300 MW
Projected Electricity Demand in the year 2022

<table>
<thead>
<tr>
<th></th>
<th>2016-17</th>
<th>2021-22</th>
</tr>
</thead>
<tbody>
<tr>
<td>Electrical Energy Requirement (BU)</td>
<td>1143</td>
<td>1566</td>
</tr>
<tr>
<td>Peak Electricity Demand (MW)</td>
<td>160,000</td>
<td>226,000</td>
</tr>
</tbody>
</table>

- Electricity Demand forecast is carried out by combination of time-series and end-use method
- Bottom up approach focusing on end-use or final electrical energy needs of different categories of consumers.
- Forecast is carried out for different consumer categories viz. domestic, commercial, public lighting, industries etc.
Typical daily load curve

Diurnal Variation

Summer

Monsoon

Seasonal Variation

Winter
Daily Maximum solar & wind output over a year in 2021-22 (One possible scenario)
Daily Peak Electricity Demand vs Electricity Demand net of Wind & Solar Output (2021-22)
Electricity Demand vs Electricity Demand net of Wind & Solar—one Possible Scenario
(2021-22)
Likely Installed Capacity in 2021-22
(One possible Scenario)

- Thermal: 270,000 MW, 52%
- Hydro: 60,000 MW, 12%
- Nuclear: 10,000 MW, 2%
- RES: 175,000 MW, 34%

Installed Capacity: 515,000 MW
Source-wise electricity generation in 2021-22
(One possible Scenario)

Thermal: 66%
Hydro: 11%
Nuclear: 4%
RES: 19%
Ramp Duration Curves (one possible scenario)
Conclusions

- With high penetration of RES in the electricity grid, basic Generation Planning philosophy has changed.
- Operational characteristics of conventional generating units, generally considered in operation planning study, have to be considered in the generation planning exercise.
- With high penetration of RES, the generation planning model must have the features of expansion planning as well as operation planning models.
- RE generators cannot be planned in isolation.
Conclusions

- Planning of RE generators, base load generators, flexible generators and transmission lines needs to be co-ordinated to avoid curtailment of electricity generated by RE generators due to transmission constraints or operational issues.
- With high penetration of RES, requirement of flexible generating units in the electricity grid increases.
- Lack of flexible generating units may lead to cycling and increased stop/start of base load coal based generating units.
- Storage technology is one possible solution for RE integration. However, feasibility of storage technology needs to be studied.
Thank You

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