Transmission System Planning in India

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<th>6</th>
<th>7</th>
<th>8</th>
<th>9</th>
<th>10</th>
<th>11</th>
<th>12</th>
<th>Upto Mar'18</th>
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Growth of transmission capacity since 6th plan

Major Inter-regional Transmission Links

11 High Capacity Power Transfer Corridors planned for generation projects coming-up in resource rich States, i.e. Odisha, Jharkhand, Sikkim, Madhya Pradesh, Chhattisgarh, Tamil Nadu, Andhra Pradesh under private sector

HVDC Links

Champa-Kurukshetra Bi-pole
BNC-Agra Bipole
Alipurduar-Agra Bipole
Rihand-Dadri Bi-pole
Vindhyachal Back-to-Back
Sasaram Back-to-Back
Gazuwaka Back-to-Back
Talcher-Kolar Bi-pole
Bhadrawati Back-to-Back
Ballia-Bhiwadi Bi-pole
Mundra-Mahindergarh Bi-pole
Growth of transformation capacity since 6th plan

<table>
<thead>
<tr>
<th>PLAN</th>
<th>6</th>
<th>7</th>
<th>8</th>
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<th>12</th>
<th>Upto Mar'18</th>
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MVA/MW IN CASE OF HVDC
Energy supply position - trend

Energy supply position over the years

Energy Requirement   Energy Availability
Peak supply position - trend

Peak supply position over the years

- Peak Demand
- Peak Met
Deficit Region
Snow fed – run-of-the river hydro
Highly weather sensitive load
Adverse weather conditions: Fog & Dust Storm

Very low load
High hydro potential
Evacuation problems

Low load
High coal reserves
Pit head base load plants

Industrial load and agricultural load

High load (40% agricultural load)
Monsoon dependent hydro
**TTC-ATC for July 2018**

<table>
<thead>
<tr>
<th>Corridor</th>
<th>Total Transfer Capability (TTC)</th>
<th>Transmission Reliability Margin (TRM)</th>
<th>Available Transfer Capability (ATC)</th>
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<td>17500</td>
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<td>ER-NR</td>
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<td>300</td>
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<tr>
<td>WR-SR</td>
<td>6000</td>
<td>500</td>
<td>5500</td>
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<tr>
<td>ER-SR</td>
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<td>4200</td>
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<td>ER-NER</td>
<td>1750</td>
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<table>
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<tr>
<th>Region</th>
<th>Export(+) / Import(-) Capacity</th>
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<tr>
<td>ER</td>
<td>(+)14300#</td>
</tr>
<tr>
<td>NR</td>
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</tr>
<tr>
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@ Excluding power transfer to SR
# Excluding power transfer to SR & NER

<table>
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<tr>
<th>Corridor</th>
<th>Constraints</th>
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<tr>
<td>WR-NR</td>
<td>Orai - Satna 765kV S/c under outage of Gwalior - Satna 765kV S/c line</td>
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<tr>
<td>ER-NR</td>
<td>Aligarh-Greater Noida 765kV S/c line under outage of Aligarh-Jhatikara 765kV S/c line</td>
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<tr>
<td>WR-SR</td>
<td>Sopaur - Raichur 765kV 2xS/c line (n-1)</td>
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<tr>
<td>ER-SR</td>
<td>Vemagiri-II (PG) - Vemagiri (AP) 400kV D/c line (n-1)</td>
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<tr>
<td>ER-NER</td>
<td>Misa 400/220kV ICTs (n-1)</td>
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</table>
TTC-ATC for July 2018 (Base Case LGB)
Legal and Regulatory Framework

- **Electricity Act, 2003**
  - Open Access, Generation de-licensed, institutional changes

- **Tariff Policy**
  - Optimal development of the transmission network to promote efficient utilization of generation and transmission assets in the country
  - Attract required investments in the transmission sector

- **Manual on transmission planning criteria**
  - First brought out by CEA in 1985, revised in 1994 taking into account the experience gained on EHV systems, further revised in 2013

- **National Electricity Plan, Electric Power Survey, 175GW RE (100S-60W) policy, Renewable Purchase Obligation, Grid Standards, IEGC, Design Codes / Safety Requirements**

- **Planning Agencies - CEA, CTU, RLDCs, STU**
Transmission Planning Study

- Planning Period
  - Load Forecast and transmission usage projection

- Generation Resources (Location, Type, etc.)

- Transmission Capacities and transmission margins

- Different Alternatives
  - Economic and Financial Constraints
  - R-O-W Limitations
  - New and Emerging Technology
  - Various Uncertainties and Risks
  - Service Reliability and Cost Consideration
Planning Period

Short Term Planning
- Planning horizon 3 to 5 years
- Feasibility determination for specific projects
- Estimation of costs

Medium Term Planning
- 5 to 10 year planning horizon
- Evaluation of alternatives
- Investment estimation

Long Term Planning
- Planning Horizon – beyond 10 years
- Determine requirement for next higher transmission voltage
- Identification of Broad Corridors
Emerging issues

• Integration of wind and other intermittent resources
• Growth in renewable resources driven by the states, renewable portfolio standards and
• potential federal actions that would promote use of renewables
• Accounting for the more aggressive energy efficiency growth policies
• Diversifying fuel resources
• Stricter environmental regulations
• Changes in regional and interregional cost allocation for new resources
• Additional merchant transmission projects
• Growth of smart grid technologies, and
• Governmental energy planning policies.
Planning criteria

Scope and Applicability

- From date of issue by CEA i.e. 01-Feb-2013 and applicable to
  - Both ISTS and Intra-State, and also Dedicated lines (As all are inter-connected, so there should be uniform approach)
  - Down to 132kV (for ISTS) and 66kV for Intra-State

Criteria for steady-state and transient state behaviour

- General principles
- Permissible normal and emergency limits
- Reliability criteria

Criteria for simulation and studies

- System studies
- Load generation scenarios
- Short circuit studies
- Planning margins

Additional planning criteria

- Reactive power compensation
- Sub-station planning criteria
- Criteria for wind and solar projects
- Criteria for nuclear power stations
- Guidelines for planning HVDC transmission system
Planning Philosophy and Guidelines

- LTA customers and Utilities (STU as Nodal agency) - their end-to-end requirements well in advance
- Planning for hydro projects - river basin wise
- Highly constrained areas - planned by taking long term optimizing the right-of-way and cost
- The system parameters and loading within limits
  - Credible contingency - plan the system
  - Extreme/rare contingencies - defense mechanism
- Critical loads (railways, metro, airports, refineries, big plants) - with 100% redundancy
- Transmission capacity is finite - bound to congestions if flows in unplanned directions
Planning Philosophy and Guidelines

Data:
- Data on existing system
- Load forecast (allocations, beneficiaries, PPA)
- Generation expansion plan (perspective / LTA)
- Seasonal load-generation scenario
- Time-frame for studies
Types of studies

• Power flow studies
• Contingency (and reliability) Studies
• Short circuit studies/ Fault analysis
• Transient and long duration dynamic stability and voltage stability studies
• Techno-economic analysis
• Investment requirements
Load flow study

- While carrying analysis of the system’s capability to adequately supply the connected load, it provides information on
  - Bus voltages and angles
  - Real and reactive power flow on each line
  - Possibility and extent of overloads on equipment during normal and other conditions

- Present load on lines for consideration and location of future loads – assess need for system augmentation

Regional Loadings and Interface Flows Mar’17
Challenges

Uncertainty in Load Growth
- Seasonal
- Long term

Uncertainty in Generation
- De-licensing of Thermal Generation
- Acquisition of Land, Fuel linkage
- Beneficiaries of IPPs projects not firmed up

Uncertainty in Hydro-electric Generation Projects
- Difficulty in Environment clearance
- Longer Gestation Period
- Geological surprise
- Local issues
- Basin wise development
Challenges

Open Access in Transmission and PX
- Market driven exchanges may influence pattern of power flow
- Increasing share of sale under STOA MTOA

Issues in Implementation of Transmission Projects
- Environment/forest/RoW
- Contractual delays
- Issues in TBCB
- Need for periodic review of plan
Uncertainties and risks

- Load growth pattern
- Generation pattern
- IPPs
- Fuel and Hydro resources
- Construction risks
- Environmental issues
- New technology
- Capital and Financial factors
- Institutional and Government factors

1. develop alternate scenario
2. analyze each scenario
3. select the best plan(s)
New Technologies

- Increase in Transmission voltage
- Upgradation of transmission lines
- High capacity 400kV Multi circuit /bundled conductor lines
- High Surge Impedance loading (HSIL) line
- Compact towers
- High temperature Low Sag conductor line
- Gas Insulated substations (GIS)
- Regulation in power flow/Facts devices
- Series compensation of lines
- Preventive maintenance
Thank you
Extra slides – Planning Criteria
Elaborated
Planning Criteria

- **General Principles**
  - In normal (‘N-0’) or single contingency (‘N-1’) operation – all the system parameters like Voltage, Loadings, Freq. should remain within permissible normal limits.
  - In second contingency (‘N-1-1’) –
    - Emergency limits,
    - To bring the system parameters back – load shedding / re-scheduling of generation may have to be applied within one and a half hour (1½) after the disturbance.

- **Permissible Limits**
  - **Loadings:**
    - Transmission line - Thermal loading limit.
    - The loading limit for ICT - its name plate rating.
    - The emergency thermal limits - 110% of the normal.
  - **Voltage Limits:**
    - Normal – Max. and Min.
    - Emergency – Max. (same), and Min.
Planning Criteria

Reliability Criteria

- **Criteria with no contingency (‘N-0’):**
  - All equipment shall remain within their normal thermal loadings and voltage ratings
  - Angular separation between adjacent buses < 30 deg

- **Criteria for single contingency (‘N-1’):**
  - **Steady -State:**
    - Loadings and Voltage – within Normal limits
    - Angular separation < 30 deg
  - **Transient-state:**
    - The system shall be stable after it is subjected to one of the following disturbances:
      - a permanent three phase to ground fault on a 765kV line close to the bus to be cleared in 100 ms
      - a permanent SLG fault on a 765kV line close to the bus with unsuccessful re-closing
    - HVDC – fault resulting in outage of one of the poles
    - Outage of single largest generating unit or a critical generating unit
Planning Criteria

Reliability Criteria

- After first contingency, the transmission system shall be stable when subjected to one of the following subsequent contingencies (called ‘N-1-1’ condition):
  - 765kV - a temporary SLG, with successful re-closing
  - 400kV - a permanent SLG, with opening of line after deadtime of 1 second
  - single phase to ground fault on a 400kV line close to the bus.
  - 220kV / 132kV networks - a permanent 3-ph-fault

- After N-1-1, system parameters – not to exceed Emergency limits - To bring within Normal through – load shedding/re-scheduling of generation

System Studies

- Power Flow Studies
- Short Circuit Studies
- Stability Studies (transient and voltage stability)
- EMTP studies (for TOV, SOV, insulation coordination, etc)
Planning Criteria

Load-generation scenarios
- Reflect the typical daily and seasonal variations in demand and availability

Load demands - Active power (MW)
- EPS report of CEA - moderated based on actual load growth of past 3 years – Annual Peak
- Seasonal Loads - to be derived based on the Annual peak demand and past pattern Seasonal variation for Winter, Summer and Monsoon
- Seasonal Light Load (motor load of pumped storage plants)
- The sub-station wise annual load data, both MW and MVAr shall be provided by the STU

Load demands - Reactive power (MVAr)
- STUs to give substation-wise maximum and minimum demand in MW and MVAr on seasonal basis in the given format
- In the absence of data the load power factor at 220kV and 132kV voltage levels may be taken
  - as 0.95 lag during peak load condition, and
  - 0.98 lag during light load condition

The STUs shall provide adequate reactive compensation to bring power factor as close to unity at 132kV and 220kV voltage levels
Planning Criteria

Planning margins

- Uncertainties – generation, load, planned network
- A margin of 10% in the thermal loading limits of lines and transformers is kept.
- the margins in the inter-regional links – 15%.
- voltage limits - a margin of about ± 2% (as per manual)
- Nominal tap for ICTs, taps for operation period
- Narrowed generation capability limits
- ATS - considering overload capacity of the generating stations in consultation with generators

Reactive power compensation

- **Shunt capacitors**
  - close to the load points
  - No reactive power flow down(or up) through the ICT – if voltage on HV side is < 0.975 pu(>1.025 pu)

- **Shunt reactors**
  - Sufficient for controlling voltages within the limits without resorting to switching-off of lines.
  - Voltage change not to exceed 5% on switching on / off of the reactors
  - Fixed line reactors provided to –
    - Control power frequency TOV
    - Line charging (may be switchable also)
**Planning Criteria**

- Maximum short-circuit level on any new substation bus - not to exceed 80% of the rated short circuit capacity of the substation.
- 20% margin - to take care of the increase in short-circuit levels as the system grows.
- Measures to limit the short circuit levels - splitting of bus, series reactor, or any new tech.
- Voltage stability studies - If the fault level is low.
- Stuck breaker condition - not to cause disruption of more than four feeders for the 220kV system and two feeders for the 400kV/765kV system.
- Effort for new substation, when the capacity of the existing has reached as given in column (B).
- The capacity of any single sub-station at different voltage levels shall not normally exceed as in col. (C).

<table>
<thead>
<tr>
<th>Voltage Level</th>
<th>Transformer Capacity</th>
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<tbody>
<tr>
<td></td>
<td>Existing capacity</td>
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<tr>
<td>(A)</td>
<td>(B)</td>
</tr>
<tr>
<td>765 kV</td>
<td>6000 MVA</td>
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<tr>
<td>400 kV</td>
<td>1260 MVA</td>
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<tr>
<td>220 kV</td>
<td>320 MVA</td>
</tr>
<tr>
<td>132 kV</td>
<td>150 MVA</td>
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</table>
Planning Criteria

**Additional criteria for wind and solar**
- ‘N-1’ criteria not to be applied to the immediate connectivity of wind/solar farms with the ISTS/Intra-STS grid
- Thermal line loading limit of the lines connecting the wind machine(s)/farm to the nearest grid point to be assessed considering 12 km/hour wind speed
- Power factor of 0.98 (absorbing) at grid inter-connection point for all dispatch scenarios to be maintained

**Guidelines for HVDC Systems**
- HVDC bipole
  - For transmitting bulk power (more than 2000 MW) over long distance (more than 700 km)
  - In AC lines carrying heavy power flows (total more than 5000 MW)
- Ratio of fault level in MVA at convertor station to the power flow on the HVDC bipole - not to be less than 3.0 under any of the load-generation scenarios and contingencies
Planning Criteria

Guidelines for voltage stability

- Carried out using load flow analysis program by creating a fictitious synchronous condenser at critical buses which are likely to have wide variation in voltage under various operating conditions

- Knee point of Q-V curve represents the point of voltage instability

- Each bus shall operate above Knee Point of Q-V curve under all normal as well as the contingency conditions

- Horizontal 'distance' of the knee point to the zero-MVAr vertical axis measured in MVAr is, therefore, an indicator of the proximity to the voltage collapse