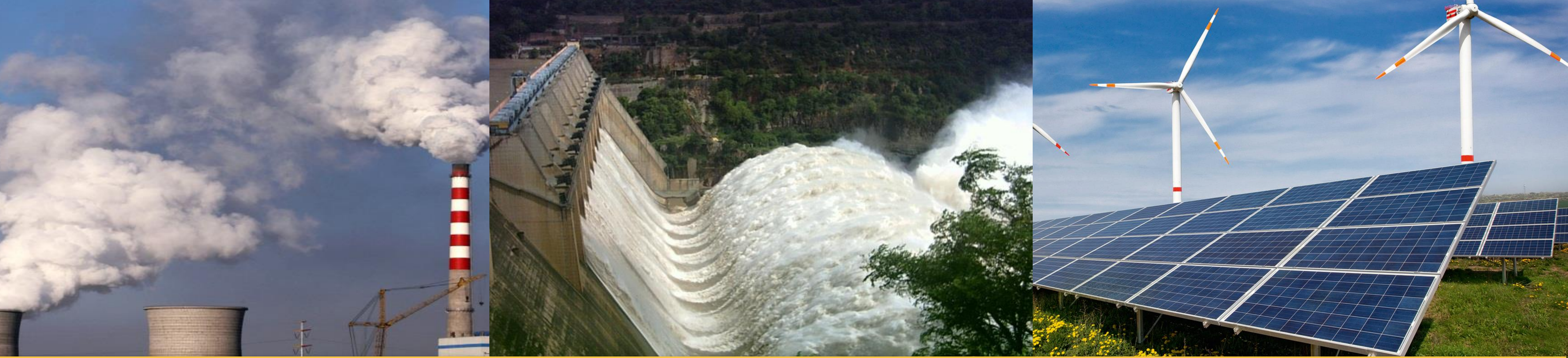

Load Forecasting: Its Role in Generation and Transmission Planning

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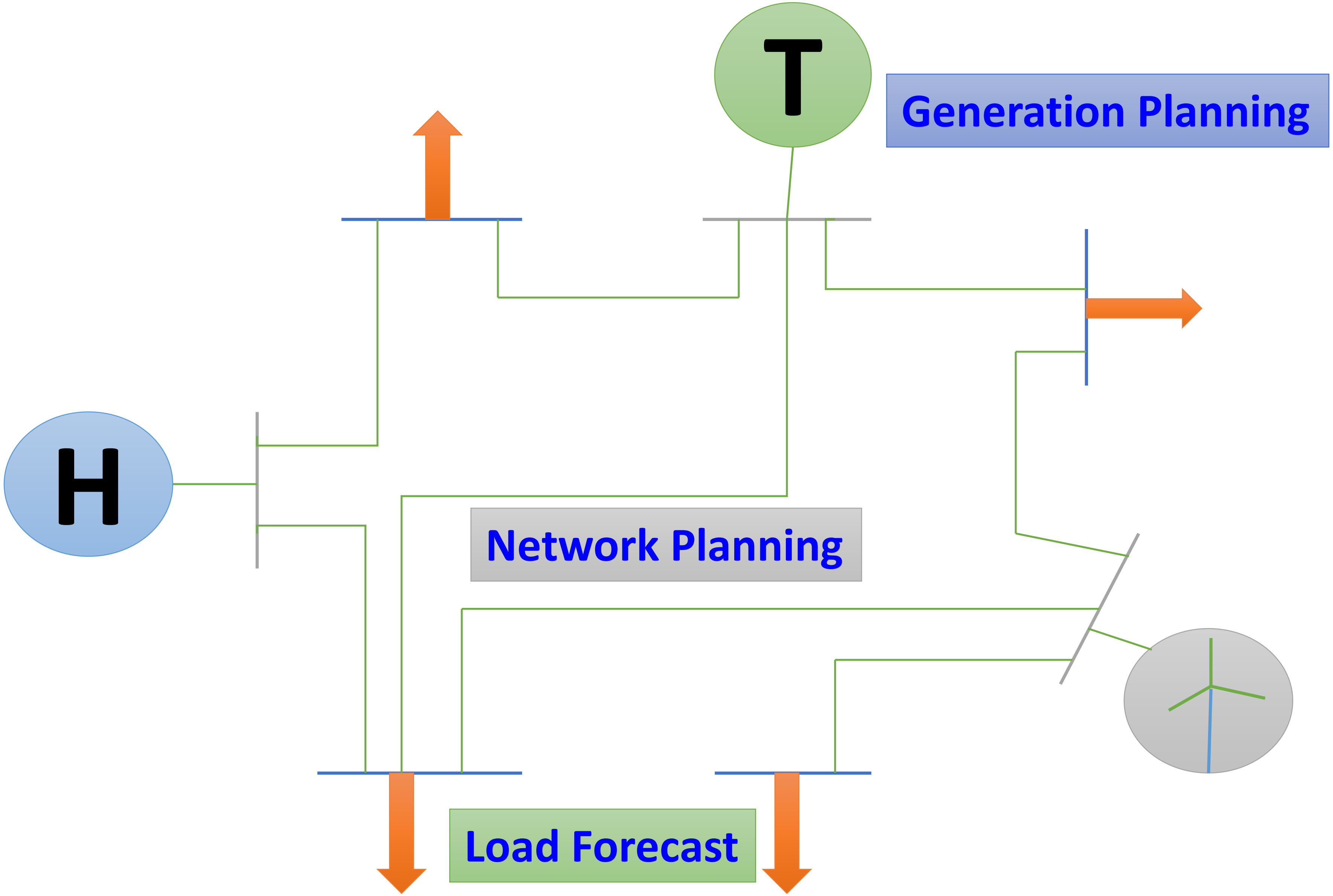
Power System Planning



Power System Planning

The process begins with electricity demand forecasting, which is followed by reliability evaluation to determine if and when additional generation is needed. Finally, optimal capacity expansions are selected based on economic considerations.

**Reliability as high as necessary,
design & operation as economical as possible!**

Generation Planning

- When to invest in new generating units?
- Where to invest in new generating units?
- What type of generating units to install?
- What capacity of generating units to install?

The reliability indices of electricity supply

Generation Planning: Outages

- ✓Generating stations require regular maintenance, which means that during some periods of the year they are not available to serve the load. This is called ‘maintenance outages’.

- ✓The stations also can be out of service due to unforeseen equipment failures; these outages, called **forced outages**, also contribute to reduced availability.

- ✓Both scheduled and forced outages needs to be considered for generation planning.

Basic Reliability Indices at HL – 1

- **Loss of Load Expectation (LOLE),** is the expected number of days (hours) in a specified period in which the daily peak load (hourly load) exceeds the available generating capacity.

- **Loss of Load Probability (LOLP),** is the probability that load is higher than available generation capacity.

- Reliability Index in reality?

Reliability Criteria Used by Utilities around the World

- **USA (source: NERC (data provided by utilities in 2008))**

S.No	Region	Reliability Index used	Remarks
1	ERCOT	LOLP	Reserve margin based on LOLP
2	FRCC	LOLP	The periodic LOLP assessment validates the reserve margin requirement is adequate.
3	MRO	LOLE	LOLE of 0.1 day/year
4	NPCC	LOLE	LOLE of 0.1 day/year
5	RFC	LOLE	Reserve margin need to satisfy LOLE of 0.1 day/year
6	SERC	LOLE	LOLE studies without considering transmission constraints
7	SPP	LOLE	Reserve margin based on LOLE of 0.1 day/year
8	WECC		Reserve margin calculation by building block approach (Contingency Reserves, Regulating Reserves, reserves for Additional Forced Outages, etc) Planning to implement a model with LOLE in one or two years

Reliability Criteria Used by Utilities around the World

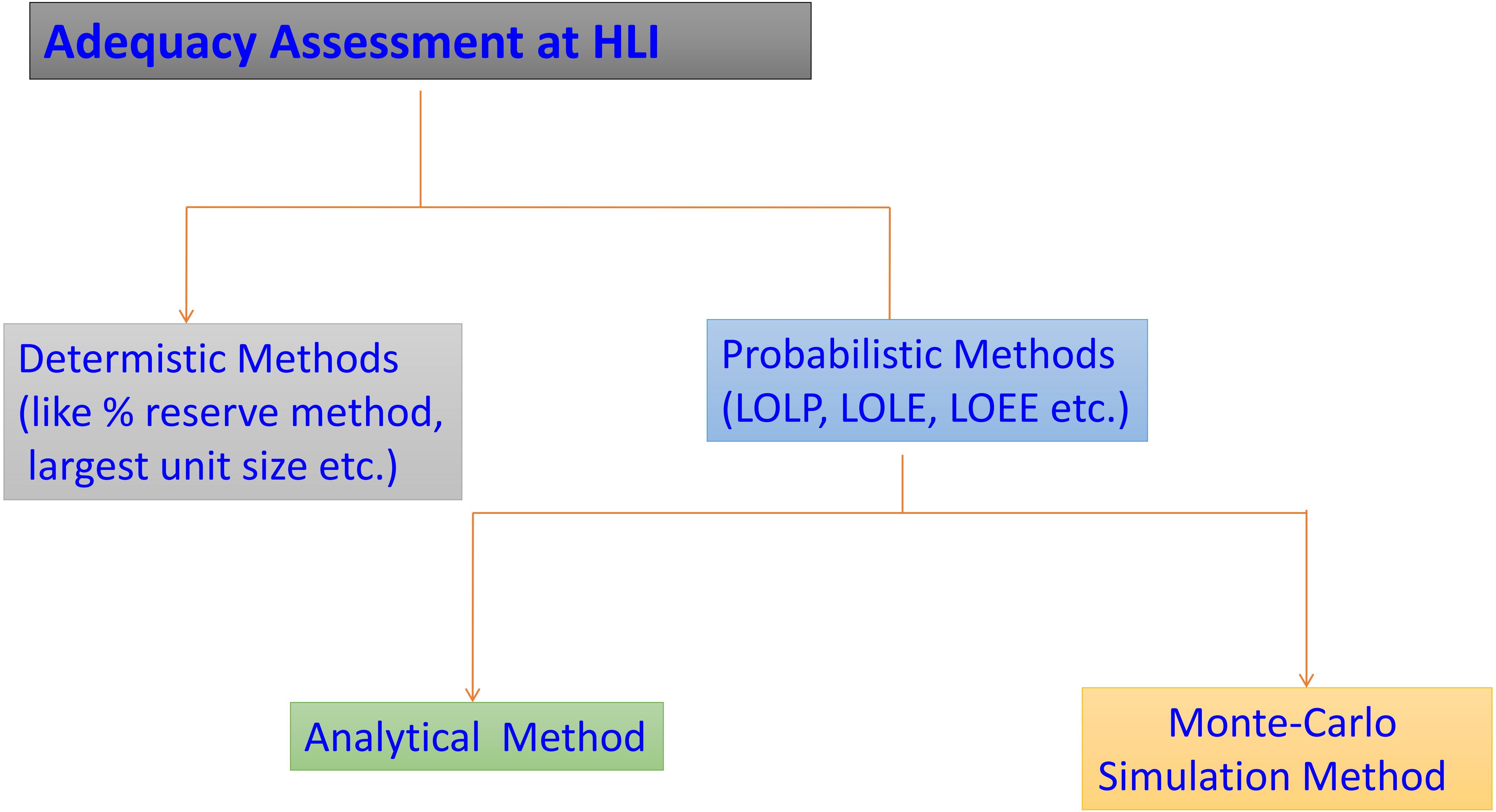
- **CANADA**

S.No	Region	Reliability Index used	Remarks
1	**Quebec (NPCC)**	LOLE	LOLE of 0.1 day/year
2	Maritimes (NPCC)	LOLE	LOLE of 0.1 day/year and reserve margin of 20%
3	Ontario (NPCC)	LOLE	LOLE of 0.1 day/year
4	Manitoba (MRO)	LOLE	LOLE of 0.1 day/year (without interconnections)
5	Saskatchewan (MRO)	Expected unserved energy (EUE)	Reserve margin based on EUE
6	Alberta (WECC)	----	Reserve margin calculation by building block approach
7	British Columbia (WECC)	----	Reserve margin calculation by building block approach

Reliability Criteria Used by Utilities around the World

S.No	Country	Reliability Index used	Remarks
1	Ireland	LOLE	LOLE of 8 hours/year
2	Thailand	LOLP	LOLP should not exceed 1 day/year
3	Malaysia	LOLP	LOLP should not exceed 1 day/year
4	France	LOLE	LOLE of 3 hours/year
5	Britain	LOLP	----
6	South Africa	LOLP or LOLE	---

Adequacy Evaluation at HLI



Monte Carlo Simulation Method

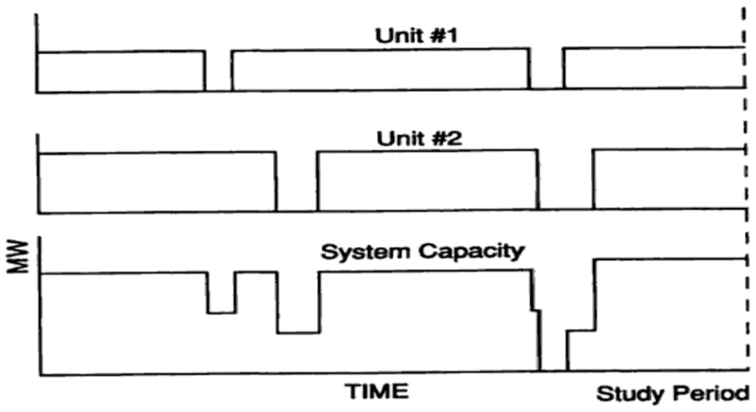


Fig: Available capacity models of each unit and the system

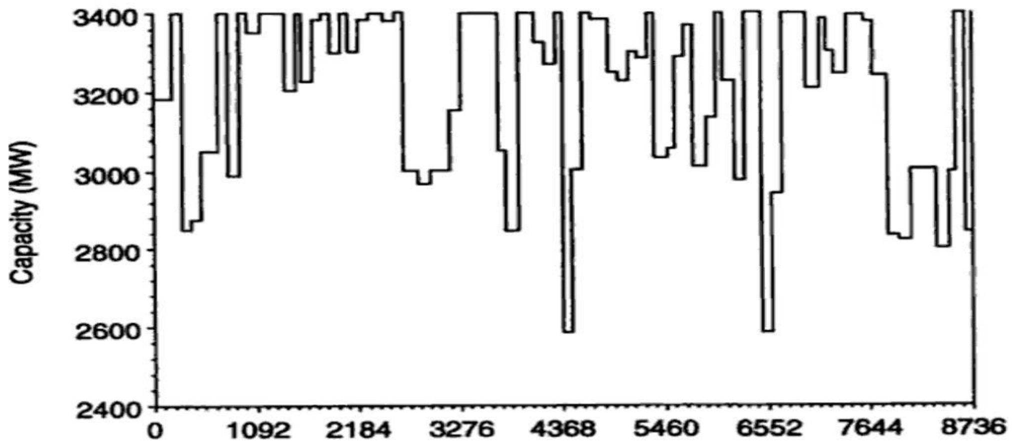


Fig: System available capacity model in a typical sample year

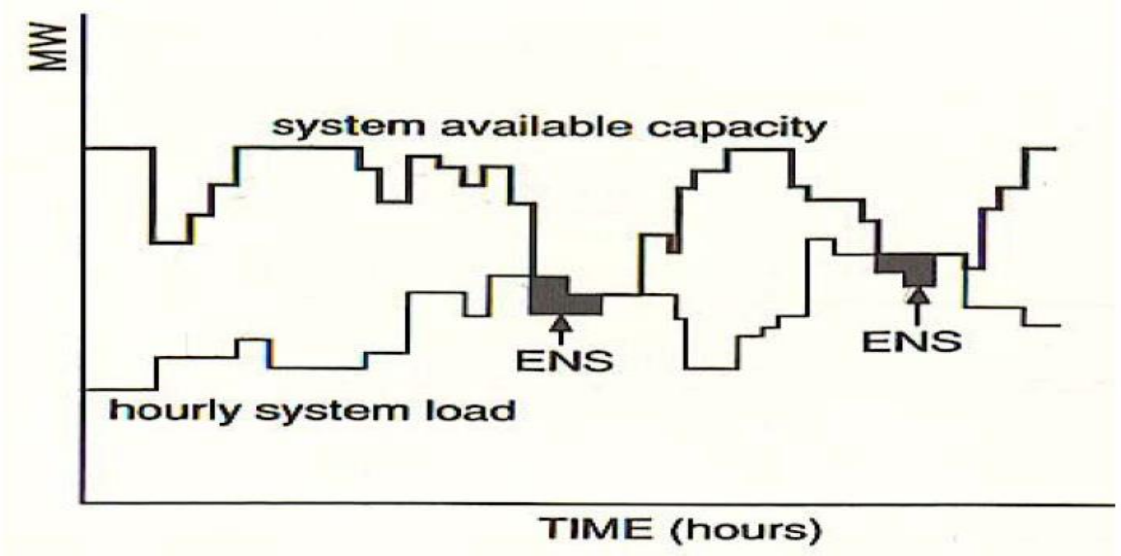


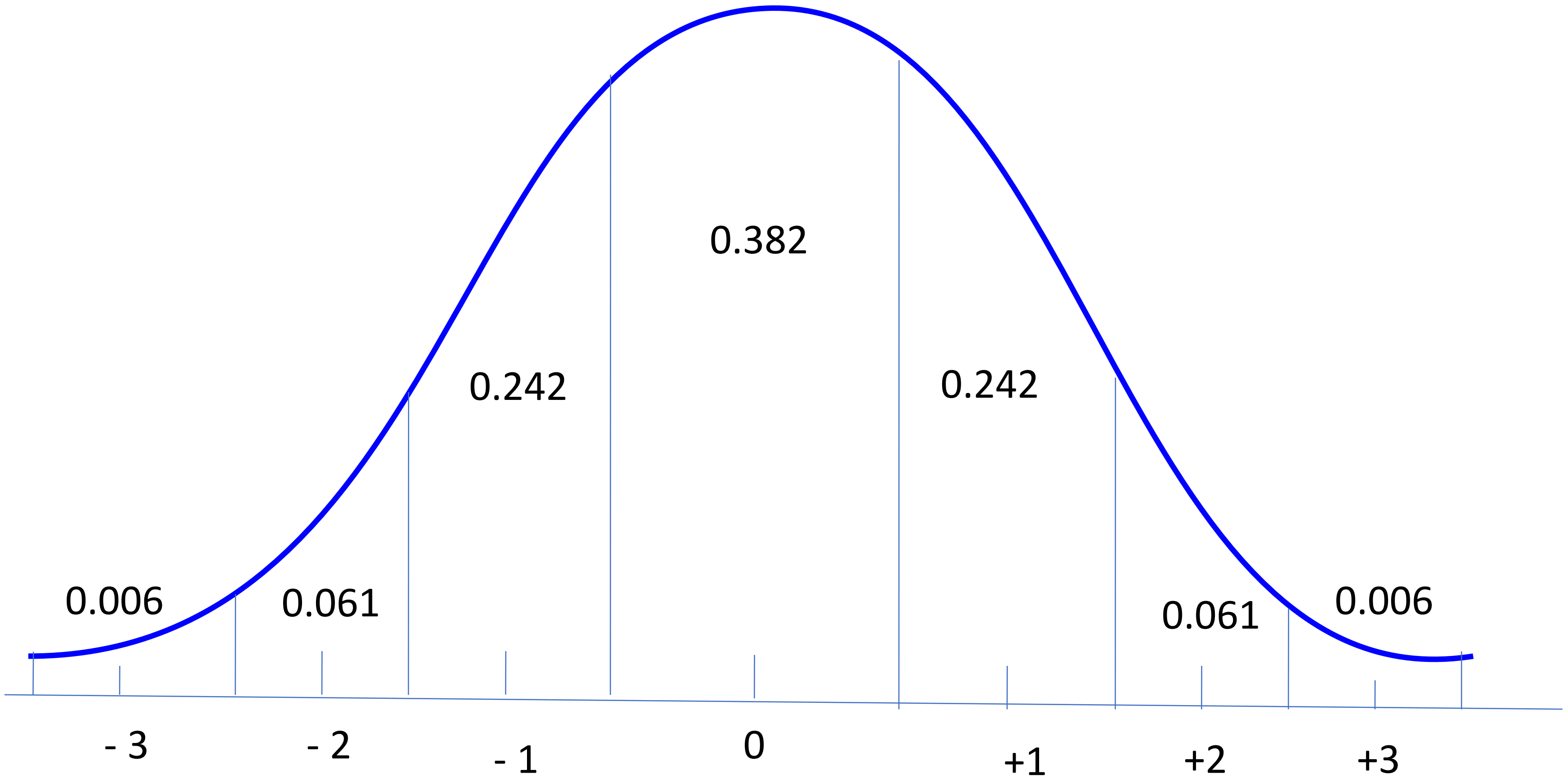
Fig: Superimposition of the available capacity on the load

Maintenance Scheduling

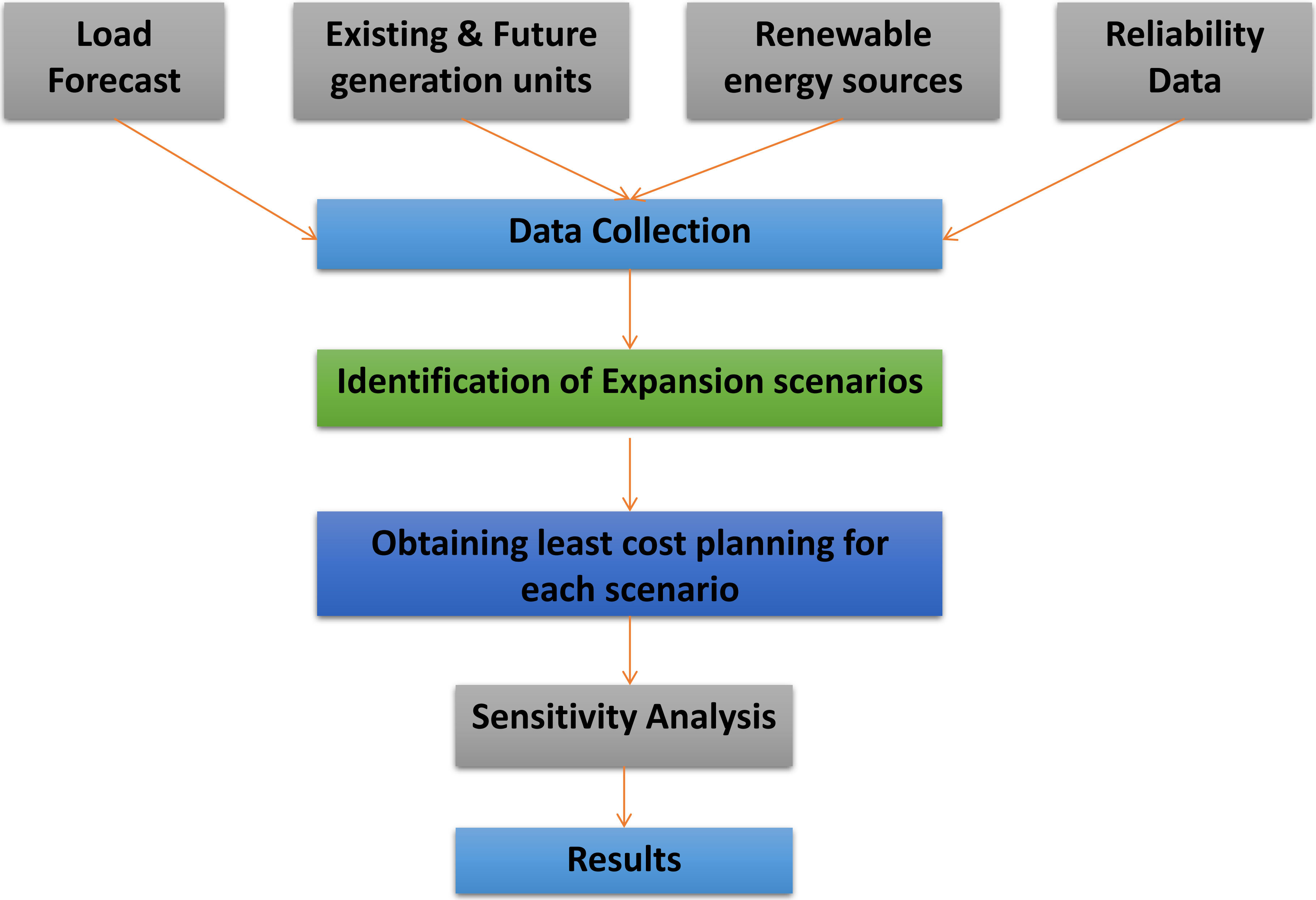
The Strategy for the Maintenance Scheduling of the Generation units:

- Maintenance will play an important role in power system planning and designing and also operation management.
- purpose:
  - To reduce equipment failures,
  - To extend the equipment life,
  - To increase the reliability and economic benefits of power systems.
- The most used maintenance schedule optimization are:
  - Levelized reserve method
  - Levelized risk method

Load Forecast Uncertainty



Generation Planning - Steps



Transmission Planning

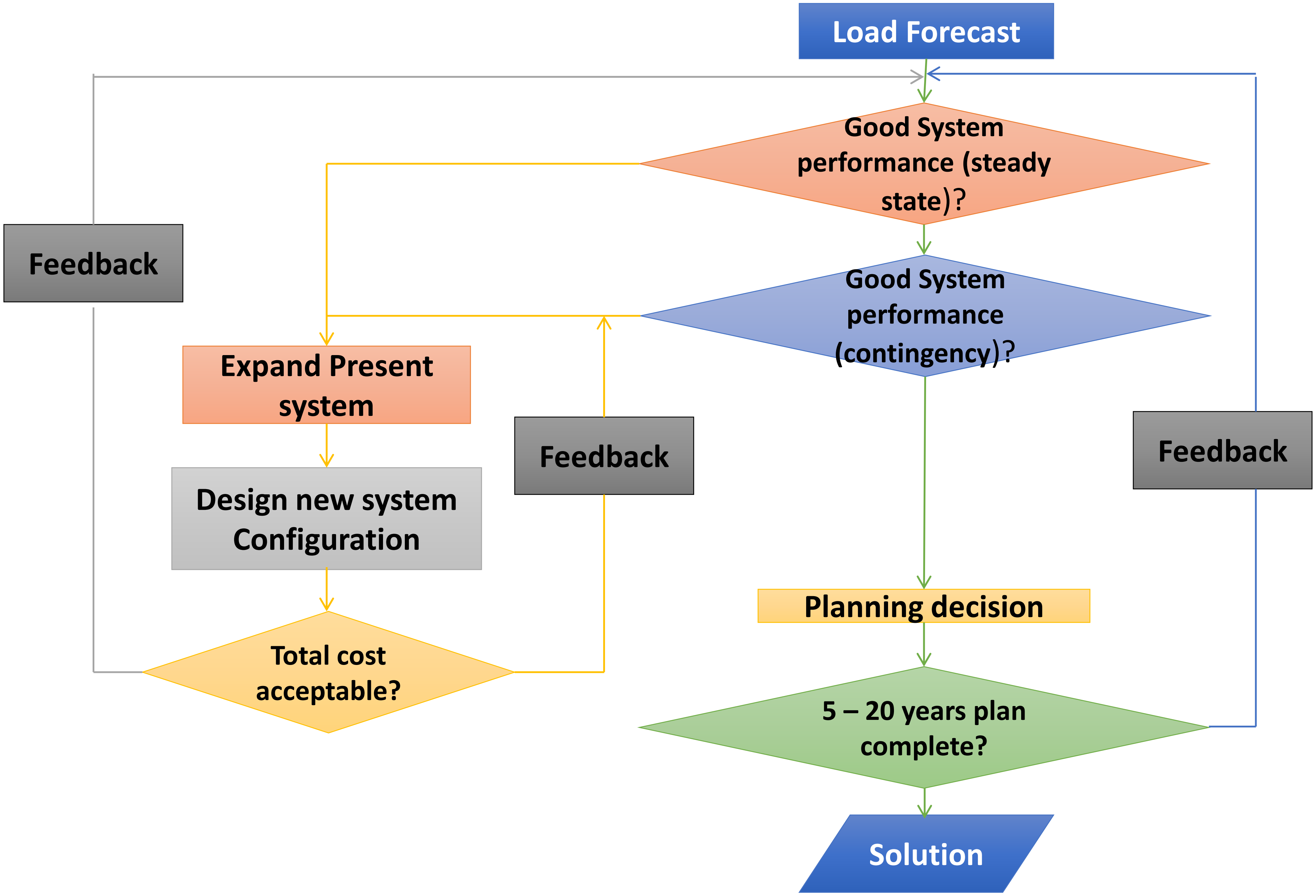
Transmission Planning : Objectives

- Where to build a new transmission line?
- When to build it?
- What type of transmission line to build?

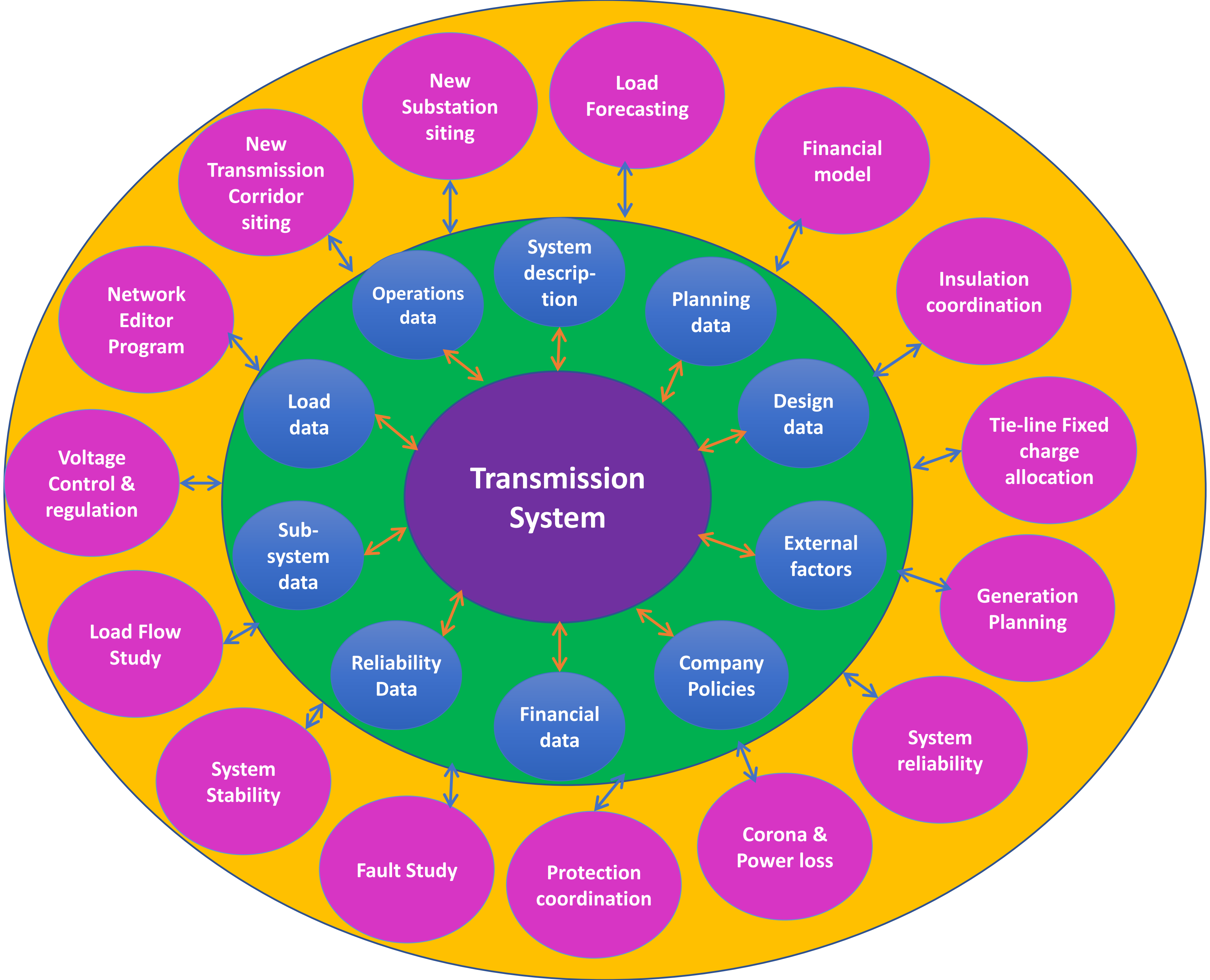
To assess and plan for changes, all power companies analyze their network of power lines considering:

- Demand growth
- New power plants
- New ways to use the transmission system efficiently

Transmission System Planning Process



Data Flow & Studies



Transmission Planning - Scenarios

- Load flow studies -
  - ✓ Peak load – summer, monsoon, winter
  - ✓ Light load – summer, monsoon, winter
  - ✓ High hydro generation,
  - ✓ Low hydro generation,
  - ✓ High thermal generation,
  - ✓ Contingency studies,
  - ✓ Line loading limits,
  - ✓ Angular separation,
  - ✓ Optimum utilization of transmission lines and transformers,
  - ✓ Variation of voltage,
  - ✓ Outage of single largest unit,
  - ✓ Outage of largest generation complex

Power System Studies: Contingency Analysis

6.2 Criteria for single contingency (‘N-1’)

6.2.1 Steady-state :

a) All the equipment's in the transmission system shall remain within their normal thermal and voltage ratings after a disturbance involving loss of any one of the following elements (called single contingency or ‘N-1’ condition), **but without load shedding / rescheduling of generation**:

- ✓ Outage of a 132kV or 110kV single circuit,
- ✓ Outage of a 220kV or 230kV single circuit,
- ✓ Outage of a 400kV single circuit,
- ✓ Outage of a 400kV single circuit with fixed series capacitor (FSC),
- ✓ Outage of an Inter-Connecting Transformer (ICT),
- ✓ Outage of a 765kV single circuit
- ✓ Outage of one pole of HVDC bi-pole.

b) The angular separation between adjacent buses under (‘N-1’) conditions shall not exceed 30 degree.

Power System Studies: Contingency Analysis

- **6.3 Criteria for second contingency ('N-1-1')**

6.3.1 Under the scenario where a contingency as defined at Paragraph: 6.2 has already happened, the system may be subjected to one of the following subsequent contingencies (called 'N-1-1' condition):

a. The system shall be able to survive a temporary single phase to ground fault on a 765kV line close to the bus

b. The system shall be able to survive a permanent single phase to ground fault on a 400kV/220/132 kV line close to the bus.

Power System Studies: Contingency Analysis

- 6.3.2 (a) In the ‘N-1-1’ contingency condition as stated above, if there is a temporary fault, the system shall not loose the second element after clearing of fault but shall successfully survive the disturbance.

(b) In case of permanent fault, the system shall loose the second element as a result of fault clearing and thereafter, shall asymptotically reach to a new steady state without losing synchronism. In this new state the system parameters (i.e. voltages and line loadings) shall not exceed emergency limits, however, there may be requirement of load shedding /rescheduling of generation so as to bring system parameters within normal limits.

Planning Considerations

- General options for Transmission strengthening are,
  - ✓ Re-conductoring of existing Transmission lines with AAAC or HTLS conductors which can carry more power
  - ✓ Propose new transmission lines where overloading is seen in normal & in Contingency studies.
  - ✓ If more than 3 circuits are needed between two substations examine use of next higher voltage interconnection between them.
  - ✓ Use of series capacitors to increase power transfer in long transmission lines.
  - ✓ Adoption of multi voltage multi circuit lines in areas where transmission corridors are an issue like in urban areas/around major cities.

Planning Considerations

- General options for Transmission strengthening are,
  - ✓ Where only two circuits are planned, planning of two independent circuits (as far as possible) instead of a double circuit line for reliable evacuation to take care of tower outages where generation is sensitive.
  - ✓ Reactive power flow through EHV system including ICTs should be minimal & all shunt capacitor planning shall be preferably nearest to loads like in distribution networks & at substations.
  - ✓ Reactive power flow through ICT shall be generally less than 10% of the ICT rating.
  - ✓ When voltage on HV side of ICT is less than 0.975 preferably no reactive power shall flow through ICT.
  - ✓ CEA manual recommends use of power factor of 0.85 for peak & 0.9 for off-peak study.

Planning Considerations

- Transmission Line loading limits:
  - ✓ One of the important parameter to decide on the network overloading/ reinforcement needed is the permissible loading of transmission lines.
  - ✓ This depends on
    - Thermal loading limits
    - Surge Impedance loading(SIL) based on line length, SIL based on reactive compensation adopted series or shunt.

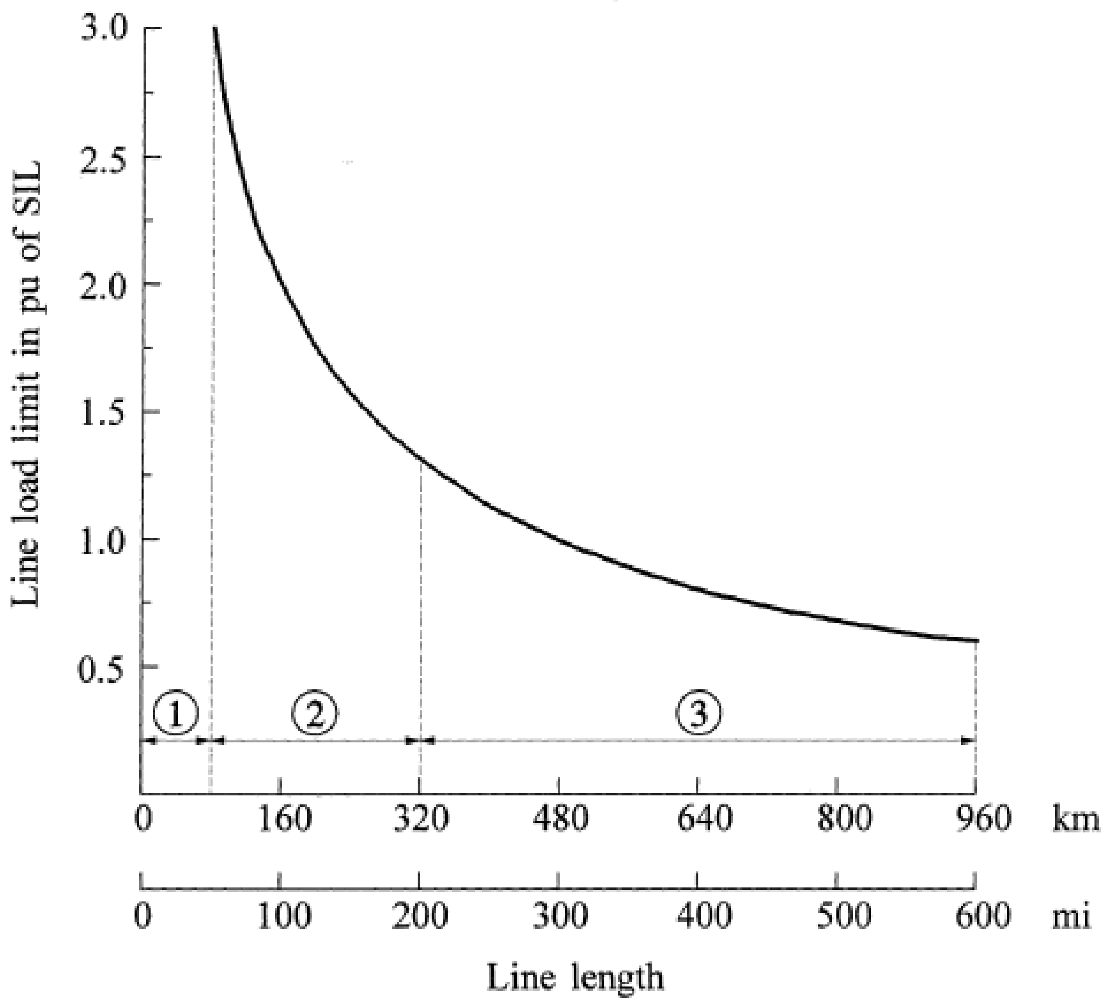
    Lowest of the above has to be adopted as the permissible loading of the line.

Planning Considerations

- Thermal Loading :
  - ✓ Depends on area ambient temperature
  - ✓ Designed allowable conductor temperature (65°C, 75°C, 90°C) and allowable sag considered in line design based on this.
  - ✓ Material of conductor used like ACSR(65/75°), All aluminum alloy (90° but to be taken as 85°C for design purposes), new High temperature low sag conductors (210°).
- Surge Impedance Loading :
  - It is uneconomical to limit line loading to SIL as the limits are very much on lower side compared to thermal limits.

Planning Considerations

- SIL for 220 kV line with Zebra ACSR is 132 MW against thermal loading of 224 MW at 75° (164 MW at 65°C) allowable conductor temperature.
- Short lines can be loaded above SIL and long lines should be loaded less than SIL because of stability limitations.



1 0–80 km: Region of thermal limitation
2 80–320 km: Region of voltage drop limitation
3 320–960 km: Region of small-signal (steady-state) stability

THANK YOU