Module 5
Power System Reliability Analysis

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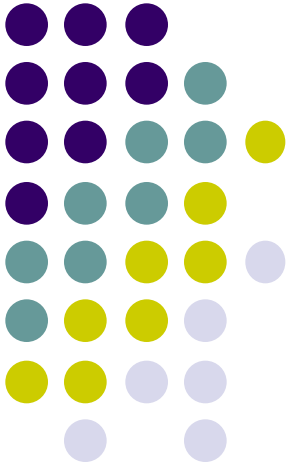


Functional Zones of a Power System

- Generation System
- Transmission System
- Distribution System

- Three major areas of power system reliability analysis.

Functional Zones of a Power System

1. Generating Capacity Reliability Evaluation

Single area

- static reserve (planning) : concerned with the adequacy of generation to supply load. The transmission constraints are not considered.
- spinning reserve assessment (operation): concerned with the assessment of spinning reserve to operate the system with an adequate reliability level.

Multi-area or interconnected system reliability: Tie line constraints are considered. Transmission constraints within an area are indirectly considered while deriving the inter-area transfer capabilities.

2. Composite System Reliability Evaluation

It considers the joint treatment of generation and bulk transmission.

3. Distribution System Reliability

Calculation of reliability indices at customer load points.

Single Area Reliability Analysis

- Introduction and Definitions
  - Generation Adequacy
  - Generation Capacity Adequacy Assessment Reliability Indices
    - Deterministic Indices
    - Probabilistic Indices

Generation Adequacy

- The objective of electric power systems is to supply electrical energy to consumers at low cost while simultaneously providing acceptable, or economically justifiable, service quality.
- Generation adequacy deals with the relative ability of the system to supply system load considering that generating units may be out of service when needed due to planned or unplanned outages or that the basic energy sources may be inadequate.
- Generation “adequacy” is to be contrasted with “security” which deals with the relative ability of the system to survive sudden shocks or upsets such as faults or equipment failures without cascading failures or loss of stability.

Generation Adequacy

- Generation adequacy is usually measured through the use of some reliability (adequacy) index which quantifies system reliability (adequacy) performance and it is enforced through a criterion based on an acceptable value of this reliability index.
- Some utilities rely on adequacy criteria whose values have been chosen based on engineering judgment to yield a reasonable balance between system cost and reliability performance and which have been validated by historical experience. However, if adequacy criteria are based on probabilistic indices which bear reasonable relationships to the actual reliability performance of the system, more pragmatic methods may be employed to determine proper values of the criteria.

Generation Capacity Adequacy Assessment Reliability Indices

- Reliability indices can be broadly divided into two categories

  1. Deterministic indices: These indices reflect postulated conditions. They are not directly indicative of electric system reliability and area not responsive to most parameters which influence system reliability performance. Therefore these indices are of limited value for choosing between planning alternatives. Their calculation is, however, simple and requires little data.

  2. Probabilistic indices: These indices directly reflect the uncertainty which is inherent in the power system reliability problem and have the capability of reflecting the various parameters which can impact system reliability. Therefore, probabilistic indices permit the quantitative evaluation of system alternatives through direct consideration of parameters which influence reliability. This capability accounts for the increasing popularity and use of probabilistic indices.

Deterministic Indices

1. Percent Reserve Margin:
   - Defined as excess of installed generating capacity over annual peak load expressed in percent of annual peak load.
   - Does not directly reflect system parameters such as unit size, outage rate and the load shape.
   - It does provide a reasonable relative estimate of reliability performance if parameters other than margin remain essentially constant.
2. Reserve margin in terms of largest unit.
   - This index recognizes the importance of unit capacities in relationship to reserve margin.

Probabilistic Indices

1. Loss of Load Expectation (LOLE)

- DLOLE is the expected number of days per year on which insufficient generating capacity is available to serve the daily peak load.
- HLOLE is the expected number of hours per year when insufficient generating capacity is available to serve the load.
- The LOLE index gives no information on a number of important system reliability attributes:
  - Magnitude of capacity shortages when they occur.
  - Duration of capacity shortage events.
  - Expected amount of unserved energy.

Probabilistic Indices

- 2. Frequency and Duration of Capacity Shortage Events (F&D)

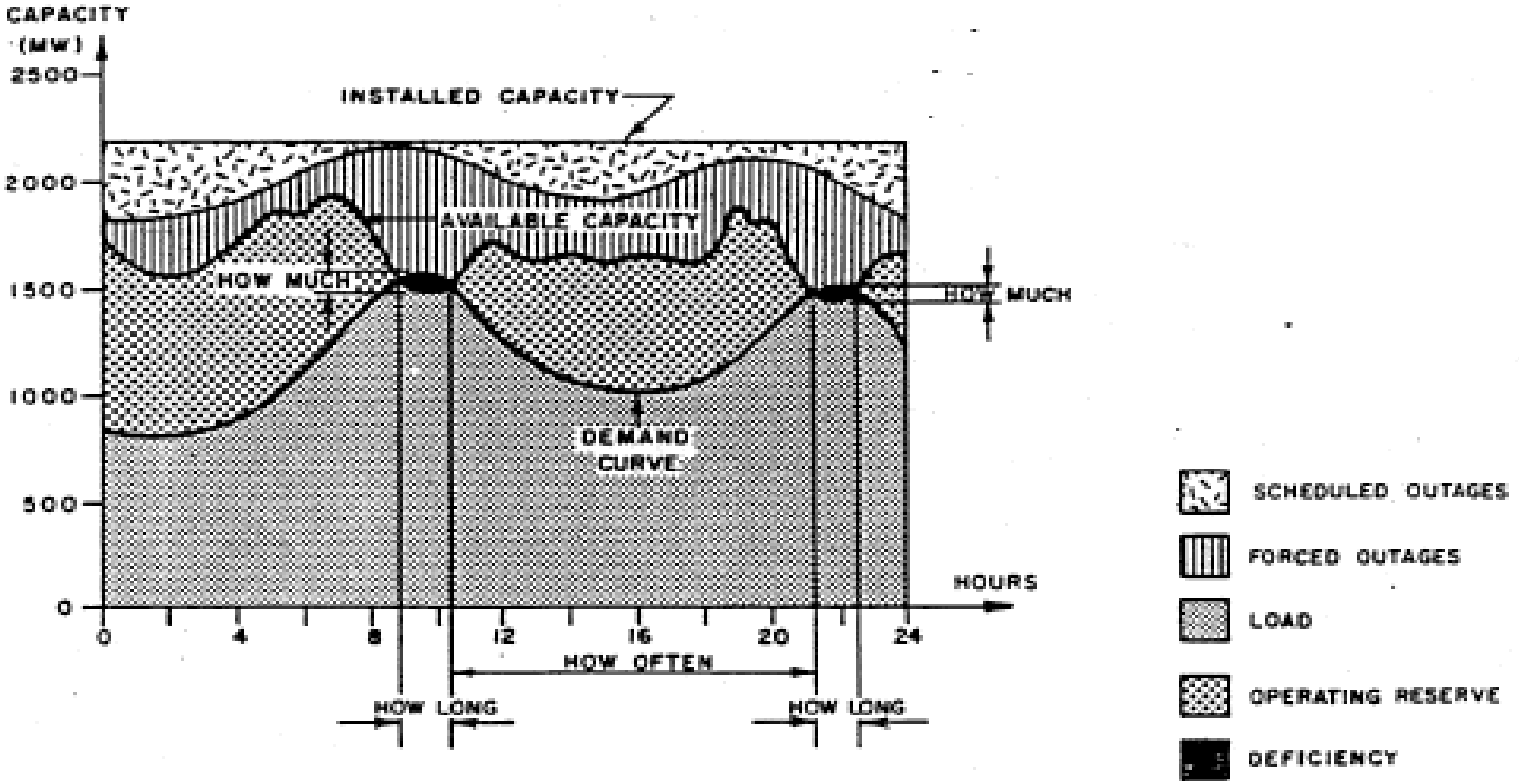
  - Frequency of generating capacity shortage events is defined to be the expected (average) number of such events per year.
  - Duration is the expected length of capacity shortage periods when they occur.
  - F&D indices use hourly load information and thus reflect the influences of daily load cycle shape.
  - F&D methods model unit parameters more fully than those models used in LOLE.
  - F&D indices are conceptually superior to LOLE. They have, however, greater data requirements.

Probabilistic Indices

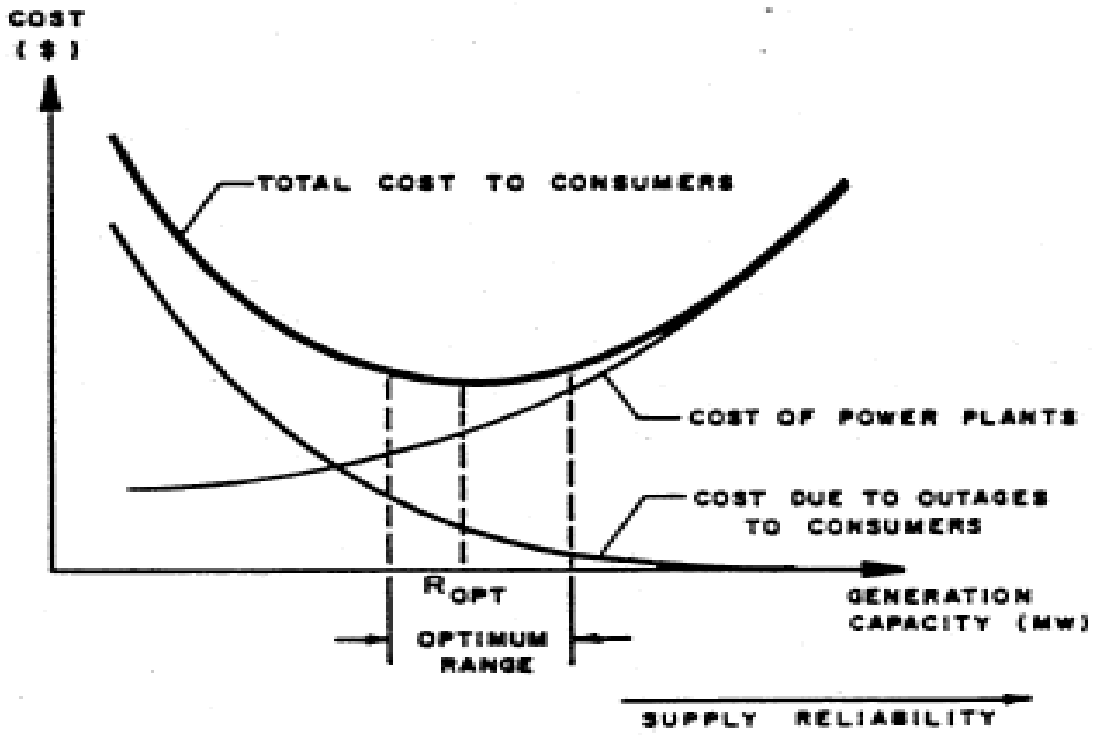
3. Expected Unserved Energy (EUE)

- The EUE index measures the expected amount of energy which will fail to be supplied per year due to generative capacity differences and/or shortages in basic energy supplies.

FREQUENCY, MAGNITURE AND DURATION OF SYSTEM OUTAGES CAUSED BY GENERATION CAPACITY OUTAGES.



OPTIMAL SYSTEM EXPANSION PLAN & RELIABILITY AS DETERMINED BY AN EXPLICIT BALANCING OF SYSTEM COSTS & CONSIMER OUTAGE COST



Methods of Analysis

- Generation Reliability Methods

- Discrete convolution
  - Unit addition algorithm
  - Fast Fourier Transform
- Continuous distribution approximation
  - Gram-Charlier series
  - Multi-parameter gamma
  - Laguerre polynomial
  - Legendre series