1. A

1.3 Planning process

- Process of taking **careful decision**.
- Process of **selecting vision**, values, **mission** and objectives, decide plan to achieve them.
- Input for planning is **quality** of systematic **thought** that goes into **decision**.
- Process of establishing power industry is **time** consuming and **capital** intensive.
- Planning saves **project time** and utilizes **resource economically**
- Planning should consider
  1. uncertinity about future
  2. alternative action choices
  3. goals and constraints

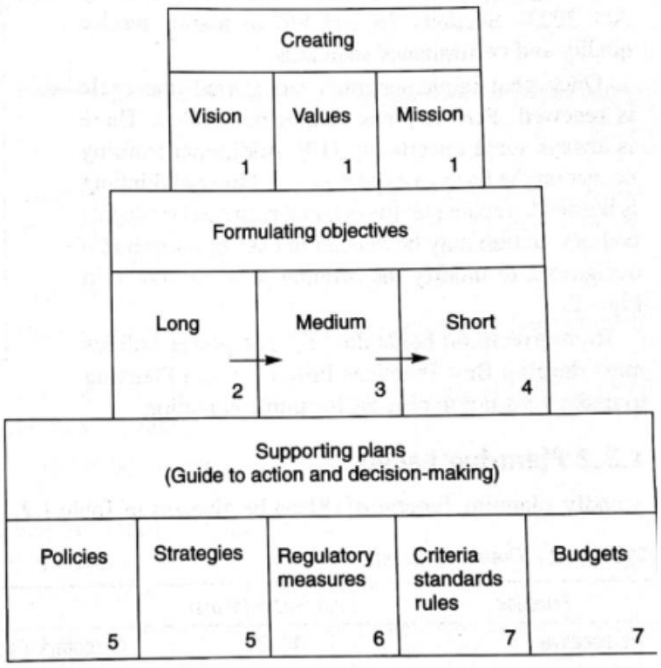


Fig. 1.1 *Components of the planning process*

It consists of **three** cyclical components

1. **Learning** about the environment related issues and possible future scenarios to identify :
   a. Strategically goals
   b. Decision criteria and constraints
   c. Technological needs and opportunities.
2. **Thinking** about existing plans, associated costs and risks.

This involves

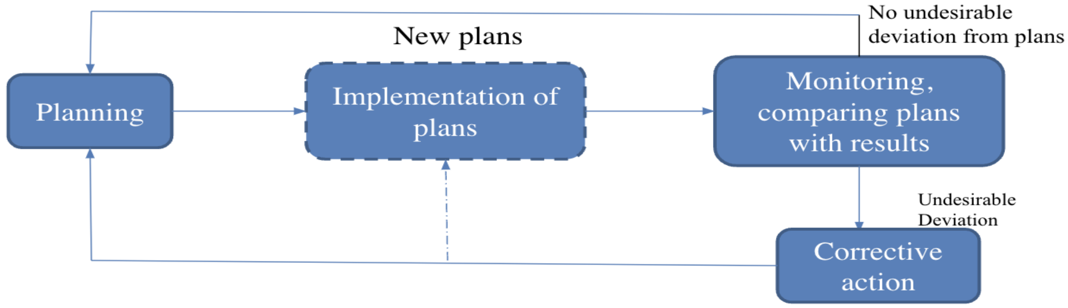
   a. Investment of resources
   b. Unforeseen factors
   c. Reliability of outcome

3. **Preferred plans** based on support analysis

Characteristics of power system that makes planning challenging

1. **High capital** intensive
2. Plan implemented in **advanced** countries cannot be implemented in **developing countries**
3. Planning **diverges** a **lot** before it **actually converges**.(Eg: Environmental effects)

Planning Actions



1.b

Mathematical Modelling-Simulation:

- In modelling, **the total load** is considered to be **the sum total of various components due to various factors**.
- These **factors** need to be measured and interrelated with load requirements.
- **individual modelling** of each **load type**
- identifying their interrelationship **to arrive at future load requirements**

- In extrapolation, future load is treated as an extension of the past

- the load curve based on past data

- Technique ➡ **detection of trends in the past** (various parameters) ➡ **fitting a trend curve**-which could be a straight line, a parabola, exponential or a polynomial of other orders or a mix of the above ➡ **finding coefficients of these curves** as given below

Straight line $Y=a+bx$

Parabola $Y=a + bx+ cx^2$

S. curve $Y=a + bx +cx^2+dx^3$

Exponential $Y=be^{cx}$

Modified exponential $Y =a + be^{cx}$

Logistics $Y =1 / (a + be^{cx})$

Where **Y is a variable to be fitted, x is time in assigned frame** (in day, week, year etc.), and a, b ,c, d are coefficients be calculated.

- The mathematical models for domestic, commercial and other sectors have been determined by the CEA

Domestic sector:

- Energy in the domestic sector → cooking, lighting, heating and other household appliances like TV, refrigerators etc.
- **Increase** in the family income ↑ **demand for electrical energy** in domestic sector.
- The following **model** has been adopted for **projecting the demand in the domestic sector**

$$\log Y = a + b \log X$$

Commercial and Other sectors:

- The increased commercial activity has resulted in increasing use of energy.
- The use of electricity for illumination, weather comforts, refrigerators, air-conditioning and water heating is being increasingly resorted to.
- The other sectors, which mainly consist of public lighting, public water works.
- energy consumption in the **foreseeable future**

industrial development

- The public lighting system in the urban areas is also likely to develop further due to increased demand for energy.
- The increase in the number of urban households has, therefore, a close relationship with the increase in energy demand relating to other sectors.
- As such, a. similar model has been adopted for projecting the energy demand is these sectors separately.

$$\log Y = a + b \log X$$

Y =Energy consumption

a and b=Constants to be determined by **Regression Analysis**

X=Number of urban households

2.a

1.8 Enterprise Resources Planning

Integrated information system ⇒ Smooth operation of system

\+

various resources

(Man, material, machine….)

⇓

Efficient and dynamic organization

- Integration of functional and geographically dispersed regions/sub-stations through cross-functional, process-oriented and virtually integrated enterprise.
- All location ⇔ ERP data centre (Gurgon and Yelahanka)
- Connectivity is given by telecom department
- Currently 43 locations are connected

2.b

2.4 Forecasting Techniques

- Involves good judgment and sound knowledge of data manipulations as techniques are getting more complex
- **time series analysis** : yields **trends in cyclic, seasonal, irregular variation**
- **Moving average :**
  - **arithmetic or weighted average** of a no. of points of the series
  - A minimum of **two years** of past energy consumption is desirable, if seasonal effects are present.
  - more the **history**, the better
- **Trend projections :**
  - A **trend line is fitted** into the **mathematical equation**
  - it is projected into the future **using the equation**
  - study of the past behavior and mathematical modeling & **extrapolation of the future behavior**

2.4 Forecasting Techniques

- **Trend projections : Two general approaches :**

  1. Regression analysis :

  - **Fitting of continuous math functions** through actual data to achieve least overall error

  2.Fitting of a sequence on discontinuous lines / curves

  - Prevalent in **short term forecasting**

- **Power system load can be broken down :**
  - (i) **Basic trend**
  - (ii) **Seasonal variation**
  - (iii) **Cyclic variation** :longer than the above

causes the load pattern to be repeated (2/3 yrs)

  - (iv) **Random variations** :day-to-day changes
    - time of the week-(weekend, week day)

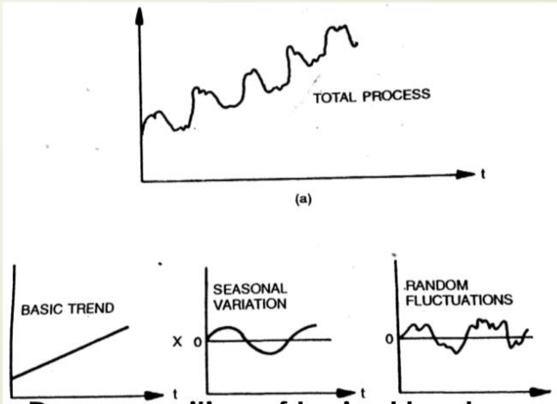
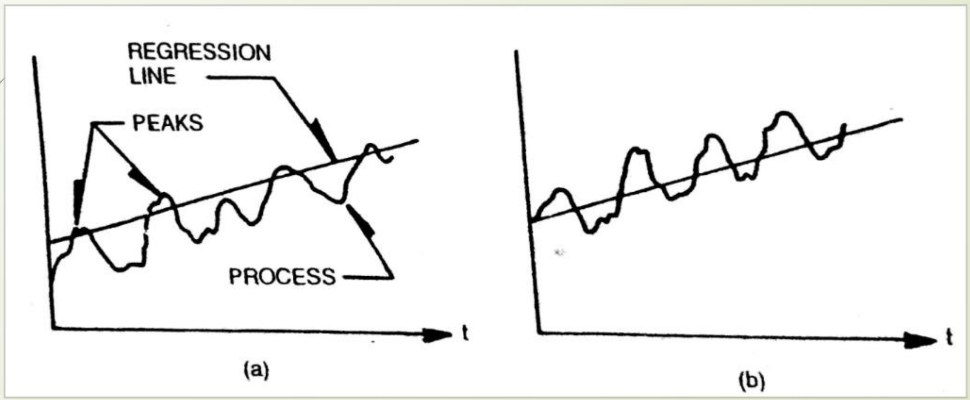


fig: Decomposition of typical load growth curve



3.a

3.4 Private Participation

- Private power projects are important as a part of the **country's investment resources**
- Under the Indian Electricity (Supply) Act, the private sector generating companies, transmission or distribution companies are encouraged **to participate in power sector**.
- Another **advantage** of private' sector participation
  - **new work** and management skills
  - **timely execution** of the project
  - **quality** in work and service

Table 3.1 *Financial parameters*

S.No.	Item	Unit	Value
1	Debt: % of capital cost	%	70
2	Equity: % of capital cost	%	30
3	Working capital: % of capital cost	%	6
4	Interest on debt	%	11.5
5	Return on equity	%	15.5
6	Interest on working capital	%	12.25
7	Discount rate	%	9.0
8	O&M charges: power plant	%	2.5
9	O&M charges: transmission line	%	1.5
10	Depreciation: power plant	%	5.28 for 12 years

interest(%) during construction is $= \dfrac{C*R*N}{2*12*100}$

where, C= Cost of project in Rs.
R = Rate of interest
N = Construction and commissioning period in months.

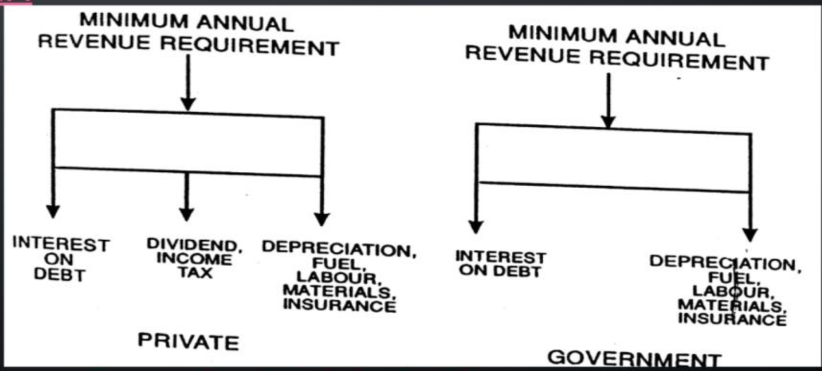
OWNERSHIP:

- **Power utilities** have a **natural monopoly**.
- The efforts are to **remove this monopoly** by creating **supply market** as in **UK** , **USA**, **Argentina**, **Australia.**
- The **consumers** will be **free to choose their suppliers**.
- **Rapid decision**-making, **risk-taking** and **innovation** are needed.
- **these qualities** are usually **lacking in state-owned undertakings.**
- **Privatization** will **restructure** the electricity **supply industry** in the near future.
- It will **break up vertically integrated monopolies** in search **of lower costs** and **higher productivities.**

- **OWNERSHIP:**

- The public sector and private sector power utilities have different financial structures
- Various private sector options
- turnkey contract, BOOT, BOO, BOL, ROL etc.
- BOO (**Build-own-operate**)
- BOOT (**Build-own-operate-transfer**)
- ROL (**Rehabilitate-operate-lease**) are common for old plants
- BOM (**Build-own-maintenance**) for new transmission lines.

- **OWNERSHIP:**
-



- **Fig: showing the finance structure of private & public utilities.**

- **OWNERSHIP:**
-

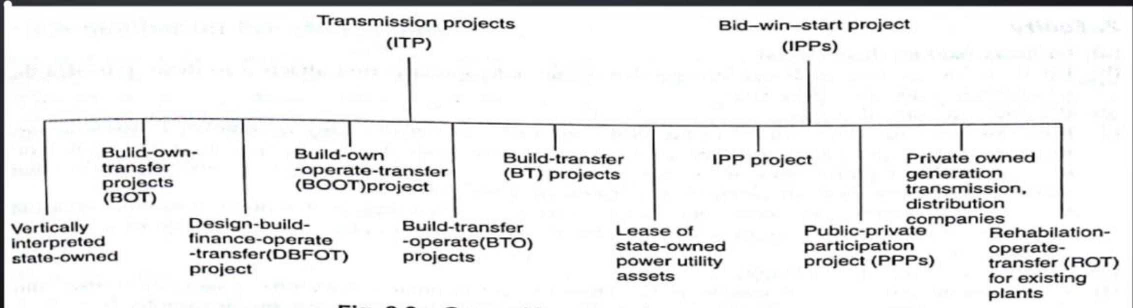


Fig. 3.3 *Ownership options for power utility*

- **Fig: ownership options of power utility**

- **Incentives given by the government to private investment are:**

1. Private sector units **can set up coal/lignite/oil/gas-based thermal**, hydel, wind and solar energy projects of **any size.**

2. a)Private enterprises **can set up units**, either as **licensees**

   distributing power in a **licensed area**

   own generation or **purchased power**

   b)as **generating companies**, generating **power for supply to the grid**.

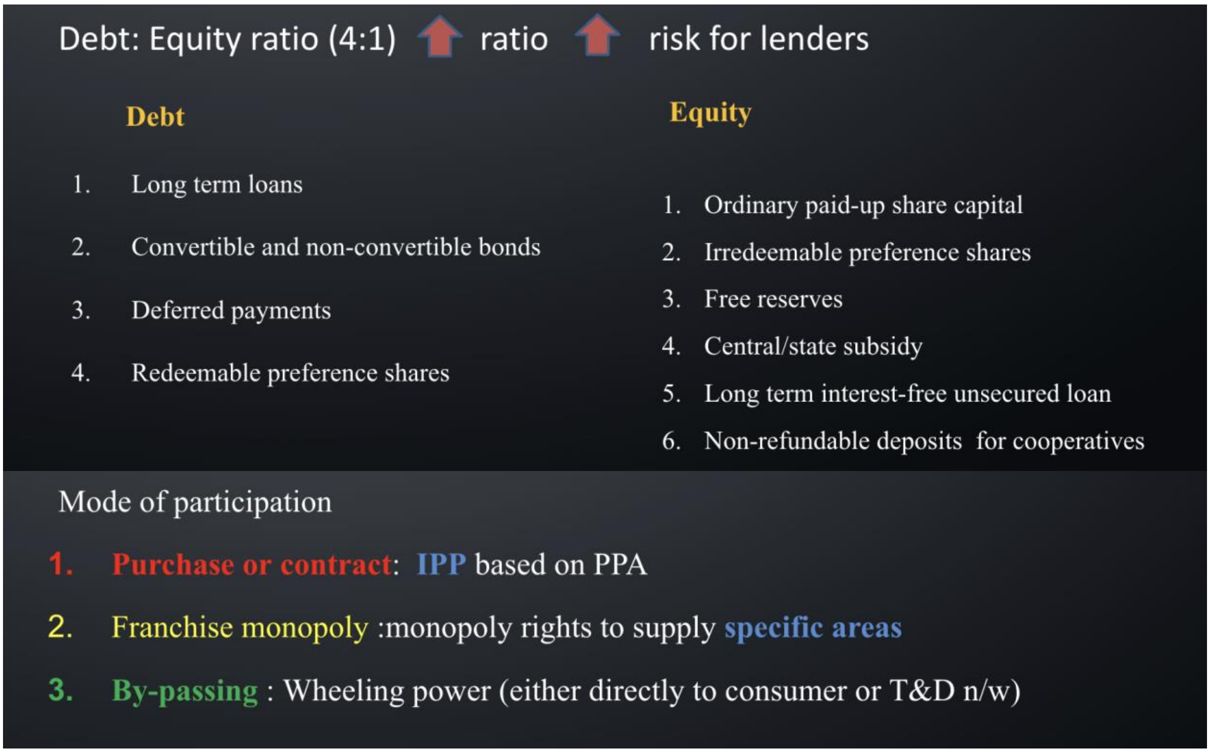
3. **Captive power plants** may be allowed to set up, they can **sell or distribute power** to state power utilities

4 .Both **licensees** and **generating companies** can **enjoy** the following **Benefits**:

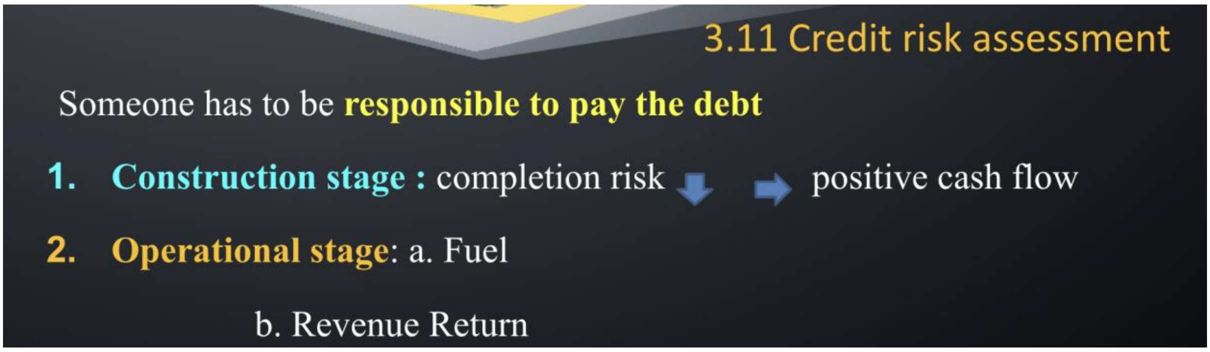
(i) Up to **100% foreign equity participation** can be **permitted for projects** set up by **foreign private investors**.

(ii) With the **approval of the government**, import of equipment for power project will be permitted.

(iii) Approved return


Debt: Equity ratio (4:1) ratio risk for lenders
Debt
1. Long term loans
2. Convertible and non-convertible bonds
3. Deferred payments
4. Redeemable preference shares
Equity
1. Ordinary paid-up share capital
2. Irredeemable preference shares
3. Free reserves
4. Central/state subsidy
5. Long term interest-free unsecured loan
6. Non-refundable deposits for cooperatives
Mode of participation
1. Purchase or contract: IPP based on PPA
2. Franchise monopoly :monopoly rights to supply specific areas
3. By-passing : Wheeling power (either directly to consumer or T&D n/w)

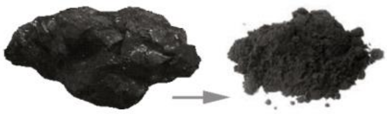
3.b


3.11 Credit risk assessment
Someone has to be responsible to pay the debt
1. Construction stage : completion risk positive cash flow
2. Operational stage: a. Fuel
b. Revenue Return

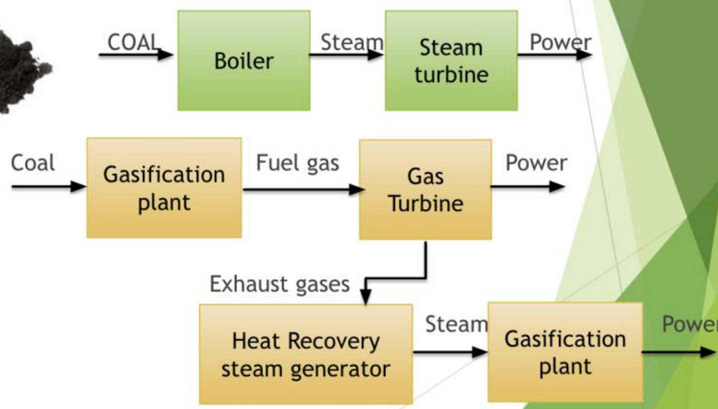
4.a

4.5 Clean coal technologies

1. Pulverized coal



2. IGCC system : 2 staged

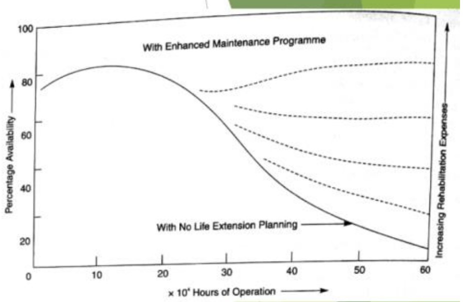


- CFBC: Clean filtering technology + boiler(400 MWe) ⇒ burn low grade fuels
- Developed by BHEL
- Advantages

1. High combustion efficiency : turbulence and residence time
2. Low Nox emission: low combustion temp. and air staging
3. Low SO2 emissions: due to use of limestone ⇒ low combustion temp.
4. Ability to burn low grade fuel: high thermal inertia of bed
5. Fuel flexibility : combustion temperatures(800-850 ℃)

4.b

5.3 Renovation and modernization of power plants



- Ageing → output ↓ + ↑ tendency to breakdown
- ↑ maintenance and repair cost

Residual life assessment(RLA) :

- Diagnostic tests : Non contact partial discharge , oil testing.
- Cost of renovation is 1/3 the cost of setting of new plant

Renovation and modernization (R&M) of thermal power plants are essential to improve their efficiency, reduce emissions, and extend their operational life. This process requires thorough assessment studies to identify areas for improvement and to ensure that the renovation is both technically feasible and economically viable. Here’s a breakdown of the key assessment studies typically required:

Condition Assessment Study

Objective: To evaluate the current condition of the plant's equipment and systems.

Scope: Includes detailed inspection and testing of major components such as boilers, turbines, generators, transformers, and cooling towers. It also involves assessing auxiliary systems like fuel handling, water treatment, and ash disposal systems.

Outcome: Identifies wear and tear, corrosion, erosion, or any other forms of degradation, helping in determining the parts that need replacement, repair, or upgrades.

Performance Assessment Study

Objective: To analyze the operational performance of the plant.

Scope: Involves evaluating the efficiency of key components, heat rate, plant load factor, and emission levels. Performance data is collected over a period to understand operational inconsistencies or deviations from design parameters.

Outcome: Helps in identifying inefficiencies and operational bottlenecks, providing a basis for performance improvement measures.

Environmental Impact Assessment (EIA)

Objective: To assess the environmental implications of the existing plant and the proposed renovation activities.

Scope: Includes an analysis of emissions (such as NOx, SOx, particulate matter, and CO_2), water usage, wastewater discharge, and solid waste management. The study should also consider the impact on local flora, fauna, and communities.

Outcome: Ensures that the renovation complies with environmental regulations and identifies opportunities to minimize the environmental footprint of the plant.

Energy Audit

Objective: To assess the energy consumption patterns and identify opportunities for energy savings.

Scope: Involves a detailed analysis of energy input vs. output, heat losses, auxiliary power consumption, and efficiency of various plant subsystems.

Outcome: Provides recommendations for energy-saving measures, which can include upgrading to more efficient equipment or optimizing operational practices.

Feasibility Study

Objective: To evaluate the technical and economic feasibility of proposed R&M activities.

Scope: Involves a cost-benefit analysis of different renovation options, considering factors such as capital costs, operational savings, downtime, and return on investment. Technical feasibility assessments may also include potential upgrades to control systems, automation, and monitoring equipment.

Outcome: Helps in selecting the most viable renovation options that offer the best balance between cost and benefit.

Risk Assessment and Safety Study

Objective: To identify and mitigate potential risks associated with renovation activities.

Scope: Includes an evaluation of potential safety hazards, the impact of renovation on plant operations, and contingency planning for unexpected failures or accidents.

Outcome: Ensures that the renovation process is safe for workers and minimizes the risk of operational disruptions.

Residual Life Assessment (RLA)

Objective: To estimate the remaining useful life of critical components and systems.

Scope: Focuses on materials testing and non-destructive testing (NDT) techniques to assess the structural integrity of components under current and expected future operating conditions.

Outcome: Provides an estimate of how long the existing components can continue to operate safely and reliably, guiding decisions on repairs and replacements.

Technology Assessment

Objective: To explore new technologies that can be integrated into the plant during the renovation.

Scope: Reviews available technologies in areas such as emission control, fuel efficiency, automation, and digitalization.

Outcome: Identifies potential technological upgrades that could enhance plant performance and align with future regulatory requirements.

Financial Assessment

Objective: To evaluate the financial implications of the R&M activities.

Scope: Includes analysis of funding requirements, potential financing options, payback periods, and financial risk assessment.

Outcome: Ensures that the R&M plan is financially viable and sustainable.

Regulatory and Compliance Assessment

Objective: To ensure that the renovated plant will comply with all relevant regulations and standards.

Scope: Involves reviewing current and anticipated regulatory requirements related to emissions, safety, water use, waste management, and other aspects.

Outcome: Ensures compliance with legal and regulatory frameworks, avoiding potential fines or operational restrictions.

Each of these assessment studies plays a critical role in the renovation and modernization of thermal power plants, ensuring that the process is effective, sustainable, and aligned with future energy needs and environmental standards.

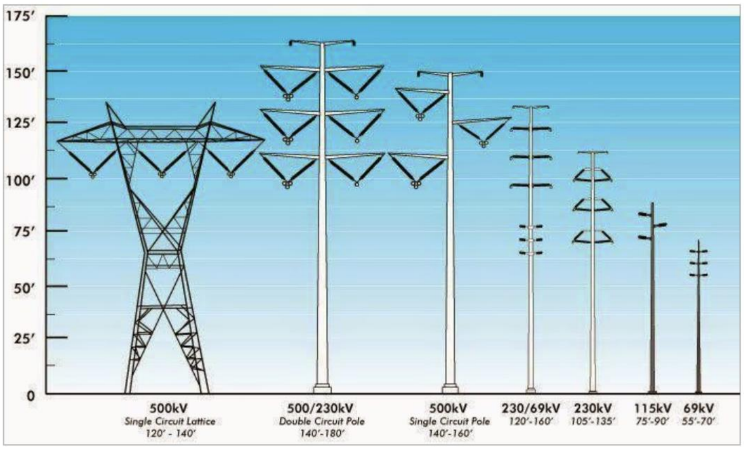
5.a

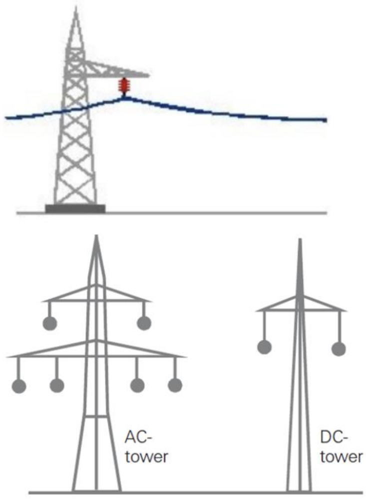
6.1 TRANSMISSION PLANNING CRITERIA

1. **N-2** criteria is adapted – **large generating** complex
- **N-1** criteria is adapted **– regional** planning

2. **Adequacy** of transmission system
- to check max burden – summer, winter and monsoon peak and off-peak load
- Inter-regional import/ export
- To operate **with / without load shedding** but with/without **rescheduling of generation**

6.1 TRANSMISSION PLANNING CRITERIA





6.1 TRANSMISSION PLANNING CRITERIA

Operation

1. Normal operation (components and parameters)
2. Grid subjected to disturbances(single contingency-- after loss of element)➡should restore to normal parameters
3. Second contingency (less probable) – back to normal limits load shedding /rescheduling of gen. . Restoration should be done within 1.5 hrs .

Steady-state stability

1. Withstand events and restore to normal without rescheduling
2. Size and no. of transformers selected ➡ outage of single unit , remaining transformers should supply 80% of load

Dispatch ability

1. Regional self sufficiency
2. Power angle separation $\leq 40^0$ b/w two buses
3. Withstand events(two ckts of 220kV/ 1 440kV/ 1 pole of HVDC bipolar) and restore to normal without load shedding
4. Evacuation of max possible o/p from gen. stations
5. Reactive compensation

5.b

6.4 HIGH VOLTAGE TRANSMISSION

3. **HVDC transmission**

a. **Mismatch** in 5 regions

b. **Disturbances** can be transmitted and may become severe

c. **National spinning reserve**

d. Reduce effect of **unavoidable grid collapse**

Advantages of DC

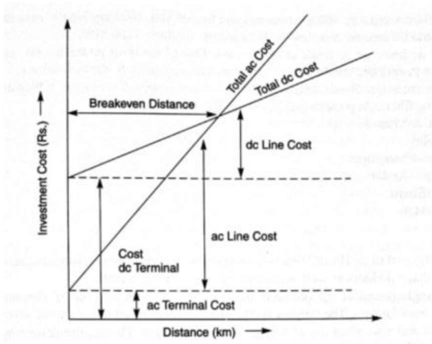
a. Right of way : HVDC is 50-60% of that of AC

b. Connect asynchronous regions

c. High transient stability

6.4 HIGH VOLTAGE TRANSMISSION

Reasons in favour with HVDC



1. Lower line costs
2. Lower losses
3. Asynchronous connection
4. Controllability
5. Less cable cost, better conductor utilization
6. Backbone system : three cases
7. Costs
8. Longlines
9. Long cables
10. Submarine cables
11. Latest technology

6. a) Explain Grid Formation and compare existing grid and Smart Grid
Grid Formation:
A grid in the context of electrical power systems refers to the interconnected network of power lines, substations, transformers, and other components that deliver electricity from power plants to consumers. The formation of a grid typically involves three main stages:
1. Generation:Power is generated at power plants using various sources such as fossil fuels, nuclear, hydro, wind, and solar energy.
2. Transmission: High-voltage transmission lines carry the electricity over long distances from power plants to substations. Transmission is necessary because higher voltage reduces energy loss over long distances
3. Distribution: From substations, the voltage is reduced using transformers, and electricity is delivered to homes, businesses, and industries through distribution lines.
Comparison Between Existing Grid and Smart Grid
1. Technology and Infrastructure:
Existing Grid: The traditional grid is primarily composed of analog technology and mechanical systems. It relies on a one-way flow of electricity from power plants to consumers, and it has limited communication and automation capabilities.
Smart Grid: The smart grid integrates digital technology, sensors, communication networks, and advanced software to create a more dynamic and responsive electricity network. It supports two-way communication between the utility and its customers, allowing for real-time monitoring and control.
2. Efficiency
- Existing Grid: Efficiency is lower due to energy losses in transmission and distribution, lack of real-time monitoring, and limited ability to respond to demand fluctuations.
- Smart Grid: Smart grids are more efficient, as they enable real-time data collection and analysis, which helps optimize energy usage, reduce losses, and improve load management. They also allow for demand-side management, where consumers can adjust their usage based on grid conditions.
3. Reliability and Resilience:
Existing Grid: The traditional grid is vulnerable to outages, especially during extreme weather events or equipment failures. Detection of issues is often slow, and restoration can take time.
Smart Grid: Smart grids improve reliability by quickly identifying and isolating faults, rerouting power, and restoring service more rapidly. They also incorporate distributed energy resources (DERs) like solar panels and batteries, which can provide backup power during outages.
4. Integration of Renewable Energy:
Existing Grid: Integrating renewable energy sources like solar and wind is challenging due to their intermittent nature and the grid’s limited capacity to handle variable power inputs.
Smart Grid: Smart grids are designed to integrate a higher proportion of renewable energy. They use advanced forecasting, storage systems, and demand response strategies to balance the variability of renewable sources.
5Consumer Involvement:
Existing Grid: Consumers are passive participants with little control over their energy use or insight into their consumption patterns.
Smart Grid: Smart grids empower consumers by providing them with real-time information about their energy use. Consumers can participate in demand response

programs, adjust their usage during peak times, and even sell excess energy back to the grid if they have renewable energy systems.

6. Security:

Existing Grid: The traditional grid has limited cybersecurity measures, which makes it vulnerable to physical and cyber attacks.

Smart Grid: Smart grids incorporate advanced cybersecurity protocols to protect against both physical and cyber threats. However, the increased connectivity and complexity also introduce new vulnerabilities.

7. Cost:

Existing Grid: Lower upfront costs for infrastructure, but potentially higher operational costs due to inefficiencies and outages.

Smart Grid: Higher initial investment required for advanced technology, but lower operational costs over time due to improved efficiency, reliability, and integration of renewables.

6b)

5.6 Sub-Stations

General factors to be considered for planning are the following:

1. Historical data of worst floods are taken into account to avoid water logging of the sub-station in case of possibility of flood. Flood plains and wetlands are avoided.
2. Atmospheric conditions like salt and suspended chemical contaminants influence selection of equipment and maintenance requirements.
3. Interference with communication signals. The construction company has to take permission from the appropriate authority.
4. Electric and magnetic field strengths are of particular concern, especially for Ultra High-Voltage (UHV) systems at 765 kV, 1200 kV, or above. Research organisations have shown the impact of strong electric/magnetic fields due to UHV sub-stations and lines on human health. Such new concerns are also required to be addressed properly.
5. To comply for approval of forest land and wildlife sanctuary. The usual process takes time to get approval from concerned authorities. This process delays the construction activities.

   The following criteria can be adopted:

   (a) The capacity of any single sub-station at different voltage levels shall not normally exceed
      - 765 kV,3000 MVA
      - 400 kV, 1000 MVA
      - 220 kV, 320 MVA
      - 110 kV, 150 MVA

   (b) The size and number of interconnecting transformers (ICTs) shall be planned in such a way that the outage of any single unit would not overload the remaining ICTs or the underlying system.

   (c) The size and number of EHT/HT transformers shall be planned in such a way that in the event of outage of any single unit, the remaining EHT/HT transformers would still supply 80% of the load.

Figure 5.6 is a schematic of a sub-station. A sub-station model describes primary equipment models and their connection relationship. An intelligent sub-station is based on IEC 61850 communication protocol;the dispatching automation system can convert the data model based on IEC 61850 in a sub-station to the CIM data model based on IEC 61970 in the dispatching control centre (master station) through the function of model transformation. The main objective is to enable inter operability between Intelligent Electronic Devices (IED) from different manufacturers to exchange engineering information. IEC 61850 for a sub-station is mainly for communication between the bay level and the station level (protection relays, local

6 c)

5.5.2 High-Rating Conductors

Use of High-Performance Conductors (HTLS: High-Temperature Low Sag) needs to be taken up to increase power-transfer intensity. High-rating, low-loss conductors are increasingly being used for efficiency and reduce the right-of-way problems. Demand for power continues to increase at an alarming rate, forcing utilities to put greater and greater electrical loads on their existing lines. However, most existing transmission circuits have been designed for operation at or below 93°C. ACSR, the most commonly used conductor, cannot handle the higher temperatures resulting from increased current loads. Additional transmission lines are not a cost-effective alternative. With the increasing de-regulation pressures, rising construction costs, and right-of-way scarcity, another option is needed. High-operating-temperature conductors(e.g., ACCC, ACSS, ACCR) allow simple replacement on existing structures. These conductors are designed to increase clearance, i.e., less sag at high temperature. The conductors are the following:

1. ACCC (Aluminium Composite Core Conductor)

Due to the composite core, its weight is decreased as compared to steel. The core consists of hybrid carbon and glass-fibre composite core;the rated continuous temperature is 180°C and operates at significantly cooler temperatures than round conductors of similar diameter and weight under equal load conditions due to its increased aluminium content and the higher conductivity. It is the most economical conductor based on lifecycle costs.

This conductor can be used to augment the capacity of existing overload transmission lines. The ACCC is a high-capacity, low-line-loss, environment-friendly overhead conductor. It is a lightweight, high-strength, low-loss, small-sag, high-operating-temperature, corrosion resistant, and anti-aging conductor, compared to conventional Aluminium Conductors Steel-Reinforced (ACSR). High capacity means saving of the aluminium conductor. Annealed aluminium strand wires can improve the electrical conductivity of 3%, and reduce power consumption of the conductor. For capacity expansion of old lines and power stations, changing the wire to ACCC but not changing the tower have more advantages[9].

Torrent Power Ltd has energised the first ACCC conductor transmission line installed in India. The ACCC 318mm^2 Lisbon size conductor was installed to double the capacity of an existing 132 kV transmission line between two sub-stations in Ahmedabad, one of the major cities in the western part of India, in the state of Gujarat. The conductor was delivered by Sterlite Technologies Ltd.

2. ACSS (Aluminium Conductor Steel Supported) and ACSS/TW(Aluminium Conductor Steel-Supported Stranded Wire)

In response to this need, ACSS and ACSS/TW conductors were developed. These conductors allow utilities to increase the amount of current up to 40%. Instead of building new transmission lines, new ACSS and ACSS/TW conductors can replace existing ACSR conductors, thus allowing utilities to increase energy output.

3. ACCR (Aluminium Conductor Composite Reinforced)

This is an all-aluminium-based conductor designed as a drop-in replacement for ACSR. Its properties enable transmission capacity, increased to twice as much or more, on existing structures, while matching or improving tension and clearances. The round-wire or trap-wire construction is composed of a multi-strand aluminium matrix core surrounded by aluminium-zirconium outer wires.

7 a)

6.2 Planning Principles

The following are the basic principles of distribution planning:

1. It is more economical to transport power at high voltage. The higher the voltage, the lower the cost/kW to transport power to a distant point. Transformers change the voltage level of the power.
2. Electricity travels as per Kirchhoff's current and voltage laws.
3. Electricity follows the least resistance/impedance path in the network.
4. Every network has two basic ingredients—nodes and connections.
5. Power must be delivered in relatively small quantities at service voltages, e.g., 400/230 V level. In urban areas, generally, three-phase, 11/0.415 kV; and in rural areas, generally, three-phase, 11/0.433 kV are used. The latter choice is due to increased LV line length in rural areas where LV distribution is used. However, in case of high-voltage distribution, the size of the transformer is kept as three-phase 11/0.415 kV.
6. Voltage drop occurs from the source point to other locations.
7. In a power grid, electricity moves by displacement.
8. *Line losses*: The farther power is been transported, the more of it is lost as heat.
9. Losses in power are incurred, creating a cost.
10. The equipment and labour have cost.
11. Operation and maintenance of service incur cost.
12. Future load growth during horizon years is accounted for.
13. When power is used for any purpose by the consumer, the responsibility lies on the consumer to share the degradation of environment on this account.
14. Nominal rated system voltage is the most efficient voltage for equipment operation. A rise above this voltage tends to reduce the power factor of equipment.
15. Demand response management is a step towards economy and supplying power at low cost to consumers.
16. *Electricity market*: Wholesale, select retail, and bilateral contracts will cut down the cost of supply if adequate power surplus and grid links are available.

7 b)

6.6 Basic Network [10]

1. *Sub-transmission circuits* in voltage ratings usually between 33 kV and 220 kV deliver energy to distribution sub-stations.
2. The *distribution sub-stations* convert the energy to lower primary system voltage for local distribution and usually improve facilities for voltage regulation of the primary voltage.
3. *Primary circuits of feeders,* usually operating in the range of 11 kV to 22 kV, supply the load in well-defined geographical areas.
4. *Secondary circuits* of 240/415 V at utilisation voltage carry energy from the distribution transformer along the street, etc.
5. *Service lines* deliver the energy from secondary circuits to the consumer premises by service lines at 400/230 V.

The six basic distribution systems used by utilities are shown in Fig. 6.1.

1. Radial

A radial system is connected to only one source of supply [see Fig. 6.1(a)]. It is exposed to many interruption possibilities. The most important are those due to overhead lines, underground cable failure, or transformer failure. Each may even be accompanied by a long interruption. It has lower reliability. Both components (feeder and transformer) have finite failure rates and such interruptions are expected and statistically predictable. Feeder breaker reclosing or temporary faults are likely to affect sensitive loads. This system is suitable for small loads.

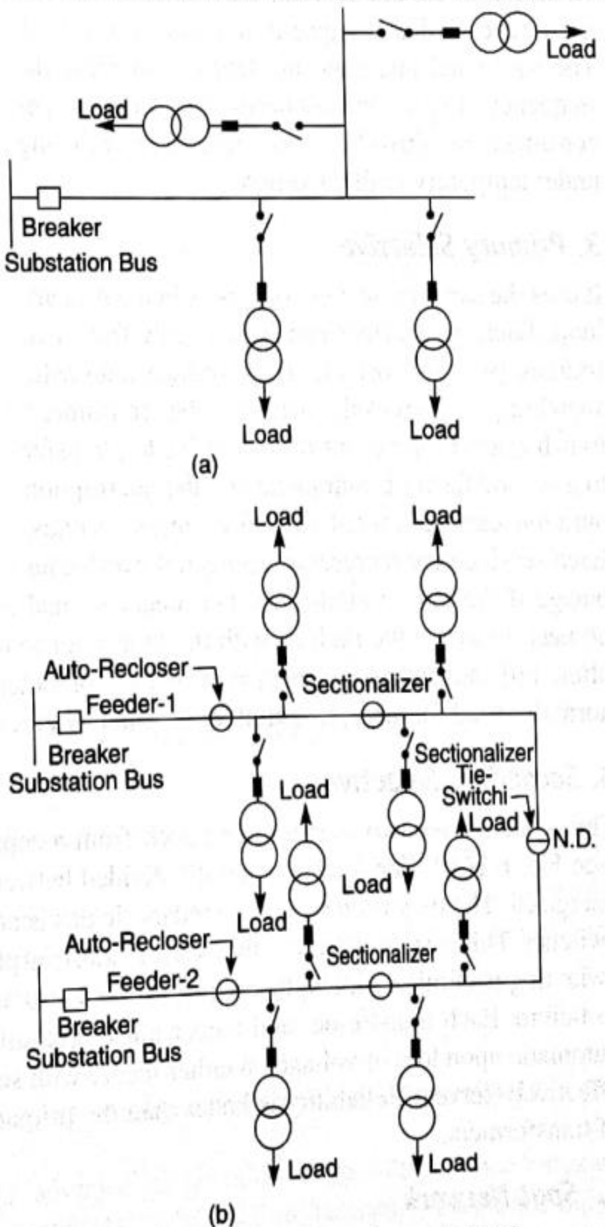


Fig. 6.1 *Basic distribution systems (contd.)*

2. Primary Loop

A great improvement over a radial system is obtained by arranging a primary loop, which provides power from two feeders [see Fig. 6.1(b)]. Power flow to the consumer is by way of single path at any one time from either side of loop depending upon the open/close status of sectionalisers and reclosers. The loop is normally operated with the tie sectionaliser switch open. Any section of the feeder can be isolated without interruption and primary faults are reduced in duration to the time required to locate a fault and do the necessary switching to restore service. Each line of the loop must have sufficient capacity to carry all the load. The additional line exposure tends to increase the frequency of faults, but not necessarily the faults per consumer. Sensitive loads are affected by reclosing under temporary fault conditions.

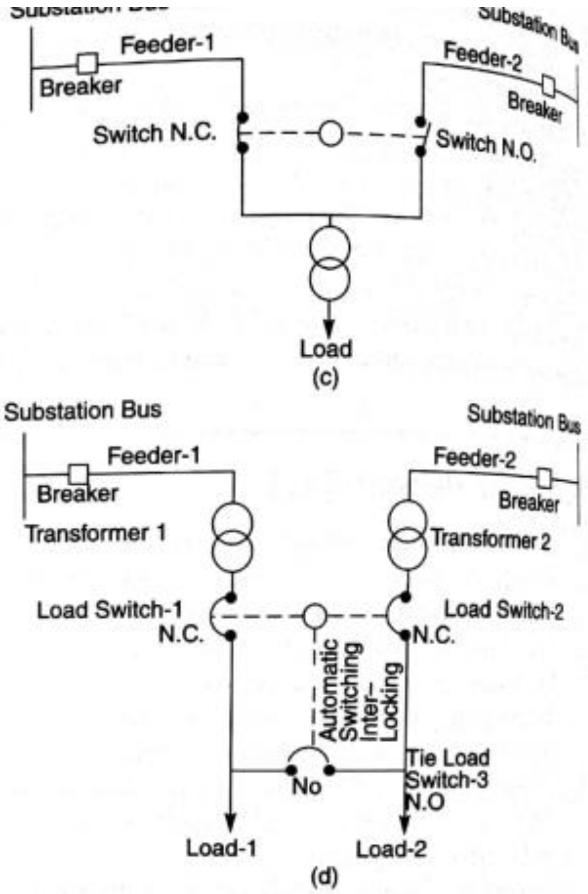


Fig. 6.1 *Basic distribution systems (contd.)*

3. Primary Selective

It uses the same basic components as in the primary loop. Each transformer can have supply from two sources [see Fig. 6.1(c)]. High-voltage automatic switching is provided ahead of the consumer's transformer. In the event of loss of feeder, transfer to a second feeder is automatic and the interruption duration can be limited to two or three seconds. Each service now represents a potential two-feeder outage if the open switch fails, but, under normal contingencies, service restoration is rapid and there is no need to locate the fault as with the loop prior to doing the switching system. Reliability is high. It also offers little advantage to sensitive loads like computer problems caused by temporary faults. This scheme is normally used for large, essential, or continuous-process industrial consumers.

4. Secondary Selective

This system uses two transformers, each from a separate primary feeder and with low-voltage switching [see Fig. 6.1(d)]. The load is generally divided between two LT buses with both transformers continuously energised. The tie switch on the secondary tie bus is normally open and is interlocked with secondary feeder switches. This system is commonly used for industrial plants and institutions like hospitals. Primary operational switching is eliminated. Duplicate transformers virtually eliminate the possibility of a long interruption due to failure. Each transformer and feeder must have sufficient capacity to supply the entire load. Transfer is automatic upon loss of voltage on either feeder with static switching equipment. Sensitive equipment can be effectively served. Reliability is better than the primary selective system because of additional redundancy of transformers.

8 a)

5.1 Transmission Planning Criteria [10]

1. In the national approach, $N-2$ criteria may be adopted for a large generating complex (3000 MW or above) and multi-line corridors (3 double-circuit lines or more)on a case-to-case basis,whereas, regional planning may be continued with $N-1$ criteria. However, while $N-1$ would be applied to test withstand without necessitating load shedding or rescheduling of generation during steady-state operation, $N-2$ would be applied to test withstand without necessitating load shedding but with rescheduling of generation during steady-state operation.
2. The adequacy of the transmission system should be tested for different load-generation scenarios corresponding to one or more of the following so as to test the scenario of maximum burden on the transmission system:
   (a) Summer peak load
   (b) Summer off-peak load
   (c) Winter peak load
   (d) Winter off-peak load
   (e) Monsoon peak load
   (f) Monsoon off-peak load

Dispatch scenarios for maximising transfer in specific inter-regional corridors should be considered to determine the adequacy of a transmission system to take care of the requirement of regional diversity in inter-regional export/import. As a general rule, the Inter-State Transmission System (ISTS) shall be capable of withstanding and be secure against the following contingency outages:

((a) Withstand without necessitating load shedding or rescheduling of generation during steady-state operation:

i. Outage of a 132kV D/C line, or
ii. Outage of a 220kV D/C line, or
iii. Outage of a 400kV S/C line, or
iv. Outage of a 400kV S/C line with series compensation, or
v. Outage of single interconnecting transformer, or
vi. Outage of one pole of HVDC bipole line, or
vii. Outage of a 765kV S/C line without series compensation

((b) Withstand without necessitating load shedding but with rescheduling of generation during steady-state operation:

i. Outage of a 400kV S/C line with TCSC, or
ii. Outage of a 400kV D/C line, or
iii. Outage of both poles of HVDC bipole line, or
iv. Outage of a 765kV S/C line with series compensation.

The above contingencies shall be considered assuming a pre-contingency system depletion (planned outage) of another 220kV D/C line or a 400kV S/C line in another corridor and not emanating from the same sub-station. All the generating units may operate within their reactive capability curves and the network voltage profile shall also be maintained within voltage limits specified.

The capacity of any single sub-station at different voltage levels shall not normally exceed:

(a) 765 kV,9000 MVA
(b) 400 kV,2000 MVA
(c) 220 kV,500 MVA
(d) 132 kV,250 MVA
(e) 110 KV, 150 MVA

The size and number of interconnecting transformers (ICTs) shall be planned in such a way that the outage of any single unit would not overload the remaining ICTs or the underlying system. The size and number of EHT/HT transformers shall be planned in such a way that in the event of outage of any single unit, the remaining EHT/HT transformers would still supply 80% of the load.

5.1.1 Operation

1. In normal operation (N-0) of the grid, with all elements to be available in service in the time horizon of study, it is required that all the system parameters like voltages, loadings, and frequency should remain within permissible normal limits.
2. The grid may, however, be subjected to disturbances and it is required that after a more probable disturbance, i.e., loss of an element ($N-1$ or single-contingency condition), all the system parameters like voltages, loadings, and frequency shall be within permissible normal limits.
3. However, after suffering one contingency, the grid is still vulnerable to experience a second contingency, though less probable ($N-1-1$), where in some of the equipment may be loaded up to their emergency limits. To bring the system parameters back within their normal limits, load shedding/re-scheduling of generation may have to be applied either manually or through automatic System Protection Schemes (SPS). Such measures shall generally be applied within one and a half hour(1½) after the disturbance.

5.1.2 Steady-State Stability

The power system is planned to supply all loads during normal conditions and the following contingency conditions without the need for rescheduling of generation and to maintain voltage and line-loading criteria. The transmission system should be capable of withstanding the following events with the voltage across the network maintained within the limits specified:

1. Simultaneous outage of two 220 kV circuits; or
2. Outage of a 400 kV S/C; or
3. Outage of a 765 kV SC; or
4. Outage of one pole of an HVDC bipole; or
5. Outage of one largest generating unit; or
6. One interconnecting transformer outage

Prior to such contingency, all elements shall be considered to be in service.

The size and number of interconnecting transformers shall be planned in such a way that the outage of any single unit would not normally overload the remaining interconnecting transformers. The size and number of **EHT/HT** transformers shall be planned in such a way that in the event of outage of any single unit, the remaining **EHT/HT** transformers would still supply 80% of the load.

5.1.3 Dispatch Ability

1. The transmission system shall be planned on the basis of regional self-sufficiency. Wherever inter-regional power transfers are envisaged, the system shall also be suitable for specific quantum of assistance from neighbouring regions.
2. The maximum power angular separation between any two important buses shall not normally exceed 40° for load flow under steady-state conditions.
3. The transmission system shall be capable of transmitting states' shares from the central sector/common projects.
4. The transmission system shall be planned to withstand outage of two circuits of 220kV system or one circuit of 400 kV ora higher voltage system or one pole of HVDC bipolar or an EHV transformer without necessity of load shedding or rescheduling of generation.
5. The transmission system shall be planned to ensure full evacuation of the maximum possible output from generating stations even under forced outage of a transmission outlet.
6. There shall be sufficient redundancy to ensure that there is no transmission constraint on rescheduling generation under the conditions of outage in any of the generating plants.
7. Reactive compensation shall be provided as far as possible in a lower voltage system with a view to meet the reactive-power requirement-loads close to load points.

8 b)

6.10 System Studies

The system may consist of group of feeders interconnected so that there is always more than one route between any two points in the feeder network. It is designed with sufficient capacity protection throughout. This system gives high level of reliable power to the consumer. The cost is very high as compared to radial systems. Voltage drop, fault behaviour, load-flow studies are somewhat complicated. Now, computer programs are available for carrying out such studies. The proposed system is analysed for meeting the load demand in horizon year so that

1. Voltages are within permissible limits,
2. Adequacy of the system is established,
3. Losses are within limits, and
4. The scheme is financially justified.

Detailed project reports are framed to identify the system strengthening works on long-term and short-term basis:

1. For feeders having poor performance, reconfiguration (bifurcation or trifurcation, etc.) of feeder or augmentation of line conductors and distribution transformers
2. New technology deployment for system improvement
3. Loss-minimisation plan

Demand-management project reports will be undertaken on pay-back to achieve tangible reduction in demand and energy consumption in the planned horizon year.

The initial system improvements can be very cost-effective in removing the above inadequacies as compared to other alternative of laying a new extended system. Thus, there are two options:

1. System improvement, augmentation and strengthening the existing system, improving the reliability and quality of supply, reduction of commercial and technical losses, and/or

2. Expansion of the existing network

The least-cost optimal solution from various alternative schemes may be worked out considering the capital cost of the proposed works and present values of the kW and energy losses over the expected life of equipment in case of expansion of network. When augmentation and strengthening of the existing system is involved, the benefits of saving in losses (kW and energy), net revenue increase due to additional sale of power and energy is calculated after adjusting the expenditure incurred on generation of the additional energy. The net present values of alternate plans are compared to choose the least cost solution. Also, financial analysis of the chosen scheme is done to satisfy the funding organisation.

6.10.1 Automated Planning

Optimisation-based methods contribute to an engineer's understanding of the interplay of costs, standards, performance and their trade-offs. The computer-aided power-flow studies of the existing sub-transmission and distribution system and proposed expansion of network up to the meter point should be carried out to assess the following:

1. Active and reactive power flows
2. Voltage variation (at each node or bus, % variation)
3. Technical peak power loss and average energy loss
4. Computation of commercial loss from feeder or sub-station energy-balance sheets
5. *Inadequacy:* Overloading of transformers and lines
6. Adequacy of new expansion
7. Security and reliability of supply
8. Load-flow analysis for voltage regulation, active and reactive power flows and loss calculations (power and energy)
9. Short-circuit analysis
10. Sub-station sizing and locations
11. Capacitor placement and sizing
12. Network reconfiguration and reinforcement
13. Voltage control through series capacitors and voltage regulators, etc.

6.10.2 Software Needs

Before purchasing any package, its strengths and weaknesses must be ascertained to find its suitability for the job. Load unbalancing, low voltage conditions, 2-phase supply or single-phase supply, and 11 kV supply for agriculture in some states need special consideration in the choice of software. A very impressive computer program, implementing a clever algorithm, will produce nothing of value if built upon a model that is inadequate when measured against the planning requirements. Generally, software is selected on the basis of *least lifecycle cost or least ownership costs (hiring or purchase + training + maintenance costs).* The other points given below can be checked up depending upon the importance attached to each.

1. Best overall performance
2. Best solution

Some of the vendors for distribution system studies software (AM/FM/GIS/Network system analysis) are

1. Electricite de France, Paris (PRAO)
2. Scott and Scott, New Delhi (SYNERGEE)
3. Swed Power Sydkraft International, Malmo, Sweden (SWENET)
4. Milsoft Integrated Solutions Inc., Abilene, Texas
5. Power Technologies South-Asia Pvt. Ltd., New York (PSS/U, NE PLAN)
6. ABB, Bengaluru
7. Trident Technologies Pvt. Ltd., New Delhi (CYME)
8. Global Energy Consulting Engineers Pvt. Ltd., Hyderabad (POWERNET)
9. KLG System Ltd., Gurgaon (SPARD)
10. International Computers, New Delhi (DINIS)
11. Indicos Information Technology (P) Ltd., Mumbai (GIS)
12. Autodesk®, Bengaluru, (GenMap)-AM/FM/GIS
13. KLG System (PSS)
14. Tata Consultancy Services (TCS), GIS, Billing, Metering, ERP
15. WindPRO 2.8: planning and design of windfarm projects
16. PowerWorld Simulator17

6.10.3 Geographical Information System (GIS)

1. Create a digitised background map of the area from Survey of India maps.
2. Carry out GPS survey with a GPS receiver to locate the sub-stations/transformers/poles/consumer points, etc. A GPS receiver figures out the distance to each satellite and uses this information to deduce its own location. A GPS receiver must have a clear line-of-sight to satellites to operate.
3. Attribute data of each pole and other facilities collected during the survey such as asset data, transformer details, cables, line poles, services, type of use, load, consumer details, etc. Draw single-line diagrams.
4. *Preparation of Network in GIS package (AutoCAD map/Map Info/Arcinfo)* Use DGPS (Differential Geographical Positioning System) to fix salient topographical details and handheld GPS (Global Positioning System) to locate network details of the consumer level up to 1-metre resolution.
5. Layers (e.g., using GeoMedia Professional software) of information are contained in these map representations.
   (a) The first layer corresponds to the distribution network coverage.
   (b) The second layer corresponds to the land background containing roads, landmarks, buildings, rivers, railway crossings, etc.
   (c) The next layer could contain equipment information, viz., poles, conductors, transformers, etc.

6.10.4 Network Analysis

The electrical database of the network can be imported (as shown in Fig. 6.4) from the GIS/AM/FM into various analysis runs for carrying out studies:

1. Voltage profile/load-flow analysis
2. Fault-flow analysis
3. Capacitor placement
4. Contingency analysis, etc.
5. For segregating the system losses into technical losses and commercial technical

9 a)

8.1 Demand Response (DR)

DR should be considered one of the resources during the planning stage. Demand Response Planning (DRP) can be defined as a programme established to motivate changes in electric use by end-use consumers in response to changes in the price of electricity over time, or to give incentive payments designed to induce lower electricity use at times of high market prices or when grid reliability is jeopardised (see Fig. 8.1). Regulatory framework also needs to be in place for implementation of demand-response strategies. Consumer awareness and maintaining transparency with them must be a priority to win their confidence and ensure acceptance of the demand-response programmes. The electrical distribution network must be strengthened to ensure reliability in operations. Common examples of demand response include ability of the industry to change their production patterns, without suffering a loss of revenue and jeopardising economy of overall operations, such that the electricity consumption can be reduced during hours of need of the grid. DR can be used to relieve congestion or overload condition on the distribution network. DR can be applied to support consumers fed from a particular distribution node by relieving overload on a feeder of the distribution system without incurring the cost of dispatching a DR event across a whole transmission area. DR is a vital improvement against load-shedding practice adopted currently to reduce the excessive power demand in India.

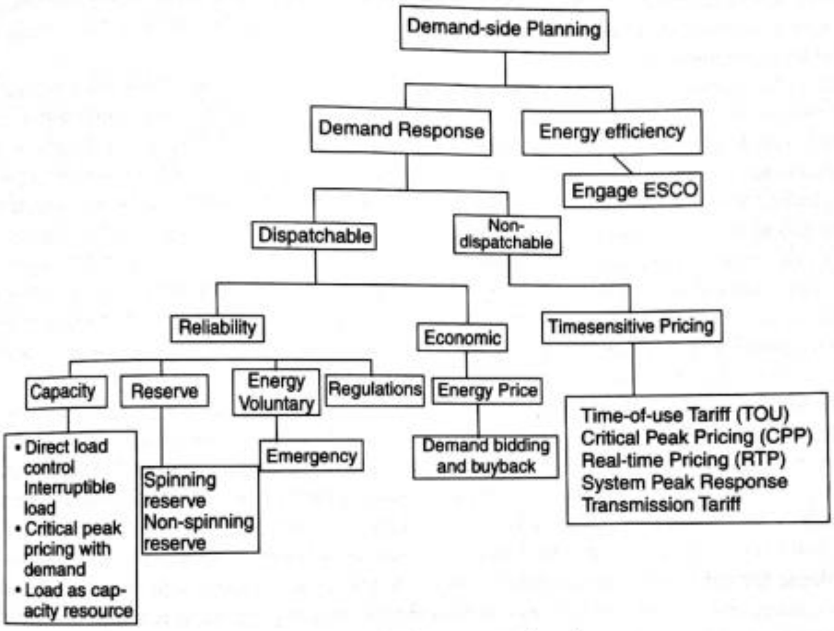


Fig. 8.1 *Demand-response planning*

8.1.1 Demand-Response Categories

1. *Voluntary Demand Response*

Participant consumers are notified of the need for demand curtailment and can select whether or not to curtail without commitment in advance. They must offer in specified curtailment proposals. Once offers are accepted, participants are obligated to curtail demand as proposed.

2. *Contractual Demand Response*

Once participant consumers have qualified for the DR programme, they are obligated to curtail their demand on execution of the trigger signal. Participant consumers receive an availability payment for committed MWs and hours for the DR programme; they must be consuming in order to receive payments.

9 b)

11.1 Market Principles

The principles for the electricity market are the following:

1. The market's mission is growth.
2. Electricity is, by its nature, difficult to store and has to be available on demand. Demand and supply vary continuously.
3. Electricity is a commodity with a highly seasonal, inelastic demand. This, combined with weather-dependent generation and demand, is prone to short-term price volatility.
4. In theory, electricity markets provide generators with incentives to reduce costs and increase productivity and thereby induce expectations of lower electricity prices to consumers. Electricity markets, however, also send strong price signals in times of scarcity. This leads to periods with price peaks and, in situations with abundant supply, very low prices.
5. Electricity does not behave like a normal commodity. If the price of red apples is high, you buy green apples; but what do you do about electricity? You cannot live in society without it. It is essential to everyone's daily life—whether you are at work or at home. There is no substitute for it.
6. Electricity flows from the power plant to the consumer at 200, 000 km/second. Some power plants must constantly change their output.
7. The most fundamental difference [illegible] system that functions much faster than any market, requiring generation (supply) and load (demand) balancing on a second-by-second basis.
8. The power market operates on the basis of long-term, short-term, day-ahead, or intra-day commitments.
9. The main feature of price formation in wholesale spot markets is the instantaneous nature of electricity. The physical laws that determine the power delivery across a grid requires synchronised energy balance between injection of power at generating points and offtake at demand points (plus some allowance for transmission losses).
10. A significant difference between electrical energy and other commodities is that energy produced by one generator in the power system cannot be directed to supply a specific consumer; rather, the energy is pooled.
11. The laws of physics determine how electricity flows through an electricity network. Hence, the extent of electricity lost in transmission and the level of congestion on any particular branch of the network will influence the economic dispatch of the generation units.
12. Markets bring efficiency in usage of transmission capacity by economic dispatch and congestion management.
13. Markets encourage investment signals to investors in generation and transmission.
14. There are daily and weekly cyclical variations in cost and price of electrical energy.
15. Marginal cost varies over the course of the day.
16. Electricity is the only network with prices that change every 15 or 30 minutes.
17. There is often shortage of markets in India. Fixing of trading margins by regulators is generally defined.
18. Peaking power must be made viable by applying time-of-the-day tariffs.
19. There is, therefore, a physical requirement (as per the Electricity Act 2003, sections 26–34) for an independent transmission system operator to coordinate the dispatch of generating units to meet the expected demand of the system across the transmission grid.

10 a)

11.7 Power Markets [14]

11.7.1 Power-Exchange Market

The power-exchange market is a market where buyers, sellers, electricity traders, open-access consumers, and members of power exchange transact on standardised contracts. Here, the power exchange, or clearing corporation, is a counter-party to such contracts and, further, scheduling is done by regional load dispatch centres or the National Load Dispatch Centre. The norms are applicable to all contracts (intraday contract/ contingency, day-ahead contract, term-ahead contract) contract transacted on power exchanges, other exchanges and also bilaterally, that is, Over-The-Counter (OTC) market. The norms require a Clearing Corporation (CC) for setting up a power exchange. There are, at present, three power exchanges approved by CERC as given below:

1. The Indian Energy Exchange (IEX)
2. Power Exchange India Limited (PXIL)
3. National Power Exchange Limited (NPEL)

The Exchange is on the pattern of the National Stock Exchange. This is a company that has entered into a Memorandum of Understanding (MoU) with a number of power producers, who commit the surplus power, and power-deficit entities looking for power. The Act provides that the appropriate commission may fix the trading margin, if considered necessary. The regulator role needs to be largely confined to monitoring to prevent collusion and unfair gaming.

The price in the Day-Ahead Market (DAM) is, in principle, determined by matching offers from generators to bids from consumers/power utilities/exchange members at each node to develop a classic supply and demand equilibrium price, usually on an hourly interval for 24 hours, and is calculated separately for sub-regions in which the grid/system operator's load-flow model indicates that constraints will bind transmission. Exchange members participate in trade, the day before, standard hourly contracts. Hourly contracts provide considerable flexibility by allowing operators to fine-tune over the delivery day (purchase addition or sell excess). Power exchanges have the following characteristics:

1. Standardized contract structure
2. Robust clearing and settlement system
3. Risk management
4. Transparent price-discovery mechanism

Block contracts correspond to the needs of participants who want to buy or sell set volumes of electricity

11.7.2 Wholesale Market-Forward Contracts

The wholesale market is open to anyone who, after securing the necessary contracts with the counter-party willing to buy their output as per contract, can generate power and connect to the grid.

1. *Bilateral Trading (Term-Ahead Market)*

Depending upon the time available and quantities to be traded, buyers and sellers can resort to different forms of bilateral trading based on agreement reached. The bilateral market aims for common price through a negotiated approach and transactions can be on short-, medium-, or long-term contracts.

(a) Customised Long-Term Contracts These usually involve large amounts of power over different periods of days and weeks, generally one to 25 years.

(b) Customised Short-Term Contracts These usually involve power over different periods of days and weeks, 3 months to 1 year period through inter-state trading licensees (only inter-state part), directly by the distribution licensees (distribution companies), through power exchanges, and the Unscheduled Interchange (UI).

2. *Term-Ahead Market (TAM)*

These are the contracts where physical delivery of electricity occurs on a date more than one day ($T + 2$ or more) ahead from the date of transaction (T) and the contracts in such a market can be transacted weekly/monthly/yearly or more in advance.

3. *Trading 'Over The Counter (OTC)'*

These transactions usually involve a small amount of power (hundreds of MW) over long periods of time (several months to several years. Buyers and sellers transact directly or through an electricity trader. The price and terms of the contract are determined through negotiations as agreed between the parties or through a competitive bidding process.

11.7.3 Renewable Energy Certificates (REC) Market

Renewable systems are less prone to large-scale failure [1] and save the environment. The Central Electricity Regulatory Commission (Terms and Conditions for Recognition and Issuance of Renewable Energy Certificate for Renewable Energy Generation) Regulations 2010 introduced the modalities of REC in the Indian electricity sector. The Renewable Energy Certificate (REC) mechanism is a market-based instrument to promote renewable energy and facilitate Renewable Purchase Obligations (RPO).

1. The REC mechanism is aimed at addressing the mismatch between availability of RE resources in the state and the requirement of the obligated entities to meet the renewable purchase obligation (RPO). The renewable energy certificate system contains a supply side (electricity producer) and a demand side (with an obligatory quota for the year) and the data that the energy certificate represents can be sold on by the bearer of the certificate. A production facility can, thus, be paid for both the physical electricity it has generated and the energy certificate that the generation has produced. The total revenue from the renewable energy will be revenues from power plus revenues from energy certificates. RECs are issued to those generators who have generated electricity through renewable sources like solar, wind, biomass, small hydro, municipal solid waste, etc. While these generators receive price for power without any premium towards green source, they receive green premium through RECs. There are two types of RECs available: solar and non-solar. To ensure the RECs are truly reflecting the green or environmental attributes of power, CERC has issued regulations giving how these generators are accredited and registered, and issued certificates.
2. One REC is issued to the RE generators for 1 MWh of electricity injected into the grid from renewable energy sources. RECs are deposited with power exchanges for sale of RPO schemes.
3. The certificate once issued remains valid for three hundred and sixty-five days from the date of its issuance.
4. The REC is issued to RE generators only.
5. The REC could be purchased by the obligated entities to meet their RPO under Section 86 (1) (e) of the Act. Purchase of an REC would be deemed as purchase of RE for RPO compliance.
6. Grid-connected RE technologies approved by MNRE would be eligible under this scheme.
7. RE generations with existing power-purchase agreements on preferential tariffs are not eligible for REC mechanisms.
8. SERC is to recognise REC as a valid instrument for RPO compliance.
9. SERC would define open-access consumers and captive consumers as obligated entities along with distribution companies.
10. SERC is to designate the state agency for accreditation for RPO compliance and REC mechanism at the state level.
11. CERC has designated the National Load Dispatch Centre (NLDC) as the central agency for registration, repository, and other functions for implementation of the REC framework at the national level.
12. Only accredited projects can register for REC at the central agency.
13. The central agency would issue REC to RE generators for specified quantities of electricity injected into the grid.
14. The REC would be exchanged only in the CERC-approved power exchanges.
15. The central agency will extinguish the RECs sold in power exchanges in its records as per information provided by the power exchanges. The certificates will be extinguished by the Central Agency in the 'first-in-first-out' order.
16. The price of electricity components of RE generation would be equivalent to the weighted average power-purchase cost of the power utility including short-term power purchase but excluding renewable power purchase.

11.7.4 Retail Market

A retail electricity (see Section 6.1) market exists when end-use consumers can choose their supplier from competing electricity retailers. A separate issue for electricity markets is whether or not consumers face real-time pricing (prices based on the variable wholesale price) or a price that is set in some other way, such as average annual costs. In many markets, consumers do not pay based on the real-time price, and, hence, have no incentive to reduce demand at times of high (wholesale) prices or to shift their demand to other periods. Demand response may use pricing mechanisms or technical solutions to reduce peak demand.

Generally, electricity retail reform follows from electricity wholesale reform. However, it is possible to have a single electricity-generation company and still have retail competition. If a wholesale price can be established at a node on the transmission grid and the electricity quantities at that node can be reconciled, competition for retail customers within the distribution system beyond the node is possible.

Although market structures vary, there are some common functions that an electricity retailer has to be able to perform, or enter into a contract for, in order to compete effectively. Failure or incompetence in the execution of one or more of the following has led to some dramatic financial disasters:

1. Billing
2. Credit control
3. Consumer management via an efficient call centre
4. Distribution use-of-system contract
5. Reconciliation agreement
6. "Pool" or "spot market" purchase agreement
7. Hedge contracts—contracts for differences to manage "spot-price" risk

Competitive retail needs open access to distribution and transmission wires. This, in turn, requires that prices must be set for both these services. They must also provide appropriate returns to the owners of the wires and encourage efficient location of power plants. Independent companies should provide distribution and transmission services. This solves the cherry-picking problem which is a major concern of distribution utilities selling retail services and the ability to institute cross-subsidies, also a major concern of pure retail companies' schemes using two transportation prices. There are two types of fees, the access fee and the regular fee. The *access fee* covers the cost of having and accessing the network of wires available, or the right to use the existing transmission and distribution network. The *regular fee* reflects the marginal cost of transferring electricity through the existing network of wires.

Electricity consumers have the freedom to choose from a range of electricity contracts, e.g., long-term contracts with a fixed price, or a combination of spot-indexed price. Large consumers can also hedge with financial contracts. In theory, competition in the retail market can motivate low prices as well as the development of products (e.g., different forms of payment conditions, customer services, billing, and product bundles) for all end-users. However, to date, this development has not been realised and the majority of end-users have stayed with their historical supplier.

11.7.6 Generation Capacity Market

The capacity markets are contracts designed to ensure sufficient reliable capacity is available to ensure reliability [6] and security of electricity supply in times of system stress, for example, during a hot summer period. It puts in place contracts to give incentive to the providers of reliable capacity to be available when needed. The Central Government entities' (e.g., NTPC, NHPC, etc.) regional power stations are installed on the basis of common sharing of 85% power in the region. This could include both generation and non-generation forms of capacity such as demand-side response and storage. The power market in India is an "energy-only market". Generators are paid for the electricity they sell and this is arranged via a marginal pricing system. In such a system, all generators receive a price equal to the bid from the most expensive generator that has been activated. The generators are motivated to bid according to their short-term marginal costs, but as a result, all receive a price that is higher (except for the marginal plant—the activated plant that bid in with the highest price). The difference between their bid short-term marginal cost, and the price received contributes to covering fixed costs.

Capacity providers are paid on a kilowatt-per-year basis for the capacity that a power plant can generate or, in the case of demand response, the capacity of power that can be reduced. Consumers receive incentive payments for providing load reductions as substitutes for system capacity.

Demand response providers work with utilities and grid operators to provide a reliable reserve of dispatchable electricity demand reduction that can be added to overall capacity calculations.

Adequate generating capacity must be available so that demand and supply are equated at all times. Otherwise, the stability of the power system can be jeopardised.

Earlier, the electricity-market reform utilities were responsible for ensuring security of supply by providing adequate generating capacity to meet demand. POSOCO has the responsibility of ensuring momentary balance, but the provision of sufficient generating capacity is a function of the market determined through price signals to investors.

10 c)

1. Price-Area Congestion Management

Spot-market bidders must submit separate bids for each price area in which they have generation or load. If no congestion occurs during market settlement, the market will settle at one price, which will be same as if no price area existed. If congestion does occur, price areas are separately settled at prices that satisfy transmission constraints. Areas with excess generation have lower prices, and areas with excess load have higher prices. Since power lines are always needed, if a failure on a line occurs (because of congestion or any other reason), the supply of electricity will be interrupted. The system operator (e.g., POSOCO) identifies the transmission bottlenecks and increases price in deficit areas: increase supply–decrease demand; and deceases price in surplus area: decrease supply–increase demand.

POSOCO will have income (capacity fee) = maximum capacity (P_H–P_L) as shown in Fig. 11.7.

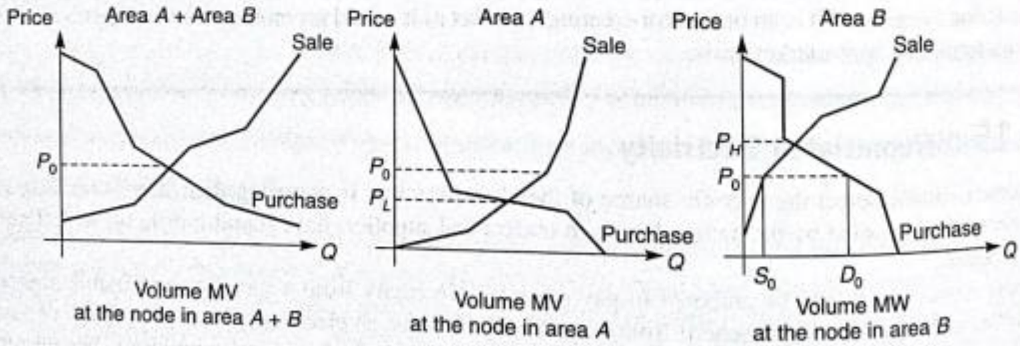


Fig. 11.7 *Market splitting for transmission congestion*

Participants have the incentive to eliminate this fee by investing in transmission capacity. Calculate the unconstrained MCP for the whole market.

2. Available Transfer Capability (ATC) Based Congestion Management

This is particularly used in the US system. The US Federal Energy Regulatory Commission (FERC) established a system where each ISO would be responsible for monitoring its own regional transmission system and calculating the available transfer capability (ATC) for potentially congested transmission paths entering, leaving, and inside its network. ATC is a measure of how much additional electric power can be transferred from the starting point to the end point of a path. The ATC values for the next hour and for each hour in the future are placed on a website known as Open-Access Same-time Information System (OASIS), operated by ISO. Anyone wishing to do transaction would access OASIS Web pages and use ATC information available there to determine if the system could accommodate the transaction.

3. Optimal Power Flow (OPF) Based Congestion Management

Optimisation is performed to minimise generator-operating cost with a set of constraints that represent a model of the transmission system within which the generators operate.

The generators send a cost function and those wishing to purchase load send a bid function to the ISO. The ISO has a complete transmission model and can then do an OPF calculation. The OPF solution gives prices/MW at each node of the system. In some countries, a zonal pricing method is followed in which the system is divided into various zones on geographical basis. The zone prices determined by the OPF are used in the following manner:

(a) Generators are paid the zone price of energy

(b) The loads must pay the zone price for energy.

If there is no congestion, there is one zone price throughout the system, and the generators are paid the same price for their energy as the loads pay. When there is congestion, zone prices differ, each generator is paid its zone's price, and each load pays its zone's price for energy.

Thus, the OPF, through pricing in the zones, performs the function of controlling the transmission flows (that is, maintaining transmission system security).

When transmission capacity is restricted, the spot market must ensure optimal dispatch of power plants. Congestion will result in a price variation, with low prices in the exporting area and higher prices in the importing area.

Congestion management may occur daily. Price differences are more frequent during the day, when demand is higher.