CMR INSTITUTE OF TECHNOLOGY	USN								
Internal Assesment Test - II									
Sub:	Power System Planning							Code:	17EE744
Date:	06/11/2020	Duration:	90 mins	Max Marks:	50	Sem:	7th(A & B)	Branch:	EEE
Answer Any FIVE FULL Questions									

		Marks	OBE	
			CO	RBT
1	Explain private participation with respect to ownership options and modes of participation	[10]	CO1	L3
2	Discuss in brief the basic tariff making philosophy	[10]	CO2	L2
3	Explain economic characteristics of generating units	[10]	CO2	L3
4	Explain clean coal technologies, also explain advantages of CFBC	[10]	CO2	L2
5	Explain Renovation and Modernizations of Power Plants	[10]	CO3	L2
6	Write a note on high voltage transmission	[10]	CO3	L1
7	a. Write a note on types of conductors used in transmission b. Write any 2 different types of conventional generation resources	[10]	CO3	L1

1.

- 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

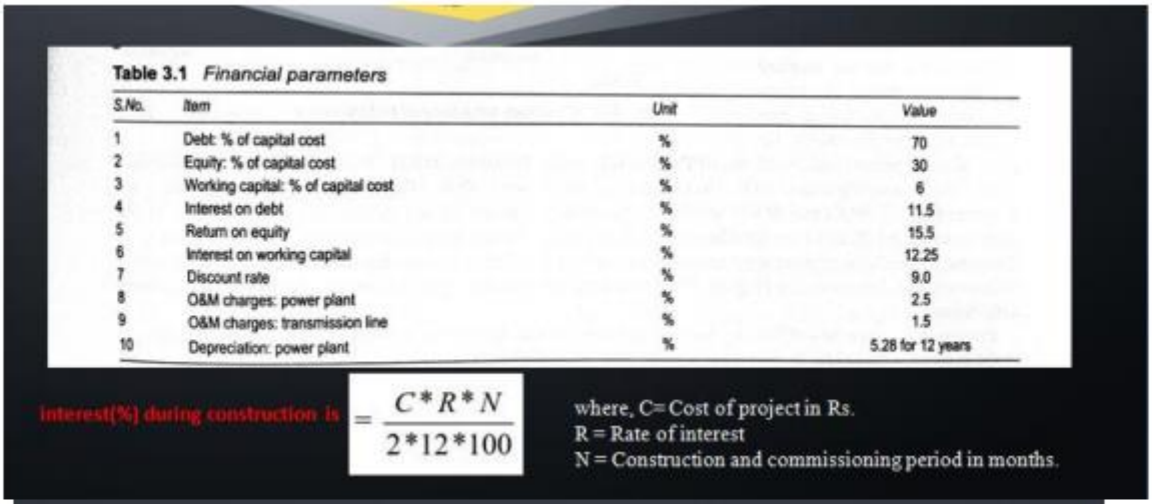


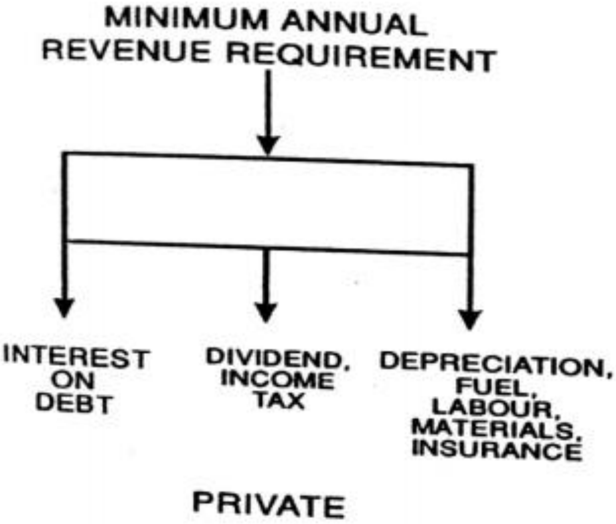
Table 3.1 *Financial parameters*

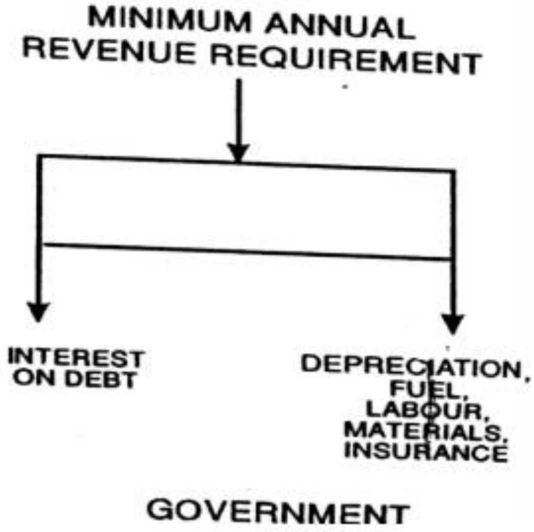
S.No.	Item	Unit	Value
1	Debt: % of capital cost	%	70
2	Equity: % of capital cost	%	30
3	Working capital: % of capital cost	%	6
4	Interest on debt	%	11.5
5	Return on equity	%	15.5
6	Interest on working capital	%	12.25
7	Discount rate	%	9.0
8	O&M charges: power plant	%	2.5
9	O&M charges: transmission line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

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

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

- **OWNERSHIP:**
- 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.





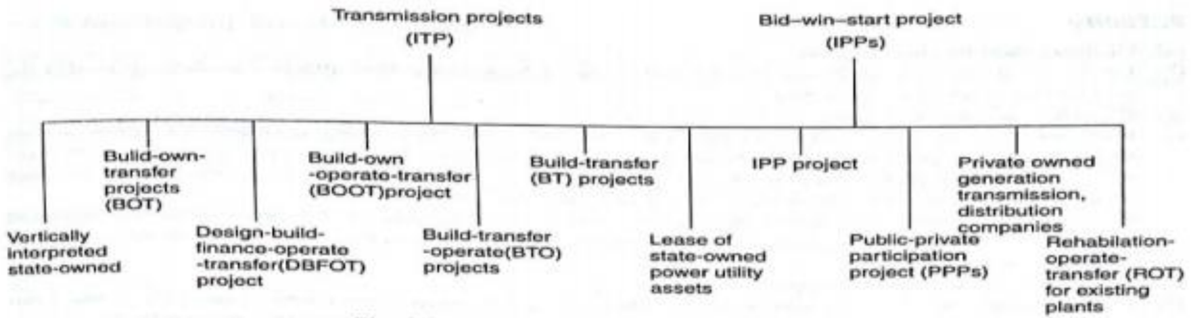
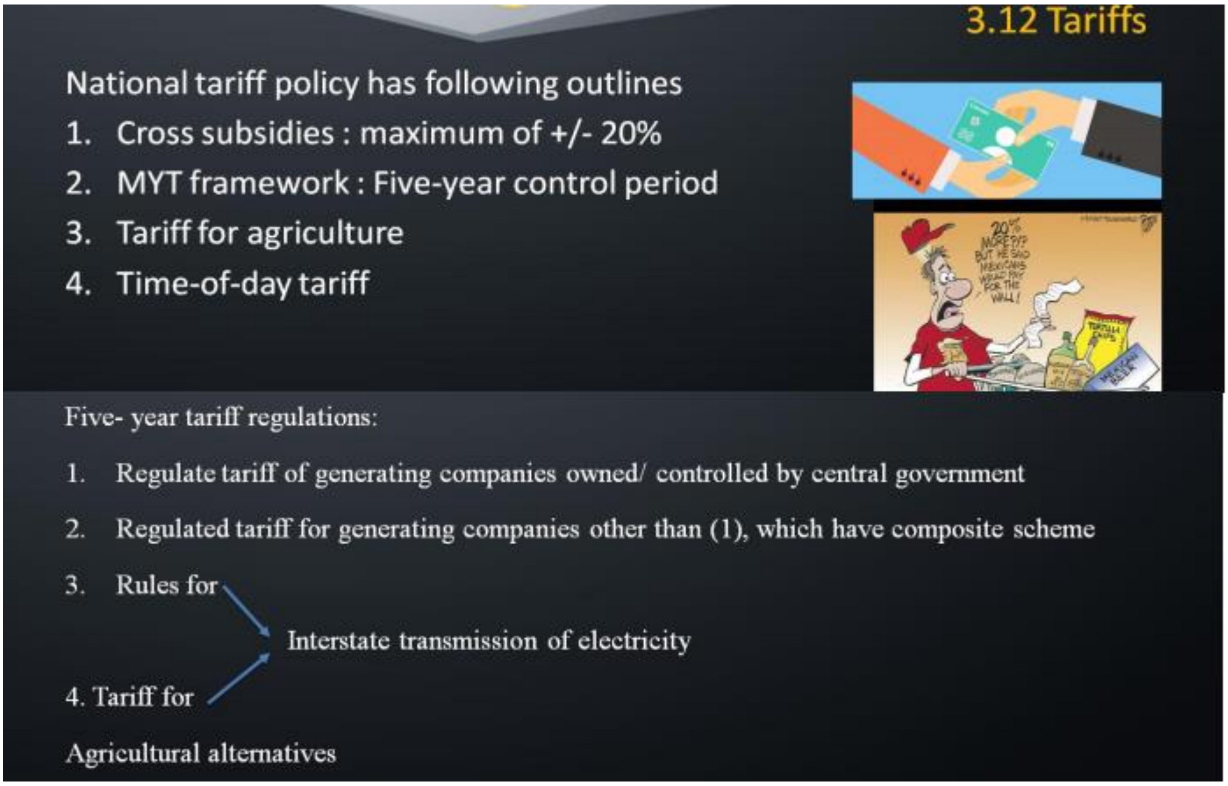


Fig. 3.3 *Ownership options for power utility*

2.



3.12 Tariffs

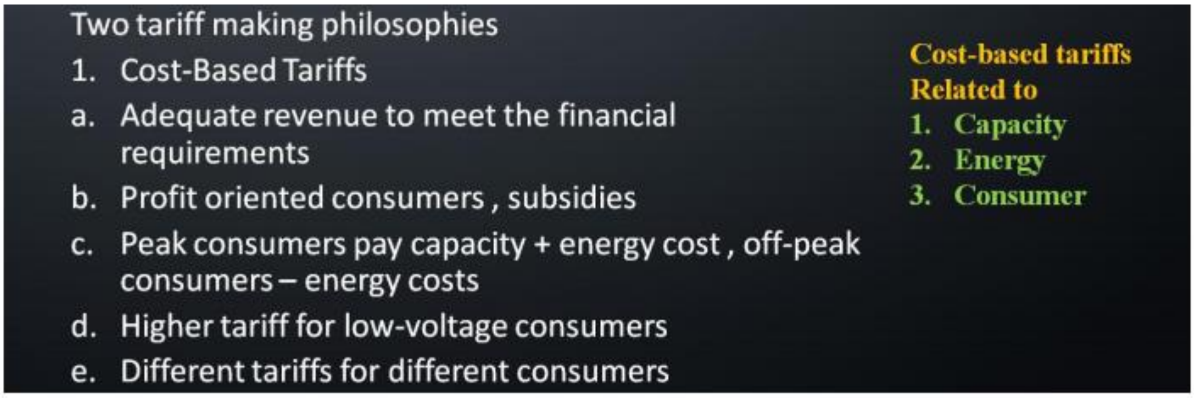
National tariff policy has following outlines

1. Cross subsidies : maximum of +/- 20%
2. MYT framework : Five-year control period
3. Tariff for agriculture
4. Time-of-day tariff

Five- year tariff regulations:

1. Regulate tariff of generating companies owned/ controlled by central government
2. Regulated tariff for generating companies other than (1), which have composite scheme
3. Rules for
   Interstate transmission of electricity
4. Tariff for

Agricultural alternatives



Two tariff making philosophies

1. Cost-Based Tariffs

a. Adequate revenue to meet the financial requirements
b. Profit oriented consumers , subsidies
c. Peak consumers pay capacity + energy cost , off-peak consumers – energy costs
d. Higher tariff for low-voltage consumers
e. Different tariffs for different consumers

Cost-based tariffs Related to

1. **Capacity**
2. **Energy**
3. **Consumer**

3.12.1 Cost-Based Tariffs

1. The tariff should have sufficient rates to raise adequate revenue to meet the financial requirements of the utility.
2. The tariff should be based on supply cost for each category of consumer. However, urban consumers will subsidise the rural consumers to some extent. Profit-oriented consumers, i.e., commercial enterprises or large industries should contribute to earn the some rate of return for the utility.
3. Peak consumers should pay both capacity and energy costs, whereas off-peak consumers such as farmers, should pay only the energy costs.
4. Lower the service voltage, greater the costs consumers impose on the system. Therefore, higher tariff for low-voltage consumers are desirable.
5. Tariffs must be based on marginal costs of serving demand which varies
   (a) for different consumer categories
   (b) for different seasonal industries such as rice sheller, ice industry, etc.
   (c) for different hours of the day, i.e., higher rate for peak hours, medium rate for daytime and lower rate for highest hours
   (d) for different voltage levels, i.e., HT or LT supply consumers
   (e) for different geographical areas

Marginal cost-based tariffs will give a correct signal to power consumers and will enhance the most effective resource management.

Inverted block rates have been used extensively to encourage energy conservation depending upon the analysis of price elasticity (E_p):

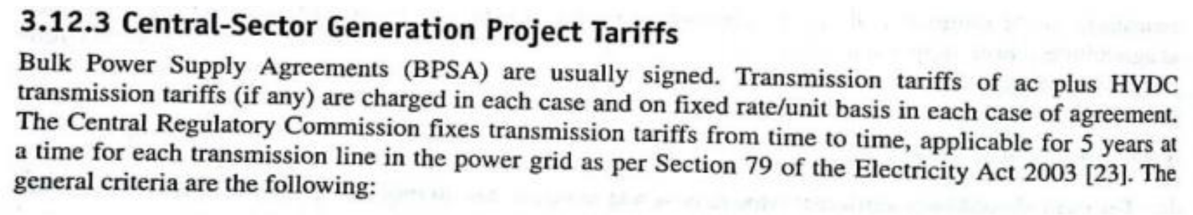
$$(E_p) = \frac{\text{\% change in energy consumption in kWh}}{\text{\% change in price kWh}}$$

The factors used in developing cost-based tariffs are identified as capacity-related, energy-related, and consumer-related. These factors vary for different classes of consumers (residential, agricultural, commercial, industrial, etc.), and require an analysis of much data in order to properly allocate costs.

3.12.2 Market-based Tariffs

Cost-based tariffs are generally preferred because they are less likely to be criticised by consumers. However, political or social considerations sometimes override the inherent fairness of cost-based tariffs, especially in developing economies. When this is done, the tariffs are said to be market-based. However, to recover costs, cross-subsidisation between various classes of consumers and/or some subsidisation by the government is inevitable.

1. Certain industrial rate classes may be subsidised to attract new industry to an area.
2. Residential rates may be subsidized by other classes for social/political purposes such as for slums for the backward classes.
3. Agricultural tubewell services may be subsidised to encourage increased food production.
4. Inverted block rates have been used extensively to encourage energy conservation.

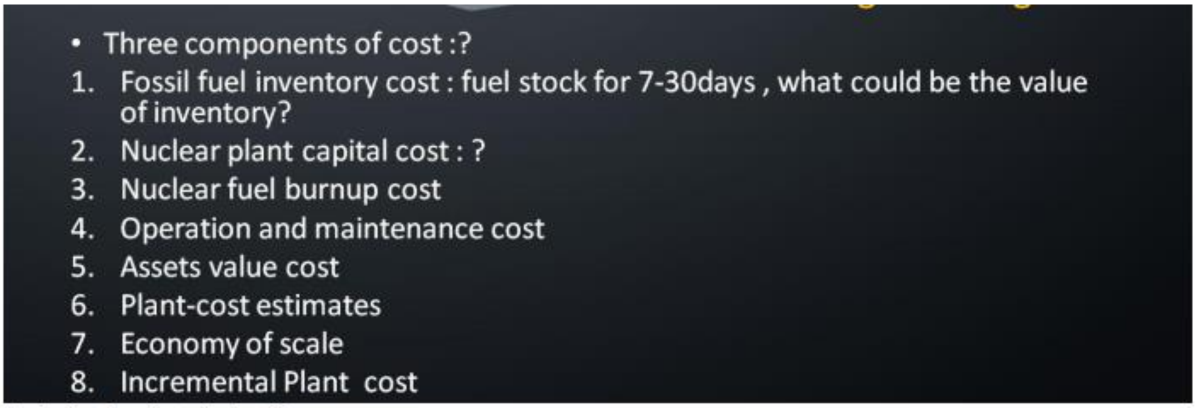


3.12.3 Central-Sector Generation Project Tariffs

Bulk Power Supply Agreements (BPSA) are usually signed. Transmission tariffs of ac plus HVDC transmission tariffs (if any) are charged in each case and on fixed rate/unit basis in each case of agreement. The Central Regulatory Commission fixes transmission tariffs from time to time, applicable for 5 years at a time for each transmission line in the power grid as per Section 79 of the Electricity Act 2003 [23]. The general criteria are the following:

Name the central generation project tariffs

3.

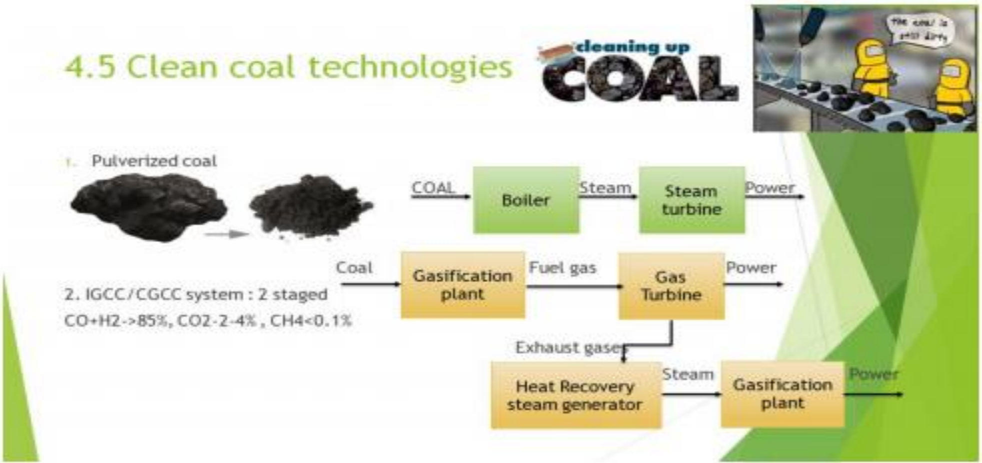


- Three components of cost :?

1. Fossil fuel inventory cost : fuel stock for 7-30days , what could be the value of inventory?
2. Nuclear plant capital cost : ?
3. Nuclear fuel burnup cost
4. Operation and maintenance cost
5. Assets value cost
6. Plant-cost estimates
7. Economy of scale
8. Incremental Plant cost

Explain all points in detail

4.

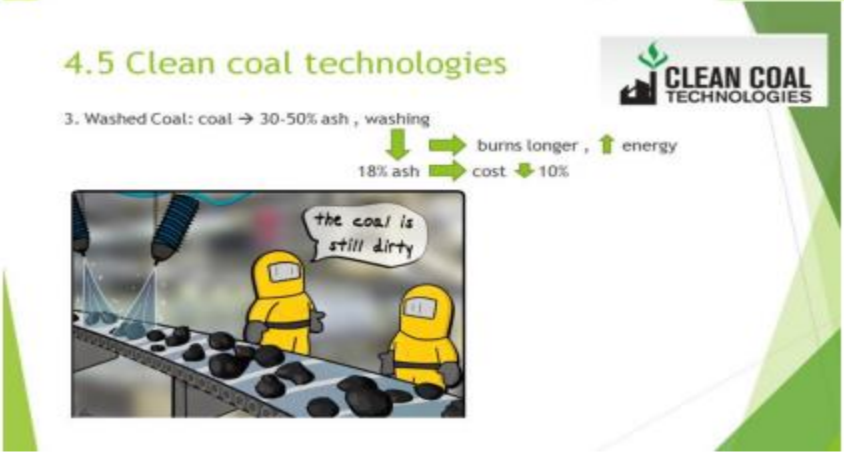


4.5 Clean coal technologies

1. Pulverized coal

2. IGCC/CGCC system : 2 staged

CO+H2->85%, CO2-2-4% , CH4<0.1%



4.5 Clean coal technologies

3. Washed Coal: coal → 30-50% ash , washing

18% ash → burns longer , ↑ energy

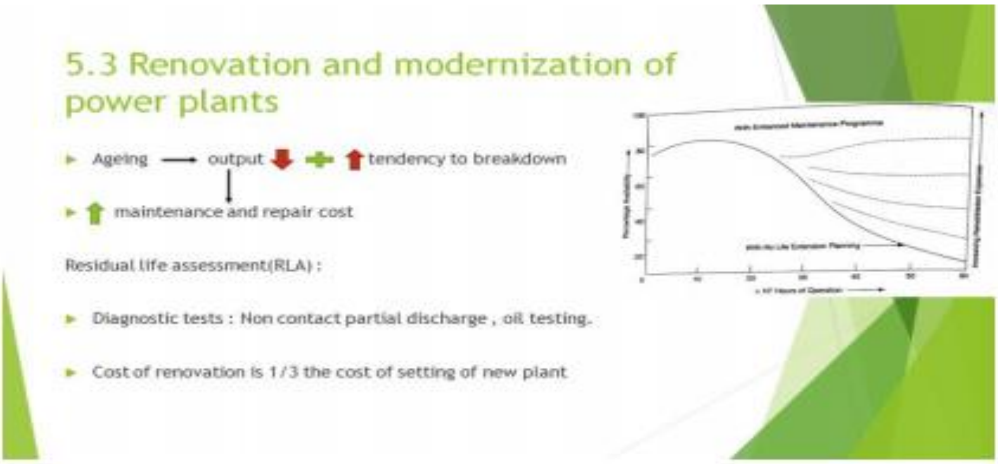
→ cost ↓ 10%

4. 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 ℃)

5.



5.3 Renovation and modernization of power plants

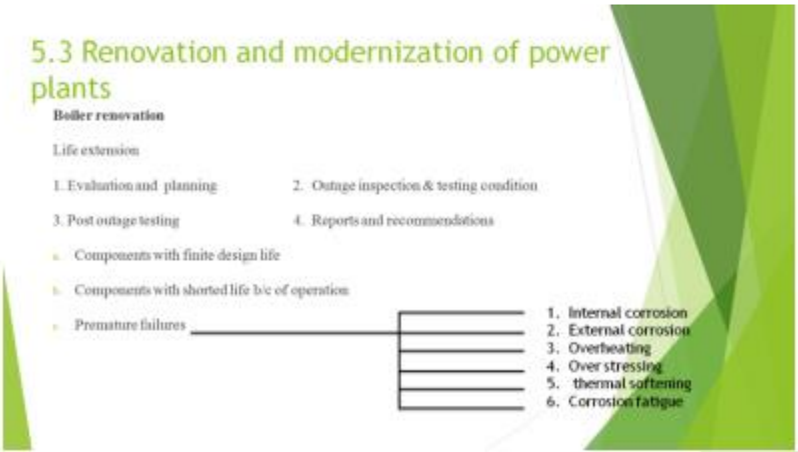
- Ageing → output ⬇ ➕ ⬆ tendency to breakdown
- ⬆ maintenance and repair cost

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

Steam turbine rehabilitation:

1. Life of turbine 21-25 years , RLA after 10 Years of operating time
2. Critical components : entry nozzle steam piping etc
3. Material life consumption: As per BHEL norms $H_{OP} = H_{AO} + n_s * 25$
4. High-cycle fatigue : leads to blade failures
5. Data book of all the parts has be available



5.3 Renovation and modernization of power plants

Boiler renovation

Life extension

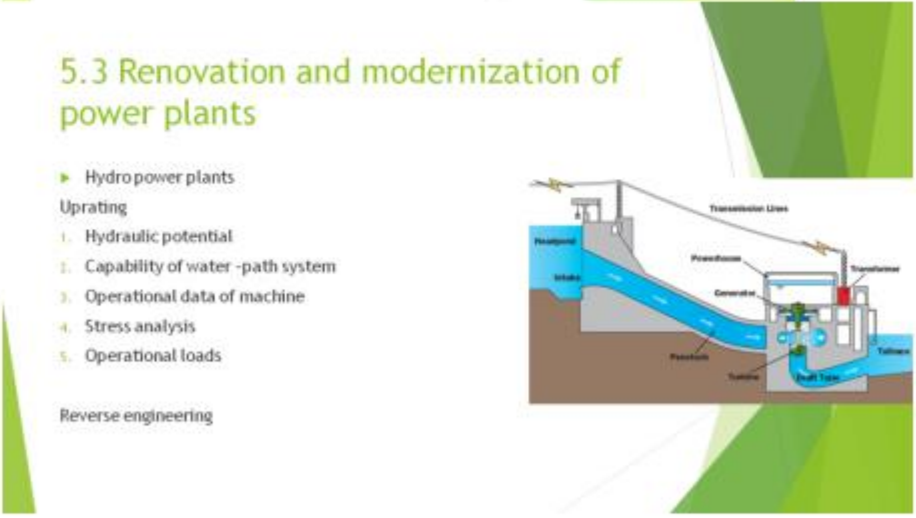
1. Evaluation and planning
2. Outage inspection & testing condition
3. Post outage testing
4. Reports and recommendations

a. Components with finite design life

b. Components with shorted life b/c of operation

c. Premature failures

1. Internal corrosion
2. External corrosion
3. Overheating
4. Over stressing
5. thermal softening
6. Corrosion fatigue



5.3 Renovation and modernization of power plants

- Hydro power plants

Uprating

1. Hydraulic potential
2. Capability of water -path system
3. Operational data of machine
4. Stress analysis
5. Operational loads

Reverse engineering

- Nuclear plant

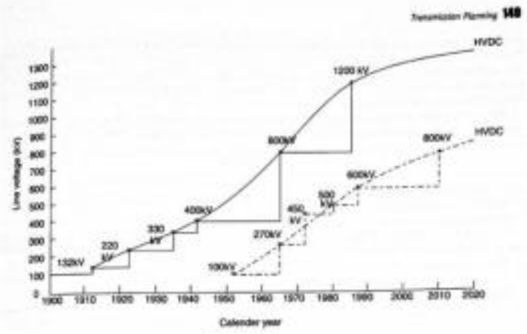
1. 25-40 years of life-time + engineering assessments 40-60 years

Ageing can cause : corrosion , cracking , partial discharges , oxidation

6.

6.4 HIGH VOLTAGE TRANSMISSION

1. **Development of transmission voltages**



HVAC and HVDC transmission voltage development in the world

6.4 HIGH VOLTAGE TRANSMISSION

2. **AC transmission** : power transfer capacity → $\frac{V^2}{X}$

1200kV is limit set , reason?

1. Insulation
2. Protection technology becomes costly
3. Increased losses compared to DC

2. a. **Phase shifting transformers** in EHV transmission

2. b. **FACTS**

2.c. **ASC**

6.4 HIGH VOLTAGE TRANSMISSION

2.c. **ASC**

High power electronic devices + series capacitors ,

Parallel reactor with series capacitor,

Control of current in reactor

By varying firing angle of thyristor

Direct and continuous current flow control

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

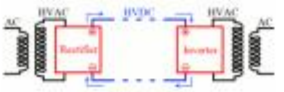
a. Right of way : HVDC is 50-60% of that of AC

b. Connect asynchronous regions

c. High transient stability

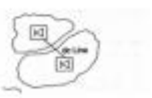
6.4 HIGH VOLTAGE TRANSMISSION

7 HVDC links in India



Three different ways of connection , in back to back Rectification and conversion are at same station

Two terminal DC line



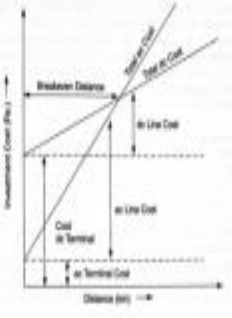
Back to back DC line with **long AC feeder**

Back to back DC line at **border of blocks**

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



7a.

6.5 CONDUCTORS

1. Conductor loading

Thermal loading : ambient temperature + max conductor temp (variations)

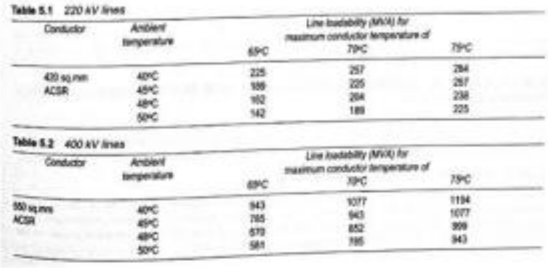


Table 5.1 220 kV lines

Conductor	Ambient temperature	Line loadability (MVA) for maximum conductor temperature of 65°C	70°C	75°C
420 sq.mm ACSR	40°C	225	257	284
	45°C	188	225	257
	48°C	162	204	238
	50°C	142	189	225

Table 5.2 400 kV lines

Conductor	Ambient temperature	Line loadability (MVA) for maximum conductor temperature of 65°C	70°C	75°C
550 sq.mm ACSR	40°C	943	1077	1194
	45°C	785	943	1077
	48°C	670	852	989
	50°C	581	785	943

2. High rating conductors

Demand → greater loads on existing system

Existing ACSR should be operated **at <=93**℃

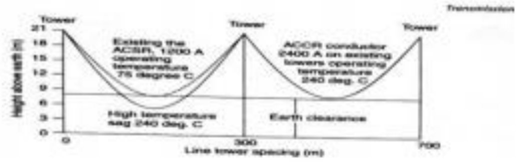
Additional lines are not cost effective

So an alternate was HTLS : low loss , high efficiency

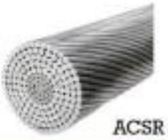
2.a. ACCC

2.b. ACSS

2.c. ACCR



6.5 CONDUCTORS



ACSR

ACCC

- **Composite**(hybrid carbon + glass fibre) core , ↓Weight
- Temp 180°C
- Works at **cooler temp** b/c↑ Al
- Economical (↓lifecycle costs)
- High strength
- ACSR→ ACCC with same tower best option

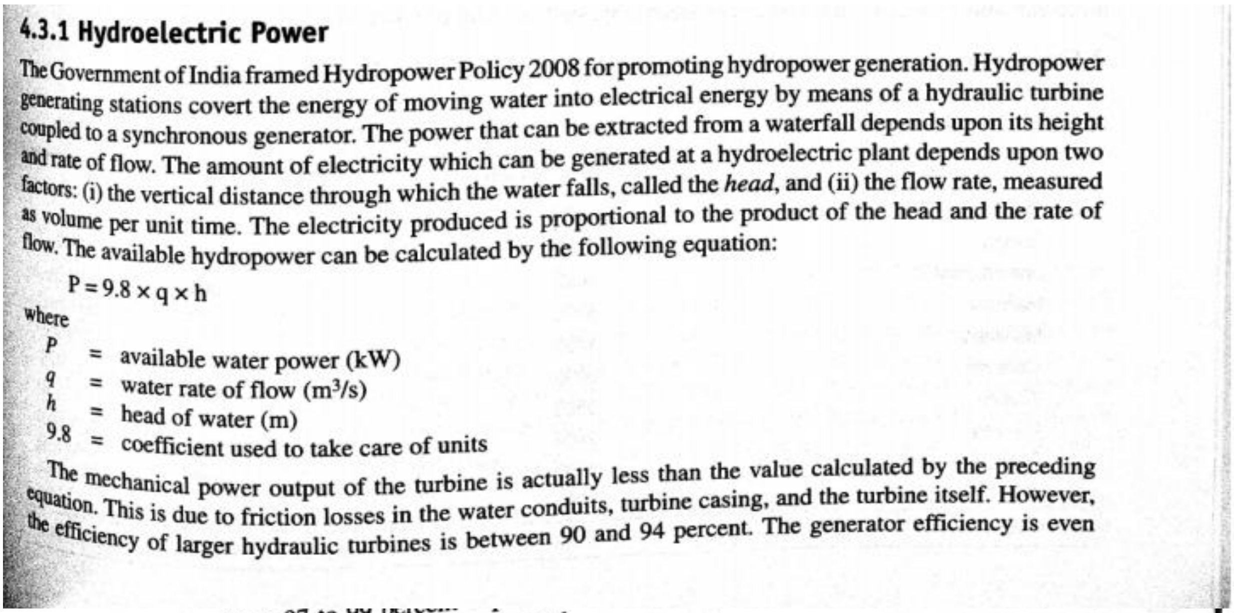
ACSS

- Increases capacity by 40%

ACCR

- Drop in replacement of ACSR
- Transmission capacity twice the existing
- Multistrand aluminium matrix core aluminium –zirconium outer wires

7b.



4.3.1 Hydroelectric Power

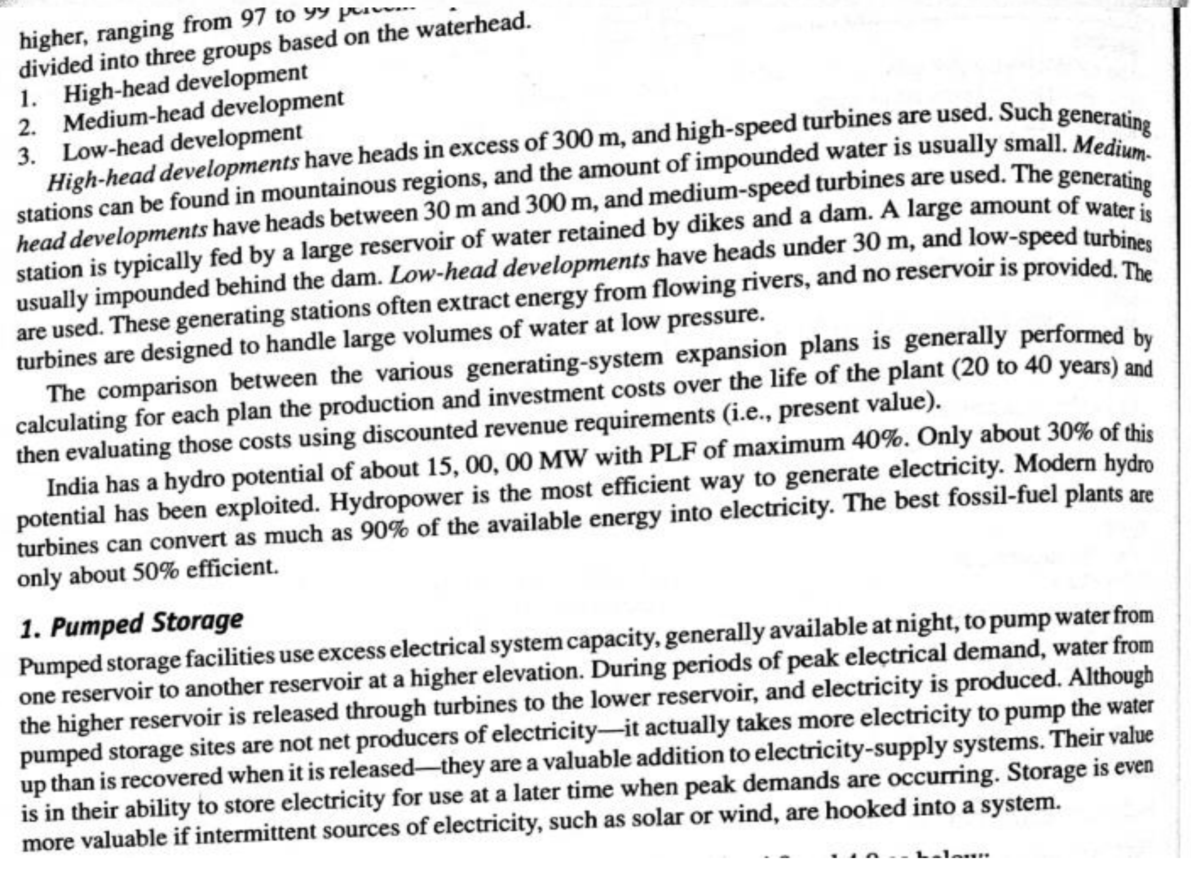
The Government of India framed Hydropower Policy 2008 for promoting hydropower generation. Hydropower generating stations covert the energy of moving water into electrical energy by means of a hydraulic turbine coupled to a synchronous generator. The power that can be extracted from a waterfall depends upon its height and rate of flow. The amount of electricity which can be generated at a hydroelectric plant depends upon two factors: (i) the vertical distance through which the water falls, called the *head*, and (ii) the flow rate, measured as volume per unit time. The electricity produced is proportional to the product of the head and the rate of flow. The available hydropower can be calculated by the following equation:

$$P = 9.8 \times q \times h$$

where

P = available water power (kW)
q = water rate of flow (m^3/s)
h = head of water (m)
9.8 = coefficient used to take care of units

The mechanical power output of the turbine is actually less than the value calculated by the preceding equation. This is due to friction losses in the water conduits, turbine casing, and the turbine itself. However, the efficiency of larger hydraulic turbines is between 90 and 94 percent. The generator efficiency is even



higher, ranging from 97 to 99

divided into three groups based on the waterhead.

1. High-head development
2. Medium-head development
3. Low-head development

High-head developments have heads in excess of 300 m, and high-speed turbines are used. Such generating stations can be found in mountainous regions, and the amount of impounded water is usually small. *Medium-head developments* have heads between 30 m and 300 m, and medium-speed turbines are used. The generating station is typically fed by a large reservoir of water retained by dikes and a dam. A large amount of water is usually impounded behind the dam. *Low-head developments* have heads under 30 m, and low-speed turbines are used. These generating stations often extract energy from flowing rivers, and no reservoir is provided. The turbines are designed to handle large volumes of water at low pressure.

The comparison between the various generating-system expansion plans is generally performed by calculating for each plan the production and investment costs over the life of the plant (20 to 40 years) and then evaluating those costs using discounted revenue requirements (i.e., present value).

India has a hydro potential of about 15, 00, 00 MW with PLF of maximum 40%. Only about 30% of this potential has been exploited. Hydropower is the most efficient way to generate electricity. Modern hydro turbines can convert as much as 90% of the available energy into electricity. The best fossil-fuel plants are only about 50% efficient.

1. Pumped Storage

Pumped storage facilities use excess electrical system capacity, generally available at night, to pump water from one reservoir to another reservoir at a higher elevation. During periods of peak electrical demand, water from the higher reservoir is released through turbines to the lower reservoir, and electricity is produced. Although pumped storage sites are not net producers of electricity—it actually takes more electricity to pump the water up than is recovered when it is released—they are a valuable addition to electricity-supply systems. Their value is in their ability to store electricity for use at a later time when peak demands are occurring. Storage is even more valuable if intermittent sources of electricity, such as solar or wind, are hooked into a system.

4.3.2 Thermal Coal

Land requirement for Indian coal-based plants is assumed as 279 ha/GW whereas the same for imported coal-based plants is almost half, that is, 154 ha/GW due to its lower ash content [9]. Water requirement varies from 3 m^3/MW to 5 m^3/MW depending upon the thermal plant size. It is important to develop ecological sound clean coal technologies for the combustion of coal. The five broad categories of coal available in India are peat (2500 kcal/kg), lignite (3500 kcal/kg), sub-bituminous (3000–7000 kcal/kg), bituminous (8000 kcal/kg), and anthracite (9000 kcal/kg). Only non-coking coal of the sub-bituminous type is available for electric

power production whose deposit is estimated at 50 gigatonnes. Coal thermal will remain as the predominant source of generation for the 21st century. Under Indian conditions, the consumptive requirement of water per MW of installed capacity varies from 9.4 cubic metres per hour for closed systems (i.e., cooling tower) to 5 cubic metres per hour for open systems (i.e., once-through systems) with a large source. The various norms of the thermal plants are given in Appendix V. The thermal-power-station gestation period for construction and commissioning is 4–5 years. Fossil-fuel or nuclear-energy steam-cycle units require tremendous quantities of cooling water [30.5 to 4.1 m^3/s] for a typical 500 MW unit, whereas gas-turbine units require essentially no cooling water. Coal-fired units rated at 500 MW would typically require over 1.7 million tonnes of coal annual.

Coal-fired units required disposal of large quantities of ash and scrubber sludge, whereas natural-gas-fired units require no solid-waste disposal whatsoever. From each of these comparisons, it is easy to see how the choice of energy source and power-generating system can have an impact on the appropriate criteria to be used in choosing a plant site. The location and physical characteristics of the available plant sites (such as proximity to and availability of water, proximity to fuel or fuel transportation, and soil characteristics) can have an impact on the choice of fuel and power-generating system.

Installed capital costs (on a rupees per kilowatt basis) and system efficiencies (heat rates) are quite different for different ratings (see Appendix V). Similarly, each of the more conventional systems is available in many variations of equipment types, equipment configurations, system parameters, and operating conditions.

Smaller units rating have higher installed capital costs (on a rupees per kilowatt basis) and higher annual fixed operation and maintenance costs (on a rupees per kilowatt-hour basis), with the increase in the costs, becoming dramatic at the lower range of ratings commercially available for that type of electric-power generating unit. Smaller generating units also generally have somewhat poorer efficiencies (higher heat rates) than large units.