CMR INSTITUTE OF TECHNOLOGY	USN										

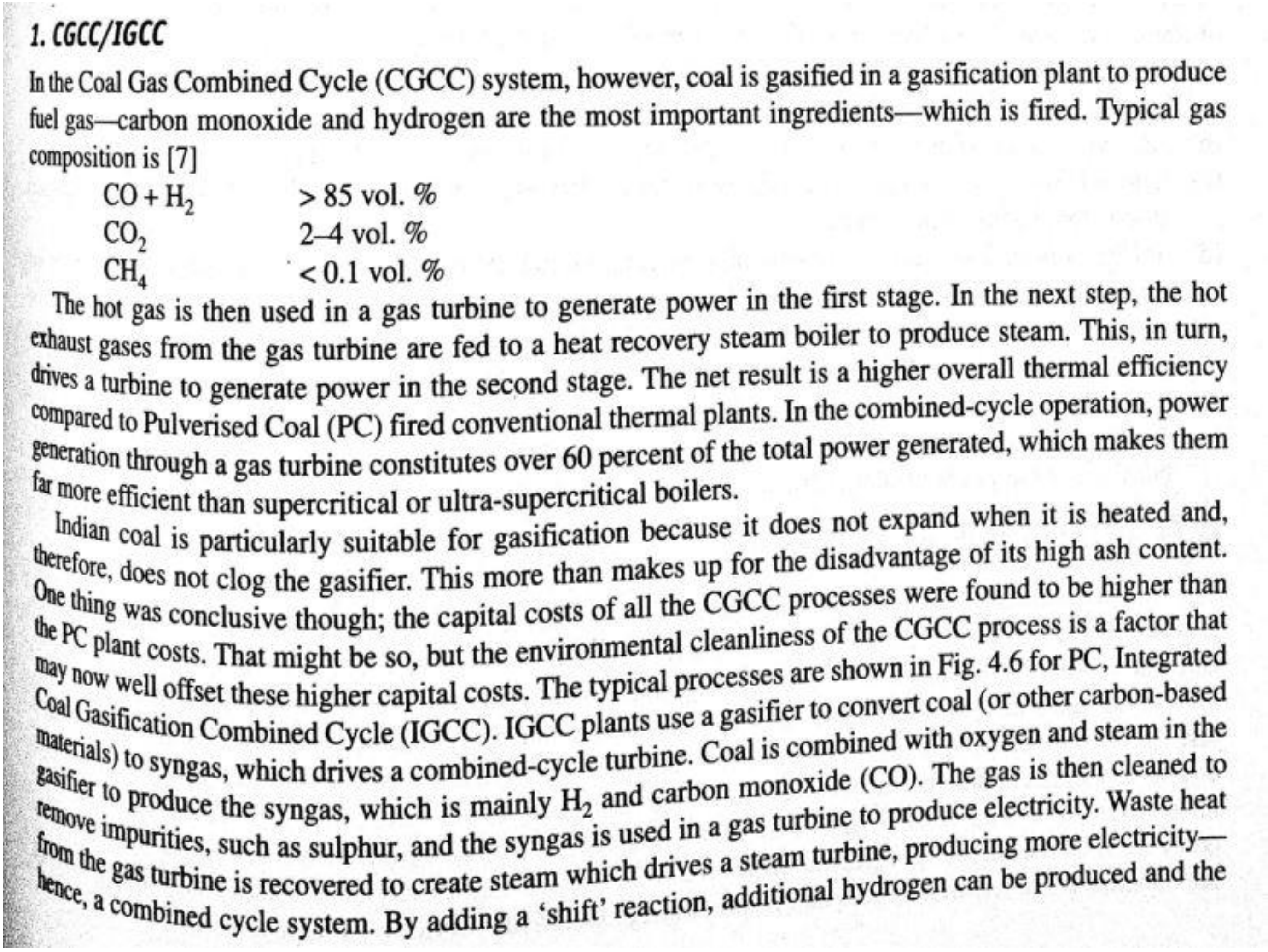
Internal Assesment Test –II Question bank

Sub:	Power System Planning	Code:	18EE824

		OBE	
		CO	RBT
1	Explain clean coal technologies.	CO1	L2
2	Explain generation capacity and Energy.	CO1	L2
3	Explain distributed power generation.	CO4	L2
4	Explain transmission planning criteria.	CO4	L2
5	Explain steam turbine rehabilitation.	CO4	L2
6	Explain network studies.	CO4	L2
7	Mention different advantages of high voltage transmission.	CO4	L2

Answers

1	**Explain clean coal technologies.**



1. CGCC/IGCC

In the Coal Gas Combined Cycle (CGCC) system, however, coal is gasified in a gasification plant to produce fuel gas—carbon monoxide and hydrogen are the most important ingredients—which is fired. Typical gas composition is [7]

$CO + H_2$	> 85 vol. %
CO_2	2–4 vol. %
CH_4	< 0.1 vol. %

The hot gas is then used in a gas turbine to generate power in the first stage. In the next step, the hot exhaust gases from the gas turbine are fed to a heat recovery steam boiler to produce steam. This, in turn, drives a turbine to generate power in the second stage. The net result is a higher overall thermal efficiency compared to Pulverised Coal (PC) fired conventional thermal plants. In the combined-cycle operation, power generation through a gas turbine constitutes over 60 percent of the total power generated, which makes them far more efficient than supercritical or ultra-supercritical boilers.

Indian coal is particularly suitable for gasification because it does not expand when it is heated and, therefore, does not clog the gasifier. This more than makes up for the disadvantage of its high ash content. One thing was conclusive though; the capital costs of all the CGCC processes were found to be higher than the PC plant costs. That might be so, but the environmental cleanliness of the CGCC process is a factor that may now well offset these higher capital costs. The typical processes are shown in Fig. 4.6 for PC, Integrated Coal Gasification Combined Cycle (IGCC). IGCC plants use a gasifier to convert coal (or other carbon-based materials) to syngas, which drives a combined-cycle turbine. Coal is combined with oxygen and steam in the gasifier to produce the syngas, which is mainly H_2 and carbon monoxide (CO). The gas is then cleaned to remove impurities, such as sulphur, and the syngas is used in a gas turbine to produce electricity. Waste heat from the gas turbine is recovered to create steam which drives a steam turbine, producing more electricity—hence, a combined cycle system. By adding a ‘shift’ reaction, additional hydrogen can be produced and the

CO can be converted to CO_2 which can then be captured and stored. IGCC plant efficiency of 50% is achievable. The 582 MW thermal station at Kemper County, Mississippi, is one the latest IGCC plant in the US.

2. Washed Coal

Indian coal contains 30 to 50% ash. At present, (2014), only 10–15% coal is used in the country as washed. Washed coal with ash content less than 18% will be supplied in future to the new thermal plant. Coal washing needs to be mandatory. The coal-washing process reduces the cost of coal by about 10% as washed coal burns longer and provides more energy.

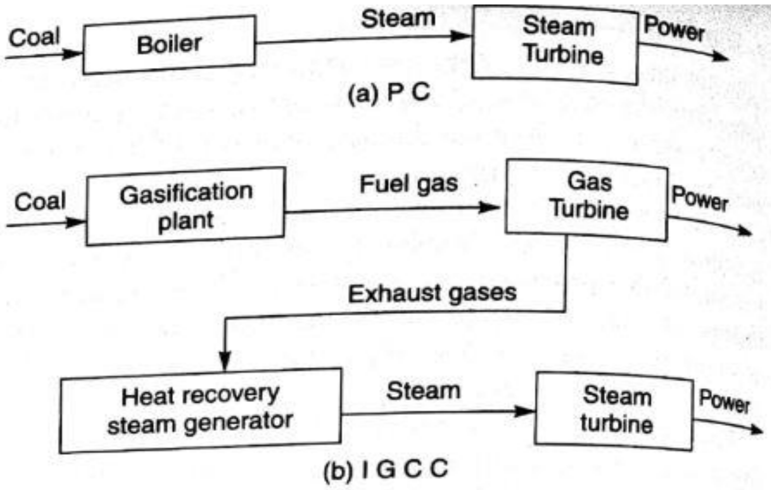


Fig. 4.6 *Clean coal technologies*
PC = Pulverized coal
IGCC = Integrated gassification combined cycle

3. Circulating Fluidised Bed Combustion (CFBC)

Circulating fluidised bed combustion in boilers at atmospheric pressure is particularly useful for high-ash coals as Indian coal. Relatively coarse particles at around 3 mm size are fed into the combustion chamber. CFBC is clean firing technology with boiler (maximum 400 MWe is available) having the qualities of burning of low-grade fuels. The advantages of CFBC technology are the following:

(a) *High-combustion efficiency*—turbulence and residence time in the combustor result in excellent fuel burnout.
(b) *Low NOx emission* provided by low-combustion temperatures and air staging.
(c) *Low SO_2 emissions*—use of limestone provides for low SO_2 emissions with limestone usage minimised at low combustion temperature.
(d) *Ability to burn low-grade fuels*—the high thermal inertia of the bed provides for stable combustion of very low grade fuels containing high ash and/or moisture. Power can be generated from the byproduct of washery (rejects) considered as waste rejects utilised for power generation with/without blending of raw coal. It is possible to attain boiler efficiency of 79% on 100% washery rejects. Burning of coal rejects reduces any handling and disposal issues.
(e) *Fuel flexibility*—combustion temperatures below ash-fusion levels and high-bed thermal inertia allow burning a wide range of fuel characteristics in a single boiler.

2	**Explain generation capacity and Energy.**

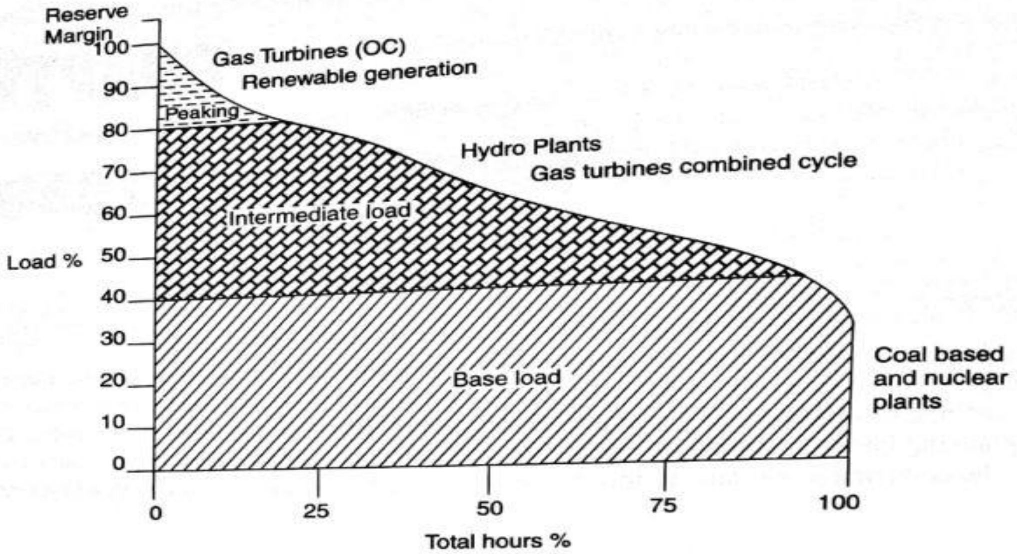
4.1 Generation Capacity and Energy

Most power systems in the world plan for capacity needs ensuring that enough resources are in place to serve the peak demand. Their ability to meet load is limited by their peak generating capacity, rather than the fuel available for their generating facilities. For these systems, the total generating capability usually far exceeds the average energy requirements. However, now generation planning is shifting from planning for peak load towards planning for system energy. More flexibility must be provided in three essential ways: balancing the generation portfolio, load control, and energy storage.

For systems that incorporate a large share of hydroelectric generation, however, planning is usually done on an energy basis. This is because reservoirs behind dams generally cannot hold enough water to run each project at full capacity all year long. These systems are considered energy-limited and capacity-surplus.

In particular, planners compute reserve margins or other measures of reliability. They simulate the operation of the system to measure operating cost and to determine if the operation is within acceptable ranges of other parameters.

In India, an installed capacity is of about 150 percent of the peak demand, against 121% in the United Kingdom, 114% in the Southern African Power Pool of 12 countries and 115 % in the United States, 120–130% in Japan, 120% in Germany, 120% in Canada, and 120–130% in Australia. *Operating reserve* is an important resource to response unpredicted generation outage and load fluctuation. In most practices and researches, the required capacity of operating reserve is pre-determined as the loss of largest power generation/consumption unit or the loss of line. The reserve margin in India is 50% including spinning reserve, which is on the higher side. Thus, there is clearly a need for better utilisation of our existing resources. Traditional electric power systems are planned on the premise of power production in a central generating station and its delivery to the points of end use via transmission and distribution systems. Types of generation capacity (see Fig. 4.1) are the following:

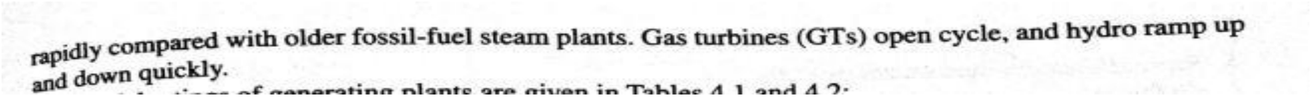


Different type of loads require different types of generation plants

Fig. 4.1 *Typical daily local duration curve*

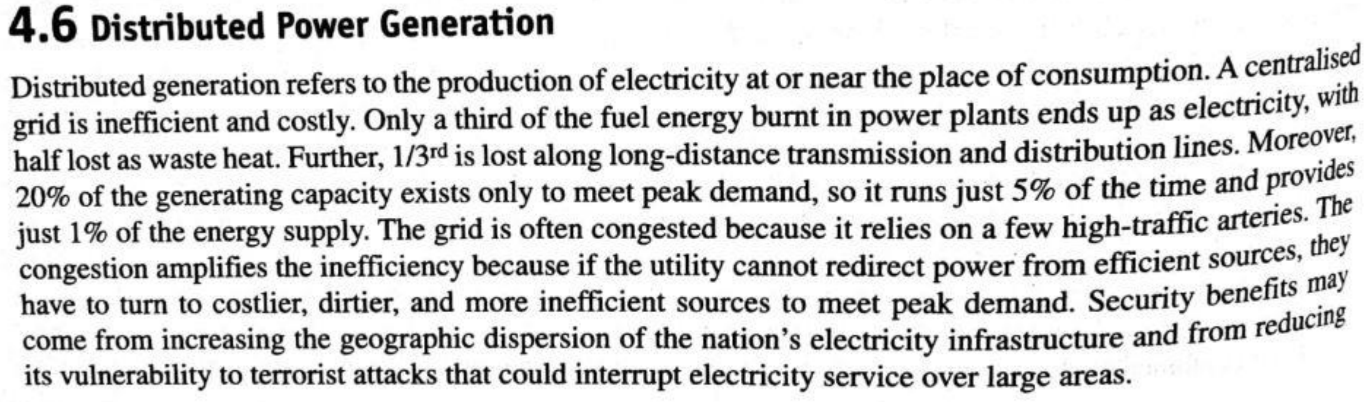
1. Base-load capacity is designed to operate for most hours of the year. Coal-fired steam-cycle power plants, nuclear plants, and hydroelectric plants are examples of base-load generation capacity. The output of base-load-type plants cannot be rapidly decreased or increased to follow load, i.e., adjusted to changes in the amount of power needed. (Sometimes, hydro plants follow load, in which case they are not base-load units.) Coal plants "ramp" up and down slowly, ~3 MW/minute.
2. Intermediate-load plants provide power during periods when demand is higher than minimal levels. Technologies for intermediate-load plants include gas turbine-combined-cycle plants and large hydroelectric plants.
3. Peak-load plants provide power when demand is highest, and may operate only a few percent of the hours in the year. Types of peak-load power plants include gas-turbine combined-cycle plants, pumped-storage hydroelectric facilities, and wind, solar, thermal, and photovoltaic systems. These generators have little inertia and fast-acting mechanical drives, allowing them to change their generation level

Table 4.1 Generating-plant unit



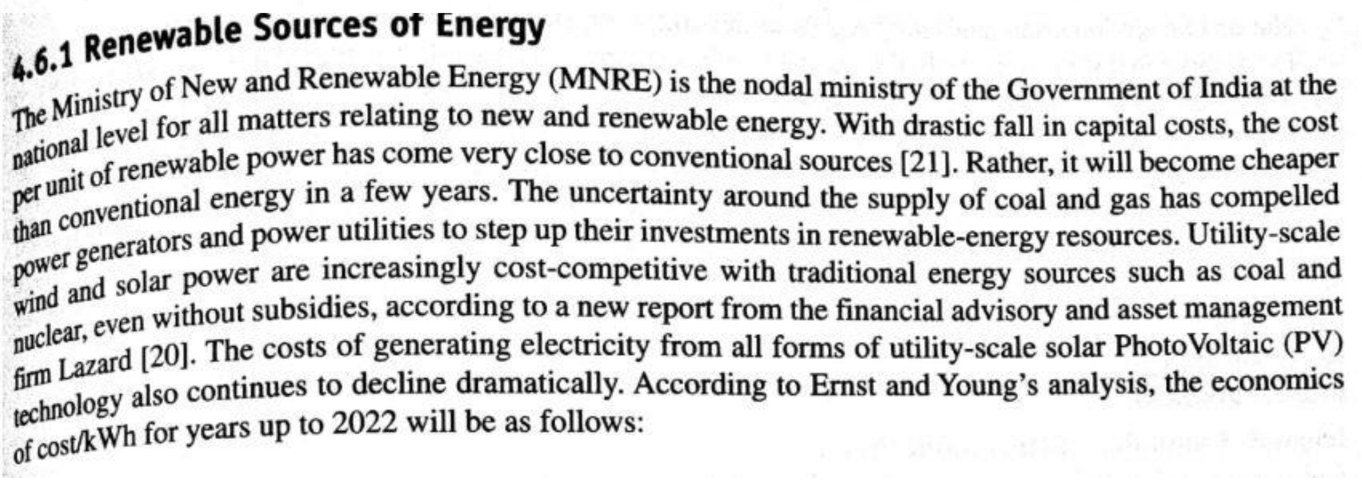
rapidly compared with older fossil-fuel steam plants. Gas turbines (GTs) open cycle, and hydro ramp up and down quickly.

3	**Explain distributed power generation.**



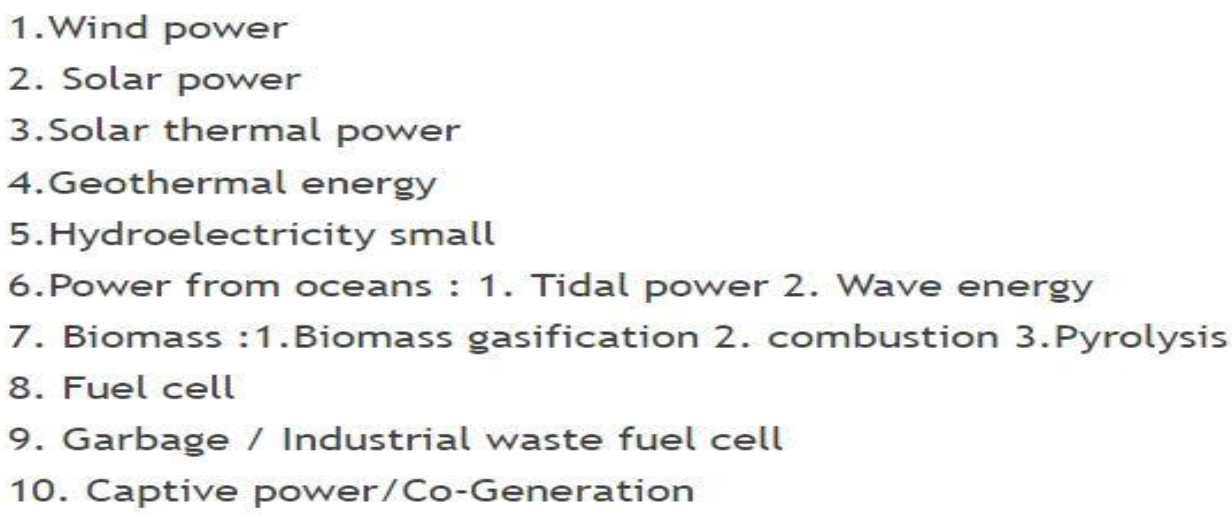
4.6 Distributed Power Generation

Distributed generation refers to the production of electricity at or near the place of consumption. A centralised grid is inefficient and costly. Only a third of the fuel energy burnt in power plants ends up as electricity, with half lost as waste heat. Further, 1/3rd is lost along long-distance transmission and distribution lines. Moreover, 20% of the generating capacity exists only to meet peak demand, so it runs just 5% of the time and provides just 1% of the energy supply. The grid is often congested because it relies on a few high-traffic arteries. The congestion amplifies the inefficiency because if the utility cannot redirect power from efficient sources, they have to turn to costlier, dirtier, and more inefficient sources to meet peak demand. Security benefits may come from increasing the geographic dispersion of the nation's electricity infrastructure and from reducing its vulnerability to terrorist attacks that could interrupt electricity service over large areas.



4.6.1 Renewable Sources of Energy

The Ministry of New and Renewable Energy (MNRE) is the nodal ministry of the Government of India at the national level for all matters relating to new and renewable energy. With drastic fall in capital costs, the cost per unit of renewable power has come very close to conventional sources [21]. Rather, it will become cheaper than conventional energy in a few years. The uncertainty around the supply of coal and gas has compelled power generators and power utilities to step up their investments in renewable-energy resources. Utility-scale wind and solar power are increasingly cost-competitive with traditional energy sources such as coal and nuclear, even without subsidies, according to a new report from the financial advisory and asset management firm Lazard [20]. The costs of generating electricity from all forms of utility-scale solar PhotoVoltaic (PV) technology also continues to decline dramatically. According to Ernst and Young's analysis, the economics of cost/kWh for years up to 2022 will be as follows:



1. Wind power
2. Solar power
3. Solar thermal power
4. Geothermal energy
5. Hydroelectricity small
6. Power from oceans : 1. Tidal power 2. Wave energy
7. Biomass :1.Biomass gasification 2. combustion 3.Pyrolysis
8. Fuel cell
9. Garbage / Industrial waste fuel cell
10. Captive power/Co-Generation

4.6.2 Renewable Purchase Obligation

As per the Electricity Act 2003, Section 86(1)(e), the State Electricity Regulatory Commission is to prescribe the percentage of purchase of renewable energy by distribution companies. The Indian government has mandated that 75 percent of the nation's cell towers have to run on renewable energy by 2020, and mobile companies are looking at everything from solar to fuel cells to replace dirty diesel generators. Generation-based incentive in the renewable schemes has been found to accelerate the installed capacities. The 12th and 13th Five Year Plans have envisaged an additional capacity of 18, 500 MW and 30, 500 MW from renewable resources respectively. The Central Electricity Regulatory Commission (CERC) launched the Renewable Energy purchase Obligation (RPO) scheme in 2010. It is stipulated that distribution companies will be penalised if they do not meet green energy obligations. The scheme makes it obligatory for distribution companies, open access consumers, and captive power producers to meet part of their energy needs through green energy.

4.6.3 Grid Connectivity

CEA Connectivity Standards (2013) for wind and solar generating stations stipulate that harmonic current injections and flicker introduced shall not be beyond the limits specified in IEEE Standard 519 and IEC 61000 respectively.

The dc current injection shall not be greater than 0.5% of the full rated output.

The wind generating station shall be capable of supplying dynamically varying reactive power support so as to maintain power factor within the limits of 0.95 lagging to 0.95 leading. The generating units shall be capable of operating in the frequency range of 47.5 Hz to 52 Hz and shall be able to deliver rated output in the frequency range of 49.5 Hz to 50.5 Hz. The wind generating stations connected to the grid at 66 kV voltage level and above shall have the fault ride through capability. During the fault/voltage dip, the individual wind generating units in the generating station shall generate active power in proportion to the retained voltage and shall maximise supply of reactive current till the time voltage starts recovering or for 300 ms, whichever time is lower.

4	**Explain transmission planning criteria.**

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

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.

5	**Explain steam turbine rehabilitation.**

1. Steam-Turbine Rehabilitation

Modern steam turbines are designed for a life of 19, 00, 00–21, 00, 00 operating hours. Predicting the residual life of a power plant at the end of its designed life is a major concern for power utilities while trying to extend the power plant's life further. Condition assessment of turbine critical components is of primary importance. *Critical components* are defined as those components not normally expected to be replaced during the life of steam turbines. These components are subjected to long-term cumulative material damage and degradation. These critical components require condition assessments including special testing not normally provided by traditional maintenance and inspection activities. The typical critical components are turbine rotors, high-temperature castings, valve castings, entry nozzles, and steam piping. The various life-assessing techniques are (i) component integrity test, ultrasonic testing, borosonic testing, dye-penetrate testing, wet fluorescent magnetic particle testing, (ii) *metallurgical tests* like microstructure studies, material-composition test, hardness test, spectrum electron microscopy, and (iii) finite-element method for thermal stress analysis made on CAD workstations.

Material-Life Consumption Behaviour

(a) *Creep component* due to the steady-state stresses caused by pressure, steady-state temperature difference and external loads (centrifugal forces during operation).

(b) *Low-cycle fatigue component* due to the transient stresses resulting from thermal stresses during transient operating conditions like start-up, shutdown, and large load and temperature changes.

As per BHEL norms, each start consumes 25 hours of equivalent actual operating hours of the turbine.

$H_{op} = H_{AO} + n_s x\ 25$

where

H_{op} = operating hours

H_{AO} = actual operating hours

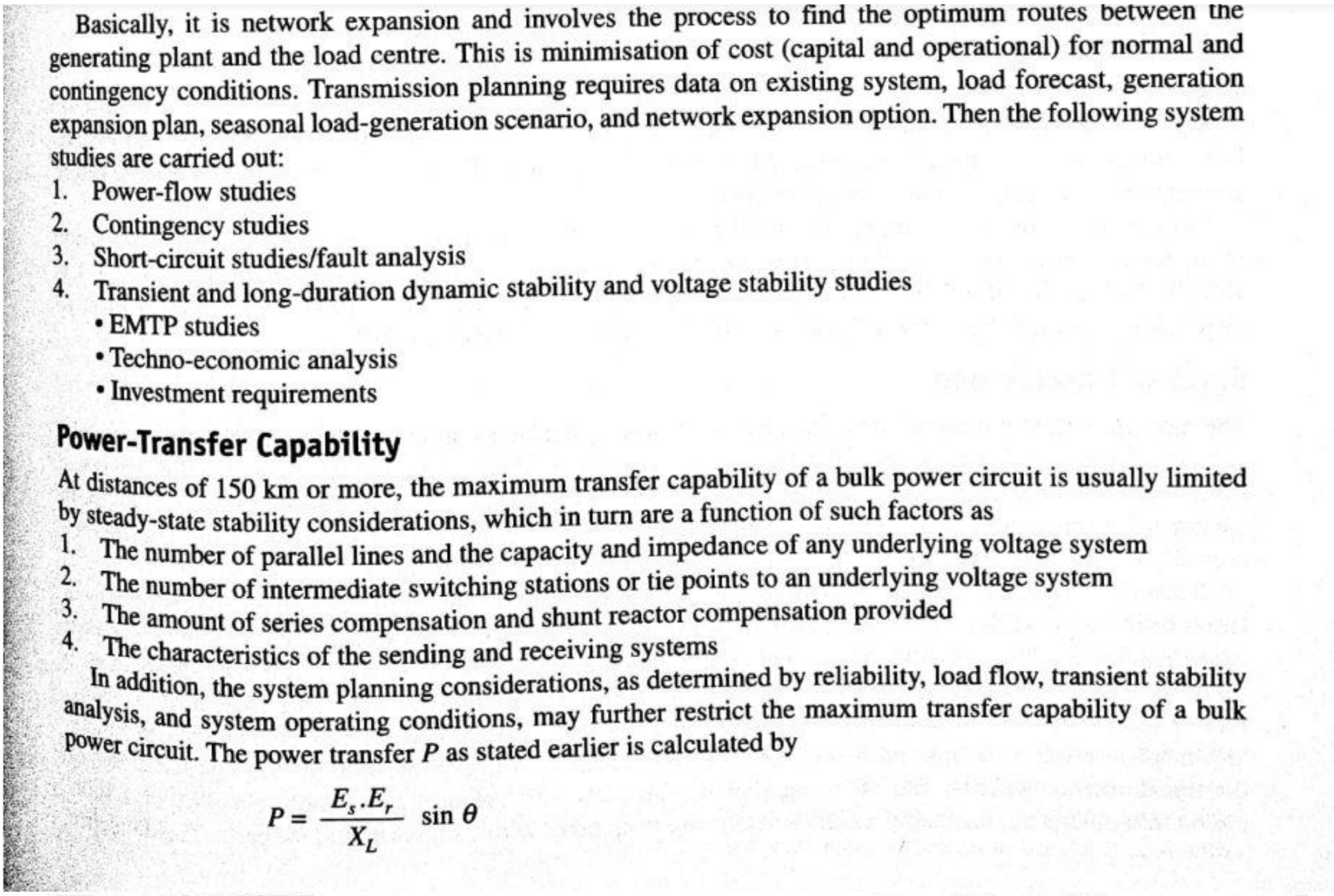
n_s = number of starts without any differentiation of cold or hot start

The analysis is done on a CAD workstation based on the algorithm of operating cycles. Metallurgical tests are primarily carried out to establish the material degradation or exhaustion of in-service materials. Component-integrity tests provide information about cracks and defects of in-service components.

(c) *High-cycle fatigue mechanisms* expose the component to greater stress than for which it is designed. High-cycle fatigue cracks propagate in turbine-rotating components. Many blade failures have been associated with high-cycle fatigue caused by abnormal vibrating stresses.

(d) It is very essential to have reliable material data from material testing in the laboratory for new materials and in-service material. A large amount of data banks are available in the country, either from power utilities' own research and development activities or from BHEL. History of all failures and service incidents, regarding special loading and failure modes of different components, is important to evaluate the remaining life of the turbines. It is also very essential to know about the various spares used and specific long-term behaviour of the units. The remaining life evaluation ensures operation, safety, reliability, and control of future operation and can enhance component service life. [11]

6	**Explain network studies.**



Basically, it is network expansion and involves the process to find the optimum routes between the generating plant and the load centre. This is minimisation of cost (capital and operational) for normal and contingency conditions. Transmission planning requires data on existing system, load forecast, generation expansion plan, seasonal load-generation scenario, and network expansion option. Then the following system studies are carried out:

1. Power-flow studies
2. Contingency studies
3. Short-circuit studies/fault analysis
4. Transient and long-duration dynamic stability and voltage stability studies
   - EMTP studies
   - Techno-economic analysis
   - Investment requirements

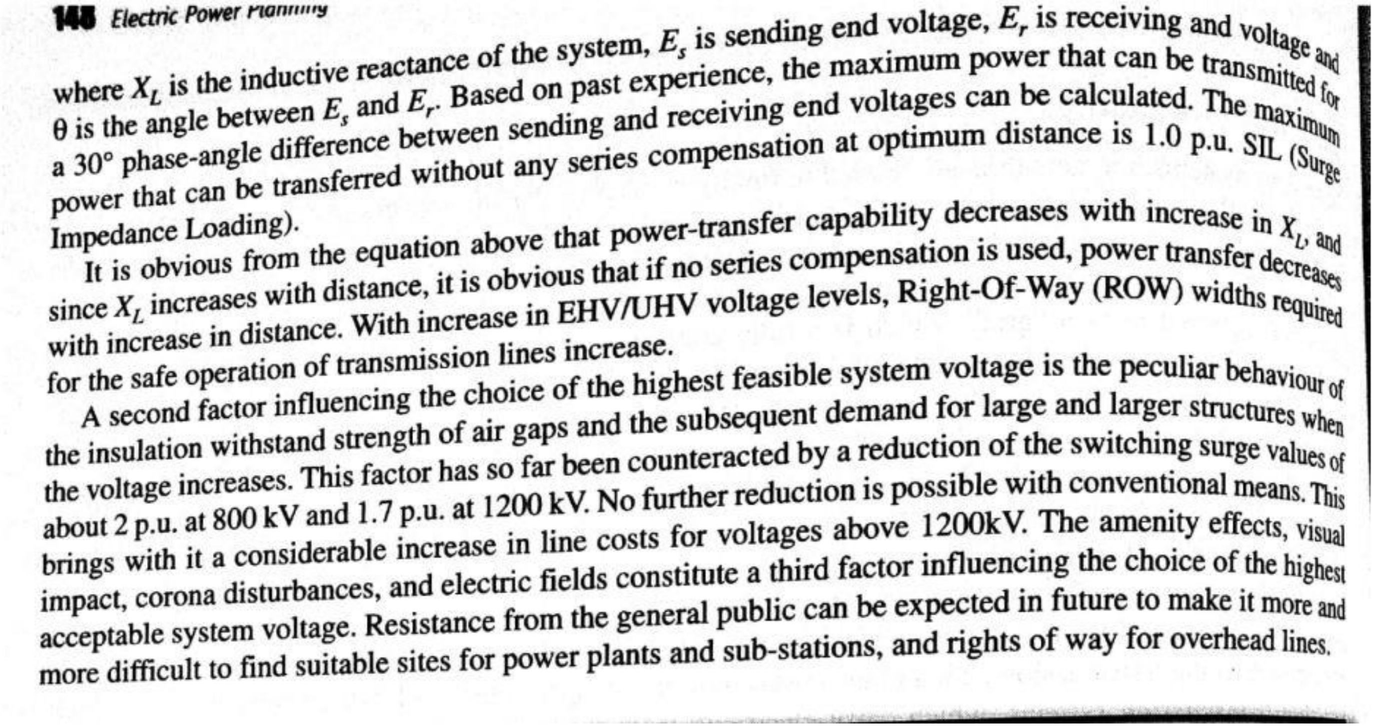
Power-Transfer Capability

At distances of 150 km or more, the maximum transfer capability of a bulk power circuit is usually limited by steady-state stability considerations, which in turn are a function of such factors as

1. The number of parallel lines and the capacity and impedance of any underlying voltage system
2. The number of intermediate switching stations or tie points to an underlying voltage system
3. The amount of series compensation and shunt reactor compensation provided
4. The characteristics of the sending and receiving systems

In addition, the system planning considerations, as determined by reliability, load flow, transient stability analysis, and system operating conditions, may further restrict the maximum transfer capability of a bulk power circuit. The power transfer P as stated earlier is calculated by

$$P = \frac{E_s . E_r}{X_L} \sin \theta$$



where X_L is the inductive reactance of the system, E_s is sending end voltage, E_r is receiving and voltage and θ is the angle between E_s and E_r. Based on past experience, the maximum power that can be transmitted for a 30° phase-angle difference between sending and receiving end voltages can be calculated. The maximum power that can be transferred without any series compensation at optimum distance is 1.0 p.u. SIL (Surge Impedance Loading).

It is obvious from the equation above that power-transfer capability decreases with increase in X_L, and since X_L increases with distance, it is obvious that if no series compensation is used, power transfer decreases with increase in distance. With increase in EHV/UHV voltage levels, Right-Of-Way (ROW) widths required for the safe operation of transmission lines increase.

A second factor influencing the choice of the highest feasible system voltage is the peculiar behaviour of the insulation withstand strength of air gaps and the subsequent demand for large and larger structures when the voltage increases. This factor has so far been counteracted by a reduction of the switching surge values of about 2 p.u. at 800 kV and 1.7 p.u. at 1200 kV. No further reduction is possible with conventional means. This brings with it a considerable increase in line costs for voltages above 1200kV. The amenity effects, visual impact, corona disturbances, and electric fields constitute a third factor influencing the choice of the highest acceptable system voltage. Resistance from the general public can be expected in future to make it more and more difficult to find suitable sites for power plants and sub-stations, and rights of way for overhead lines.

7	**Mention different advantages of high voltage transmission.**

1. Lower Line Costs

A dc line with two conductors is more economical to build than an ac line with three conductors.

2. Lower Losses

With HVDC, there is no reactive power transmitted. This is one of the reasons why the line losses are lower with dc than with ac. The losses in the converter terminals are approximately 1–1.5 percent of the transmitted power, which is low compared with the line losses.

3. Asynchronous Connection

Sometimes, it may be impossible to connect two ac networks due to stability reasons or because they operate at different ac frequencies. In such cases, the solution is HVDC since it is an asynchronous connection.

4. Controllability

Today's advanced semiconductor technology, utilised both in power thyristors and microprocessors for the control system, has yielded a substantial improvement in reliability and controllability of HVDC systems. In a normal ac system, it is not possible to control the power flow while in an HVDC system,the power flow can be controlled as to both amount and direction very quickly. This characteristic has often been used to stabilise different ac networks.

5. More Advantages

(a) The dc cables are cheaper compared to ac ones.
(b) One single cable can take up to 500–1000 MW.
(c) A dc cable does not contribute to the short-circuit power.
(d) Costly and difficult overhead line paths in a city centre can be avoided by cabling.
(e) Better conductor utilisation.
(f) Three times the capacity, using the same conductors.
(g) Even higher capacity with new towers in an existing right of way.
(h) Possibility to control reactive power in a city centre.
(i) Increased ac system stability.
(j) Increased power capacity in parallel ac lines.
(k) Controlled power flow.
(l) Double-circuit performance of a converted single-circuit ac line.
(m) Higher power without increased short-circuit power.
(n) Better control of the load line factor.

6. Backbone System

Major electrical networks are built up with a backbone system into which the generated power is fed and from which the load is tapped. In such a power systems today, there exist three distinct cases, where the dc technique may offer favourable alternatives to ac applications.

The three cases are

(a) Long-distance bulk power transmission from remote energy sources to the backbone system
(b) Interconnection between power systems or pools
(c) High-power underground (submarine)distribution-system feeders

7. Costs

(a) The most costly part of an HVDC link is the converter stations. The thyristors are assembled in modules containing voltage dividers as well as control and supervision circuits.

(b) The largest single pieces of equipment in the convertor stations, and one of the most costly items are the converter transformers. The purpose of the transformer is to achieve galvanic separation between the dc and ac side and also adapt the ac voltage to the dc voltage. The requirements imposed on converter transformers differ from those on normal ac transformers in two respects.

   i) The currents have a high harmonic content.

   ii) The valve-side windings must be able to withstand direct voltage stresses in addition to ac, switching surges, and lightning impulses.

8. Long Lines

For long ac lines, one must consider the reactive power compensation, the transient stability and switching over voltages, and how many intermediate sub-stations one needs. If the line length is longer than approximately 600 km, one should also consider if an HVDC alternative brings lower investment costs and/or lower losses or if the inherent controllability of an HVDC system brings some other benefits.

9. Long Cables

Cables have large capacitances and, therefore, if fed with ac, large reactive currents. Cables for dc are also less expensive than for ac.

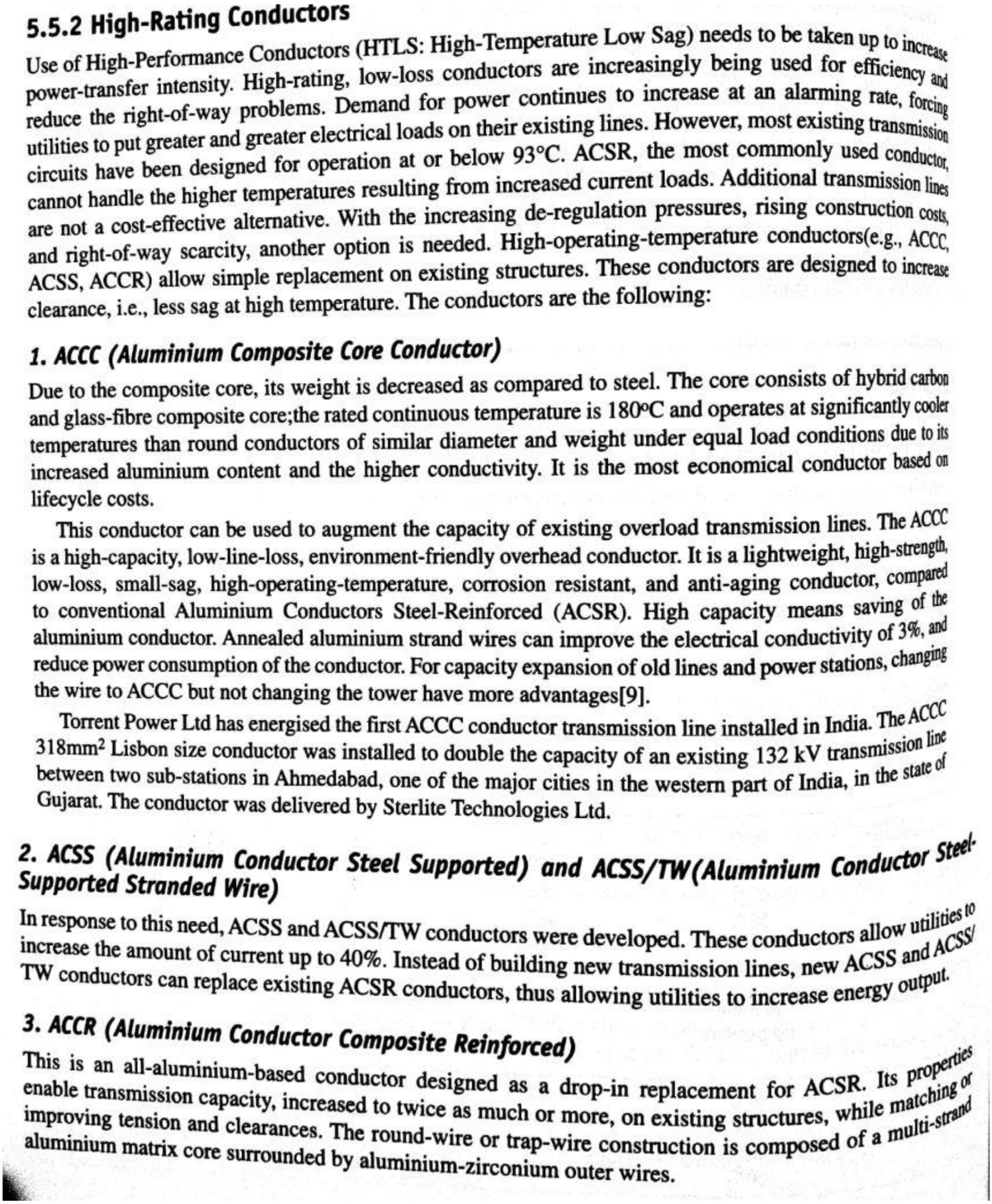
The HVDC light cables from 40 km up to 580 km are in operation with power ratings from 40 to 700 MW. It has lower investment cost and lower losses.

10. Submarine Cables

Since no shunt reactor can be installed at intermediate points (in the sea) and dc cables are less expensive, the majority of submarine cables > 50 km are for dc. Generally, they are of copper conductors.

Long underground cables (> 50 km) are generally avoided since the cost for an overhead line was deemed to be only 10–20 % of the cost for the cable.

11	**Explain about high rating conductors.**



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 $318 mm^2$ 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.

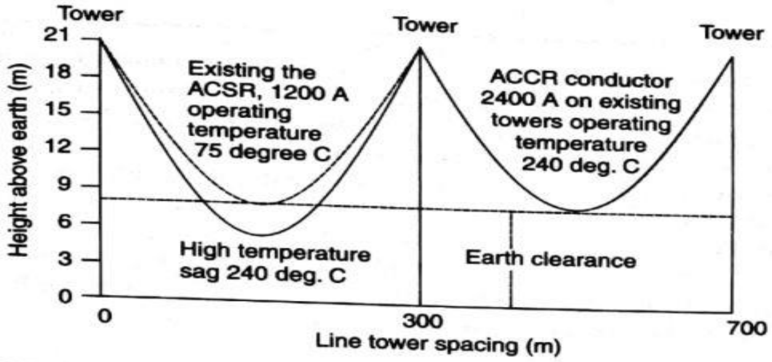


Fig. 5.5 *Typical sags of 220 kV existing line ACSR and upgraded with ACCR*

Also, ACCR conductors have a 240-degree centigrade working temperature. Figure 5.5 shows the lower sag conditions[22].

12	**Explain about** **a) Substation Bus bar schemes** **b) Gas Insulated substations (GIS).**

supply. This also favours

5.6.2 Sub-Station Bus-Bar Schemes

The arrangement of bus bars and circuit-breakers plays an important part in determining the efficiency of a power-transmission-and distribution system. The type of arrangement to be adopted is determined by the degree of flexibility of operation, immunity from total shutdown, importance and nature of loads, security, capital cost and minimisation of fault level by way of sectionalisation, maintenance, area of extension, land area, etc. The most prevalent bus-bar arrangements are the following:

1. Single-Bus System

It is the cheapest arrangement and is used for small sub-stations where power outage for short periods for maintenance and repairs is permissible. The disadvantage of the system is that in case of contingency, the whole system has to be closed down. Improvement to this is possible by sectionalising the bus by installing isolating switches or a circuit-breaker so that different sections can be operated independently.

2. Duplicate Bus System

This arrangement is commonly used in large systems with many feeders. There is a coupling switch for the circuit-breaker between the two bus bars. Isolators and circuit-breakers are connected so as to have power flow without interruption. This is a comparatively more expensive arrangement. Feeder-breaker maintenance is difficult without interruption of supply of feeder.

3. Transfer-Bus Arrangement

With this arrangement, line circuit-breaker can be taken out for maintenance and repairs without interruption of supply. This is a very costly,but more flexible, scheme.

4. Breaker and a Half-System

The arrangement is suitable for systems where power outage is not permissible for any reason whatsoever. The supply has to be kept uninterrupted even in case of bus fault and the bus can be taken out for maintenance. The cost and area required are 90% and 50% as compared to that with main bus and transfer-breaker scheme.

5.6.3 Gas-Insulated Sub-stations (GIS)

GIS using SF_6 has compact size and superior performance against contamination. There are several additional factors to consider:

1. Indoor installations are always possible.
2. It has higher reliability and less maintenance as compared to conventional air-insulated equipment.
3. There is low visual impact on the environment.
4. It has lower costs for site clearance and buildings.
5. It has lower erection costs.
6. It has superior performance in areas with severe seismic conditions.

For applications at EHV/UHV for continuous current-carrying ratings of 3000 A or above, aluminium enclosures are preferred over steel to minimise losses. While three-phase bus bars are installed at voltage levels as high as 420kV, the main applications for GIS using three-phase enclosures are for voltage levels up to 170 kV with single-phase enclosures normally used for voltages above 170 kV.

The circuit-breakers used in the GIS are almost exclusively single-pressure SF_6 puffer-type breakers. Disconnecting switches are generally of the no-load type but can operate successfully with the normal inherent capacitive currents (0.3to 1.0 A at 145 to 800 kV). Earthing switches only intended for maintenance are provided with slow action manual or electrical drive mechanisms and have no making capabilities. To cope with the possibility of induced line voltage sand currents, earthing switches with making capacity of upto 80 kA at 550 kV are available and may be added to ensure personal safety.

The main elements built into the sub-station and completely enclosed in the SF_6 installation include transformers, circuit-breakers, load-break switches, disconnecting switches, ground switches, current and potential transformers, bus bars, coupling capacitors, and SF_6 lead-outbushing insulators for connection to overhead lines, transformer, or other external equipment. Equipment such as shunt reactors, shunt capacitors, power-line carrier line traps, etc., are not manufactured as part of the SF_6 insulated system. However, long runs of bus using SF_6 insulation may extend some distance from the sub-station in order to make the connection to the other conventional equipment.