CMR INSTITUTE OF TECHNOLOGY			USN						
Internal Assesment Test –II									
Sub:	Power System Planning							Code:	18EE824
Date:	13/04/24	Duration:	90 mins	Max Marks:	50	Sem:	8th	Branch:	EEE

Answer Any FIVE FULL Questions

		Marks	OBE CO	OBE RBT
1	Draw the generation mix flow chart and explain in detail.	[10]	CO2	L2
2	Explain about uprating and modernization of hydro plants.	[10]	CO2	L2
3	Explain distributed power generation.	[10]	CO3	L2
4	Explain about high rating conductors.	[10]	CO3	L2

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6	What are the criteria for planning static VAR system?	[10]	CO3	L2
7	Mention different advantages of high voltage transmission.	[10]	CO3	L1

CCI HOD/EEE

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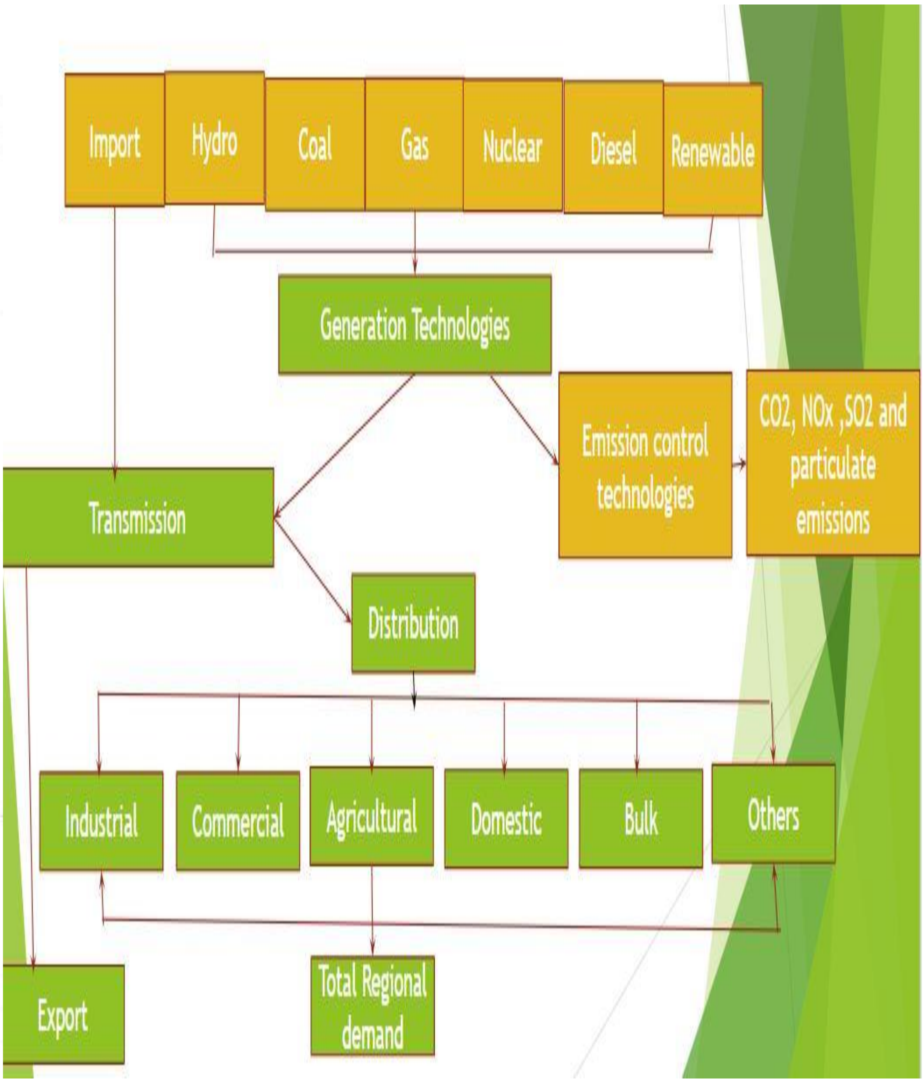
1	**Draw the generation mix flow chart and explain in detail.**

The generation mix is decided on the basis of load-curve duration peak, intermediate, and base loads. The base load is catered by high-inertia turbo generators such as nuclear thermal plants and thermal based on coal. Use of fossil fuels to meet the energy needs is inevitable and shall have to co-exist in the fuel mix. The intermediate load which is for normally about 25% of the calendar year is catered by low-inertia thermal plants such as gas-turbine combined-cycle plants, hydro-generators, renewable resources power, etc. The peaking capacity is well maintained by the hydro-generation pump-storage hydro, open-cycle gas turbines, diesel generators, etc. The essential feature of these stations is that they are able to switch off and on easily and quickly. A delicate balance has to be maintained for providing energy in the most environment-friendly manner at "optimal cost". Any technology that fits the optimal cost should be considered for long-term sustainability. Wind is already competitive with fossils in several parts of Asia, and solar tariffs has dropped by 50% in India itself.

Reducing and increasing the fuel in a continuous cycle will have a damaging effect on the equipment in coal, thermal, or nuclear plants. Adding the base-load stations only will require backing down (GWh/MW) of thermal plants during night at much higher levels. This will lower the PLF of thermal stations, where possible. Excess power available during night can be used to pump water up, in case of hydro plants. There are called *pumped storage systems* and are ideal peaking stations. The typical



2	**Explain about uprating and modernization of hydro plants.**

1. Uprating

Hydropower stations can accommodate higher available water potential at site, i.e., discharge and head of enhanced power generation. Generally, 10 to 15% higher generation is possible because of hydraulic and mechanical margins without any changes in mechanical components.

In many other cases where uprating to the extent of 30–35% is required, major changes in water-path components like runner, draft tube cone, shaft and labyrinth seals, etc., may become inevitable. However, smooth dynamic behaviour must be ascertained before continuous operation is recommended at higher outputs. When uprating of power stations is foreseen with major changes in water-path components, the

performance of the machines is first established in a hydraulic laboratory by model testing with respect to efficiency, output, cavitation, and runaway characteristics. Systematic analysis of available water potential, operational data, major operating problems, hydraulic and mechanical design, and dynamic behaviour of the machine is required to ascertain the uprating capability of machines conforms to the following:

(a) Actual hydraulic potential at site and extent of uprating required keeping in view the compatibility of generator excitation equipment and transformers.

(b) Operational data of the machine, i.e., output vs. runner and guide apparatus servomotor stroke, pressure rise and speed rise, guide-vane closing time, maximum oil pressure required for closing/opening the servomotor, guide-bearing temperatures and vibrations.

(c) Operating loads on various machines with duration of operation and major repair carried out on water-path components due to excessive cavitation, silt erosion, or vibrations.

(d) Capability of water-path system, i.e., penstock, spiral casing and draft tube to accommodate higher discharge resulting in higher mechanical output without adversely affecting the cavitation coefficient. In case of a Kaplan machine, hydraulic moment acting on the runner blade on higher opening is also analysed in addition to hydraulic moment acting on guide vanes.

(e) Stress analysis of shaft-coupling bolts and other mechanical assemblies at higher output with the review of margins of runaway speed on critical speed.

(f) Analysis of operating data, i.e., guide-vane opening and runner-blade opening vs. servomotor stroke, guide-bearing temperature, oil pressure required for operating the guide vane and runner blades, and load thrown-off results to identify the margin over design values.

(g) Once the uprating potential of the machine is established with or without change in water-path components, the dynamic behaviour of the machine is observed at uprated, rated, and partial load conditions at the site. The spectrum of pressure pulsation, noise level, and vibration levels in displacement, velocity, and acceleration mode are analysed at various loads and overall levels are decided. The spectrum analysis also indicates the dominating frequencies at critical levels of vibrations and pressure pulsation which can be improved to get smooth operating of machine enhancing the generation. In addition, the following parameters should be recorded to establish the uprating of a machine.

(i) Pressure pulsation of different frequencies and locations such as spiral casing, turbine top cover, draft-tube cone below the runner and crown portion of the runner

(ii) Vibration in displacement, velocity, and acceleration modes at different frequencies on the turbine guide bearing, top cover, and draft-tube cone

(iii) Noise level in the draft-tube pit, turbine floor, generator floor, and control room

(iv) Temperature of guide bearings and thrust bearings at uprated load conditions

(v) Speed rise and pressure rise from uprated load throw-off condition

(vi) Guide-vane opening and runner-blade opening (for Kaplan machines) at uprated load conditions.

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 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 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.

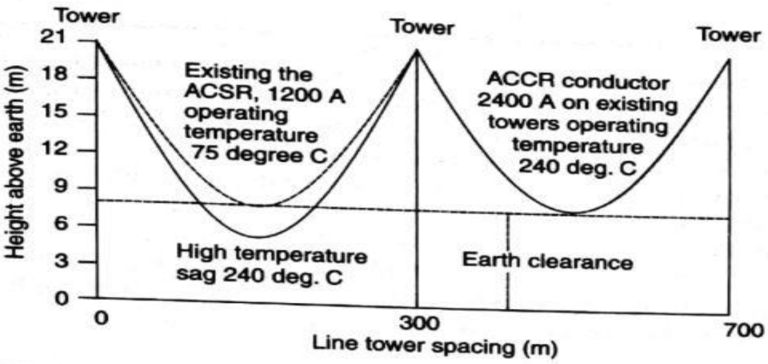


Fig. 5.5 *Typical sags of 220 kV existing line ACSR and upgraded with ACCR*

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

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

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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

7

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.

6	**What are the criteria for planning static VAR system?**

1. Static VAr Compensator (SVC) [6, 26]

An SVC is an automatically controlled supply of VArs. The supply of VArs is regulated by the thyristor switching of reactors or capacitors in shunt with the transmission or distribution system. The result is that the voltage of the bus at the location of the SVC will be controlled. The response time of an SVC is in the range of a few cycles and can be switched as often as the control allows.

Fixed and switched shunt capacitors and reactors have been used to supply VArs for steady-state VAr regulation as a supplement to the automatic VAr regulation. Switched banks can be regulated by automatic controls. The controls for automatically switched shunt capacitor banks are much slower than the SVC controls and the system is limited to the repeat rate of switching owing to the decay time of the capacitors. Switched banks produce transients when switched. However, the addition of shunt-capacitor banks can make the transmission and distribution systems even more sensitive to transient voltage change in the system. Static VAr Systems (SVSs) contain mechanically switched shunt capacitors with an automatic control. SVSs typically have response times faster than the switched capacitor of reactor systems, but slower than an SVC.

We may decide the following in the process:

(a) If an SVC is needed
(b) Performance criteria
(c) Where to locate an SVC
(d) What size to specify
(e) What type to choose

2. System Characteristics which Require an SVC

An SVC provides the fastest response to the need for the supply of VArs of any system available today. The minimum response time for a stable system is dependent upon the short-circuit strength of the transmission

system. Typical response times are in the range of 2–3 cycles. An SVC can operate over its complete rating range in a few cycles repetitively.

Rapidly varying loads cause voltage fluctuations in the transmission or distribution system. Arc furnaces, welders, steel rolling mills, induction furnaces, cement mills, large pumps and compressors, mining shovels, wood choppers, and electric traction loads are examples of rapidly varying loads. Many times, the industry with these loads does not complain, but the other electricity-using consumers in the area do. SVCs are fast enough to stabilise voltage for the types of applications listed above and reduce or eliminate consumer complaints of voltage fluctuations.

Weak transmission and distribution systems with varying loads are applications which could be served by an SVC. If the load is constant, switched capacitors can usually supply the VArs for the load and the line losses, thereby reducing current in the line, improving the power factor and thus regulating the voltage. If the load varies and the switched banks cannot be dispatched rapidly enough to meet the load then an SVC may be required. The quality of the product for some industrial loads is affected if the voltage varies too much. The quality of a weld is one example; an SVC can stabilise the voltage at the welder so that the same electrical conditions exist for each weld. The quantity of a product which can be produced is often a function of the voltage level available. Electric arc furnaces can produce more steel with an SVC than without it, owing to the elimination of the voltage drop through the transmission system and the step-down transformers to the arc furnace,saving time for the industry and earn more revenue for the electric utility.

Addition of an SVC near a heavy load on a weak transmission system will make the transmission line appear stronger. Depending on the load and the line characteristics, the line capacity can theoretically be doubled. A practical rule of thumb for transmission lines is that an additional 25% can be added to the capability of a transmission line with the use of an SVC.

An SVC can make it possible to serve some industrial loads at levels three to four times higher than could be served with the existing transmission and distribution system without the SVC. The reason for this is that many 'distressed' loads tend to be detrimental to the transmission and distribution systems which serve them. Large motor loads, such as mining shovels, are a good example. If the voltage serving a motor drops substantially, the current increases greatly, and the voltage drops further. The result is that the transmission and distribution system cannot serve the load.

Improvement of the stability of a transmission system following the outage of a line or transformer is another use of SVCs. The SVC is usually fast enough to catch a system which has lost a major line or transformer. A system following the clearing of a fault on a line or transformer will have a transient behaviour which deviates from the steady state. If the loss of line or transformer is near a major load, the voltage will be depressed. As mentioned above, if the load has substantial motor components to it, the voltage will drop and the system may collapse following severe disturbance. Air conditioners, a large number of electricity-driven irrigation pump tubewells, and large industrial pumps and compressors have this characteristic. The SVC can supply the transient VAr requirement to return the system voltage to normal conditions and the system to stable operation.

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.