HVDC TRANSMISSION

2 MARKS Q&A

UNIT-1

PART-A

1. Give the types of dc links.
   a. monopolar, b. bipolar c. homopolar

2. What is monopolar link?
   Monopolar is a type of dc link which has one conductor usually of negative polarity and use ground or sea return.

3. What is bipolar link?
   Bipolar is a type of dc link which has two conductors, one positive and the other negative.

4. What is homopolar link?
   Homopolar is a type of dc link which has two or more conductors all having the same polarity (usually negative) and always operated with ground or metallic return.

5. State at least two hvdc systems in service, in india.
   1. Rihand-Delhi (1991-92)-1500 MW, ± 500KV, 814 km
   2. Talcher-Kolar(2003)- 2000MW, ± 500KV, 1400 km

6. State at least two hvdc systems in service, in the world.
   1. Swedish Main land- Island of Gotland (1954)- 20MW, 100KV
   2. Utah- California (USA) - 2000MW, ± 500KV, intermountain project

7. Define power grids or national grid.
   Power grids are electric power system networks, which have conductors transmitting power between the different parts of the country (regions) by connecting all power plants with load centers.

8. Name the power grid operator in India.
   PGCIL- Power Grid Corporation of India Limited

9. What is the use of hvdc link?
   Hvdc link is used to transmit the dc power between sending and receiving end stations.

10. What are the modern trends in converter control of dc transmission?
    Light Triggered Thyristors (LTT) usage in power converters, Electrically Triggered Thyristors (ETT) usage in power converters, GTO and IGBT based power converters, dc breakers, Capacitor Commutated Converters (CCC).

11. What are the areas of applications of dc transmission?
    Long distance bulk power transmission, Asynchronous interconnection of two adjacent systems, Submarine/underground cable transmission, control of stabilization of power flows in AC ties

12. List the applications which are considered as representative for hvdc transmission planning.
    Long distance bulk power transmission, Asynchronous interconnection of two adjacent systems, Submarine/underground cable transmission, control of stabilization of power flows in AC ties

13. State the factor on which the comparison of ac and dc transmission system can be made.
    Economics of transmission, technical performance, reliability, Skin effect, corona losses etc.

14. What are the stability limits in transmission line?
    The maximum power transfer capacity is limited by the considerations of thermal limit, steady state stability and transient stability.

15. What are the basic requirements of transmission line?
    1. Power transfer capability
    2. minimum transmission losses
    3. lowest cost
    4. minimum outages

16. What is break even distance?
    It is the distance at which the cost of ac transmission and dc transmission meet together.

17. Give the highest operating dc voltage in India.
    ± 500KV (800KV project is in progress, India steps in 1200KV in future)

18. Give the first hvdc project commissioned in india and its details.
    Vindyachal(1989) – BTB, 500MW, **2 × 69.7**KV

19. Give some advantages of hvdc transmission system.
    1. Lower losses- corona,R.I
    2. Suited for long distance water crossing
    3. Asynchronous interconnection
    4. No switching transient
    5. No charging current
    6. Controllability of active power in transmission line.

20. Give some disadvantages of hvdc transmission system.
    1. Converter stations are much expensive
    2. Converters produce lot of harmonics
    3. Economical only for long distances
    4. Not easy to step up or step down dc voltages directly.

21. Why negative pole is used in monopolar link?
    Negative pole is used to avoid corona loss and communication interferences.

22. What is BTB connection?
    Back to back connection provides asynchronous interconnection between two adjacent systems. Rectification and inversion are carried out in the same converter station with dc line.

23. What is multi-terminal dc link (MTDC)?
    MTDC system provides tapping of power from existing two terminal systems (point to point system). It has more than two converter stations, some of them operating as rectifiers and others as inverters.

24. List some pioneer companies doing hvdc projects.
    BHEL, ABB (Asea Brown Boveri), SIEMENS, GEC ALSTHOM

25. Abbreviate the terms MTTF and MTTR.
    MTTF- Mean Time To Failure
    MTTR- Mean Time To Repair

26. Give the applications of hvdc transmission.
27. Long distance bulk power transmission, Asynchronous interconnection of two adjacent systems, Submarine/underground cable transmission, control of stabilization of power flows in AC ties

28. Give the usage of smoothing reactor.
    1. To limit the short circuit current
    2. To prevent the commutation failure due to rate of rise of current or dip in the inverter ac voltage

29. Define short circuit ratio (SCR).
    The strength of ac systems connected to the terminals of a dc link is measured in SCR.

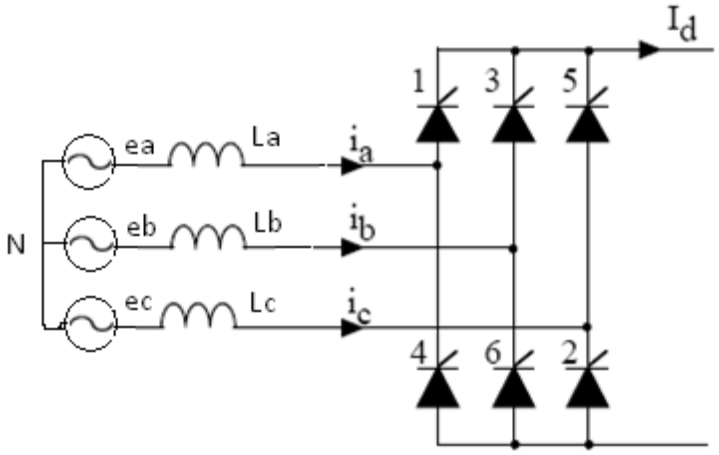
$$SCR = \frac{\text{short circuit level at the converter bus}}{\text{rated dc power}}$$

UNIT-2

Part-A

1. What is GRAETZ Bridge?

The six pulse bridge converter is called GRAETZ Bridge



2. Distinguish between VSC and LCC?

TECHNOLOGY	HVDC Classic(LCC)	HVDC Light(VSC)
Semiconductor (control)	Thyristor (turn on only)	IGBT (TURN ON/OFF)
Power control	Active only	Active/reactive
Ac filters	Yes	No
Minimum Short Circuit Ratio	Less than 2	0
Block Start capability	NO	Yes

3. How the firing is done in converter station?

A valve control circuit generate firing signal, each thyristor level receives signal directly from a separate fiber optic cable

4. Define Pulse number?

Pulse number is the ratio of base frequency of DC voltage ripple to the fundamental frequency of ac voltage. It is also defined as the number of ripple of dc voltage per cycle of AC voltage

Pulse number, P = qrs

Where, q =no. of valves in commutation group
r=no. of valves connected in parallel
s=no. of valves connected in series

5. Define commutation group?

Commutation group is defined as a group of valves in which only one valves conduct at a time (neglecting overlap).

6. Define commutation?

Commutation is the process of transfer of direct current from one path to another with both paths carrying current simultaneously.

7. Define angle of overlap (u)?

Overlap angle is the angle during which the both converter arms undergoing commutation are carrying current.

- Time during which two consecutive converter carrying current simultaneously.

8. Define delay angle (α)?

Angle between the voltage crossings of phase voltages undergoing commutation is called delay angle.

- $\alpha=\pi-\beta$
- $\alpha=\pi-\gamma-u$.

- Time duration from zero crossing of idealized sinusoidal commutating voltage to starting instant of forward current

9. Define extinction angle (γ) or margin angle?

It is angle between end of commutation and next voltage crossing of phase voltages undergoing commutation.

- $\gamma=\beta-u$
- $\gamma=\pi-\alpha-u$
- Time from end of current conduction to zero crossing of idealized commutating sinusoidal voltage.

10. Define angle of advance (β)?

Time from starting of current to zero crossing of idealized sinusoidal commutating voltage is known as angle of advance.

- $\beta=\pi-\alpha$
- $\beta=\gamma+u$

11. Overlap is due to what?

Overlap is due to leakage inductance of converter transformer and/or impedance in the supply network.

12. List the modes of converter operation with overlap?

- 2&3 valves are conduction(u<60)
- 3 valve conduction(u=60)
- 3&4 valve conduction(u>60)

13. Give the objective of PWM?

(i) To control output AC voltage for the constant dc voltage.

(ii) To minimize the harmonics, switching loss, generation of noise etc..

14. Why the feedback control of power in a dc link is not desirable?

(i)At low dc voltage the current required is excessive to maintain the required level of power; this can be counter-productive because of excessive requirements on reactive power which depresses the voltage further

(ii) Constant power characteristics contribute to negative damping and degrades the dynamic stability.

15. What is commutating voltage?

It is defined as the voltage appearing on the DC line when no commutation is taking place.

16. What is commutation reactance?

It is defined as the reactance of the circuit consisting of commutating arms and the commutating voltage source during the process of active commutation. Commutation reactance reduces steepness of rise of current in oncoming valve arm. It is pre-dominantly inductive due to the reactance of transformer winding.

17. Give the function of valve group control?

It oversees valve monitoring and firing logic through optical interface. It also include bye-pass pair selection logic, commutation failure protection, tap changer control, converter start/stop sequence, margin switching and valve protection circuit..

18. List the type of firing angle control?

1) Individual phase control (IPC)
2) Equidistant pulse control (EPC)
   - Pulse frequency control(PFC)
   - Pulse period control
   - Pulse phase control(PPC)

19. What are the types of control in converter operation?

- Constant current control(CC)
- Constant DC voltage control
- Constant AC voltage control
- Constant extinction angle control(CEA)

20. What are 12 pulse converters?

- Two six pulse converter are connected in series
- For HV rating, ease of control and protection
- 30degree phase shift between consecutive pulse is obtained.

21. Draw the equivalent circuit of bridge converter/rectifier, inverter, and HVDC link.

- Refer K.R.Padiyar book (second revised edition) page nos. 53, 84

22. Draw the timing diagram of firing instant of LCC without/with overlap.

- Refer K.R.Padiyar book (second revised edition) page nos. 27, 51

UNIT III

PART-A

1. **List some of the converter faults?**

There are three basic types of faults that can occur in converters given below:

(i) Faults due to malfunctions of valves and controllers

a) Arc backs (or back fire) in mercury arc valves

b) Arc through (fire through)

c) Misfire

d) Quenching or current extinction

(ii) Commutation failures in inverters

(iii) Short circuits in a converter station

2. What is self-clearing faults? List some of the self-clearing faults?

Some of the converter faults such as commutation failure, arc through and misfire are self-clearing if the causes that led to these faults are of transient nature. However, they can still cause a major disturbance unless the system including the controllers is properly designed.

3. What are the causes of faults in DC system?

The faults in a DC system are caused by

(i) Malfunctioning of the equipments and controllers and

(ii) The failure of insulation caused by external sources such as lightning, pollution etc.,

4. Define arc back?

The arc back is the failure of the valve to block in the reverse direction and results in the temporary destruction of the rectifying property of the valve due to conduction in the reverse direction.

5. Define arc through?

This is a fault likely to occur mainly at the inverter station, where the valve voltages are positive most of the time (when they are not conducting).

6. Define misfire?

Misfire occurs when the required gate pulse is missing and incoming valve is unable to fire. The probability of the occurrence of misfire is very small in modern converter stations because of duplicated converter controls, monitoring and protecting firing of valves.

7. Define current extinction (or) quenching?

The extinction of current can occur in a valve if the current through it falls below the holding current. This can arise at low values of the bridge currents when any transient can lead to current extinction.

8. Define commutation failure?

The reduction in the voltage or increase in the current or both can result in an increase in the overlap angle which can result in $\gamma < \gamma_{min.}$ This gives rise to commutation failure.

9. Define false firing?

The firing of a valve or an arm at an incorrect instant is known as false firing.

10. Define firing failure?

The failure to achieve firing of a valve or an arm during the entire forward voltage interval is known as firing failure.

11. Define conduction-through?

In inverter operation the situation that a valve or an arm continues conducting at the end of the normally conduction period or at the end of the hold-off interval.

12. Define break-through?

The temporary loss of the reverse blocking ability of a controllable valve or an arm with the result that forward current is able flow even the valve or arm should normally be blocked.

13. Define valve breakdown?

A failure that permanently deprives a valve of its property to block voltage.

14. What is forward breakdown?

A failure that permanently deprives a valve of property to block forward voltage.

15. What is reverse breakdown?

A failure that permanently deprives a valve of its property to block reverse voltage.

16. What are the types of over voltage?

The types of over voltages, as in a AC system, can be classified into three categories:

1. The switching overvoltages (with wavefront times of more than 100ms)
2. Temporary overvoltages (lasting few seconds)

3. Steep front overvoltages (with front times in the range of 0.3 to 3 msec).

17. What is corona?

Luminous discharge due to ionisation of air surrounding an electrode (conductor, hardware, accessories or insulator) caused by voltage gradient exceeding a certain critical value.

18. What are the effects of corona in DC line?

The effects of corona are

1. Corona loss
2. Radio and television interference
3. Audible noise
4. Space charge field

19. What is the functions of smoothing reactor?

The functions of smoothing reactor are:

1. They decrease harmonic voltages and currents in the DC line.

2. They smooth the ripple in the direct current in order to prevent the current becoming discontinuous at light loads.

3. They reduce the incidence of commutation failure in inverters caused by dips in the AC voltage at the converter bus.

20. Write down the expression for Radio Interference?

The expression for RI is obtained as

$$\mathbf{RI=25+10 \log n+1.5 (g-g_o)}$$

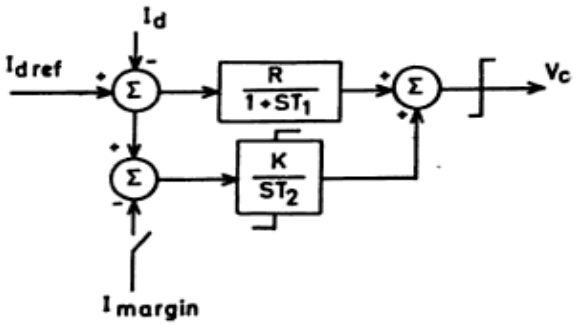
21. What is transient overvoltage?

Pole to ground faults in bipolar DC lines can result in transient over voltages in the healthy pole of magnitude exceeding 2.0 p.u.

The maximum over voltages occur at midpoint in a pole when the fault is also at the midpoint of the other pole.

22. Draw the block diagram for current controllers?

The block diagram for the current controller is



Block diagram of current controller

23. What is surge arrester?

When a switching surge appears, the resistance of the surge arrester decreases thus causing a large discharge current to flow to earth. The switching surge is thus diverted to the earth and its energy is absorbed by the surge arrester. Once the surge disappears from the system, the resistive properties of the surge arrester improve and it again acts like an open circuit. Thus the system voltage is not subjected to an earth fault.

The two main types of surge protection devices used for reducing the magnitude of the surge voltage are:

i) Metal oxide (e.g. ZnO) type surge arrester;
ii) Capacitance-resistance (C-R) type surge suppressor.

24. What are the categories of overcurrent due to faults?

The faults producing overcurrent are classified into 3 categories:

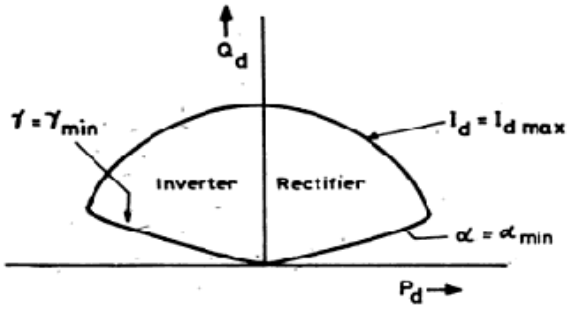
1. **Internal faults** which cause high overcurrents but are very infrequent.
2. **Line faults** which cause overcurrents in the range of 2 to 3 p.u.
3. **Commutation failures** at inverter may be quite frequent.

UNIT –IV

PART-A

1. **Draw the operating region of bridge converter?**

The region of operation of Converter Bridge is bounded by the limits on the DC current and the firing angle. Neglecting the minimum current limit, the operating region of a bridge in $P_d - Q_d$ plane for a constant (rated) AC voltage is given below:



Operating region of a bridge in $P_d - Q_d$ plane

This region is bounded by i) minimum α characteristics ii) minimum γ characteristics iii) constant rated DC current.

2. **Draw the phasor diagram for inverter and rectifier?**

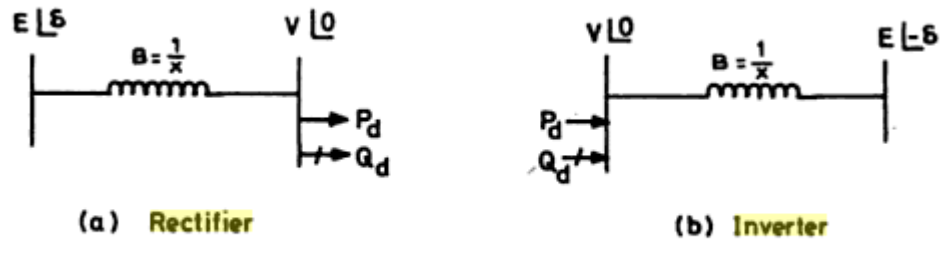
The phasor diagram for inverter and rectifier is

Phasor diagram (a) rectifier (b) inverter

Where φ is the power factor angle

3. Draw simplified system diagram for inverter and rectifier?

A simplified diagram for inverter and rectifier are given below:



Simplified system diagram (a) rectifier (b) inverter

4. What are the types of Static VAR system (SVS)?

There are basically three types of SVS schemes. They are

i) Variable impedance type SVS
ii) Current source type SVS
iii) Voltage source type SVS

5. What are the sources of reactive power?

The reactive power requirements of the converter are met by one or more of the following sources:

i) AC system
ii) AC filters
iii) Shunt capacitors
iv) Synchronous condensers
v) Static var system.

6. What is forced commutation?

The reactive power equirements of a converter can be reduced to zero or evereversed if the forced commutation is used. This also helps in avoiding commutation failures in invrters.

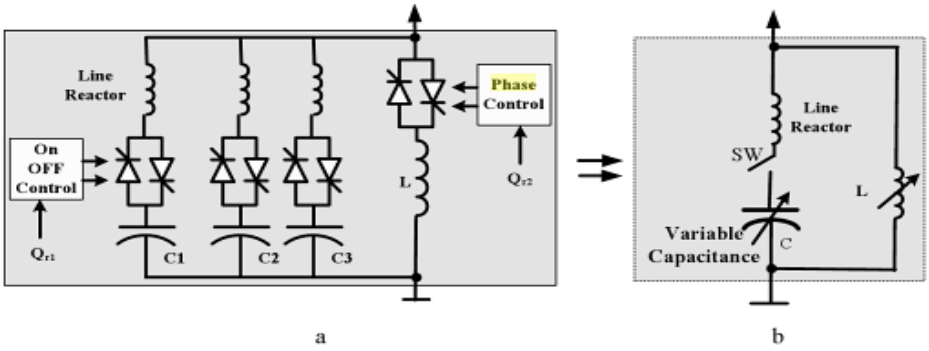
7. Define TCR and TSC?

TCR is a Thyristor Controlled Reactor. In this scheme the duration of the current flowing through reactor during every cycle is controlled by controlling phase angle of thyistor gate pulses.

TSC is a Thyristor Switched Capacitors. The principle of thyristor switch is employed in switching of required number of capacitor units. The thyristors are used as power switching device.

8. Draw single phase TCR and TSC?

A single phase TCR and TSC are



a.TSC-TCR. b.Equivalent model

9. What is non-characteristics harmonics?

These are also called as abnormal harmonics which are caused by

i) Firing angle errors
ii) Negative sequence components in the converter bus AC voltage and
iii) Unequal converter transformer leakage impedances.

10. What is characteristics harmonics?

The converters in HVDC stations generate harmonics – both AC and DC. Some of these harmonics are called characteristics harmonics that will always be present even under ideal conditions.

11. What is a filter ?

The circuit comprising of R, L, C which reduces the amplitude of current or voltage harmonics of one or more frequency order.

12. What are the types of AC filters ?

The following are various types of AC filters that can be used :

1. Single tuned filter
2. Double tuned filter
3. High pass filter

   i) Second order filter

   ii) C type filter

13. What is the effect of unbalanced voltages ?

The presence of the negative sequence component in the AC voltages shifts the zero crossing of the commutation voltages. With individual phase control (IPC) system, this introduces firing angle dissymmetry and results in non-characteristics harmonics even if the DC current assumed to be constant and the overlap angle is neglected.

14. Define harmonic distortion ?

This can be measured by

$$D = \frac{\sum_{n=2}^{m} In\ Zn}{E1} * 100$$

in percentage where In,Zn and E1 are the harmonic current injected, the harmonic impedance of the system and the fundamental component of the line to neutral voltage respectively. m is the highest harmonic considered.

15. Define Telephone Influence Factor (TIF) ?

This is an index of possible telephone interference and is defined as

$$TIF = \frac{[\sum_{n=2}^{m}(In\ Zn\ Fn)]^{\frac{1}{2}}}{E1}$$

Where

$F_{n=} 5nf_1p_n$

16. Define Telephone Harmonic Form Factor (THFF) ?

This is analogous to TIF except that

$F_n = (nf1/800) W_n$

Where

W_n is the psophometric weight at the harmonic order n.

17. Define AC and DC filter ?

AC filters are designed to reduce the flow of harmonic current into associated AC system.

DC filters are which in conjuction with DC reactors and DC surge capacitors serves primary function of reducing current or voltage ripple on DC line.

18. What are the effects of DC filters ?

The effects of DC filters are

1. Maximum voltage TIF on DC high voltage bus
2. Maximum induced noise voltage (INV) in milli volts/km in a parallel test line one kilometer away from the HVDC line.
3. Maximum permissible noise to ground in dB in telephone lines close to HVDC lines.

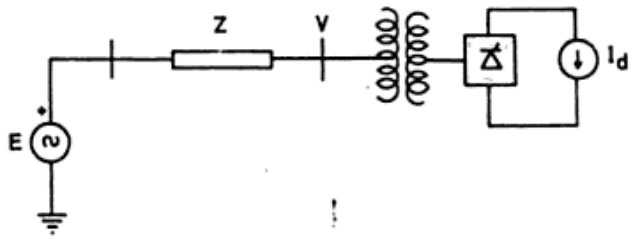
19. How to protect the filters ?

The filter is exposed to an overvoltage during switching in and magnitude of this overvoltage is a function of the short circuit ratio and the saturation characteristics of the converter transformer.

If the network frequency deviates from the nominal value, higher currents and losses will result in AC filters. If they exceed the limits, the filters have to be disconnected.

20. Draw the equivalent circuit of harmonic current ?

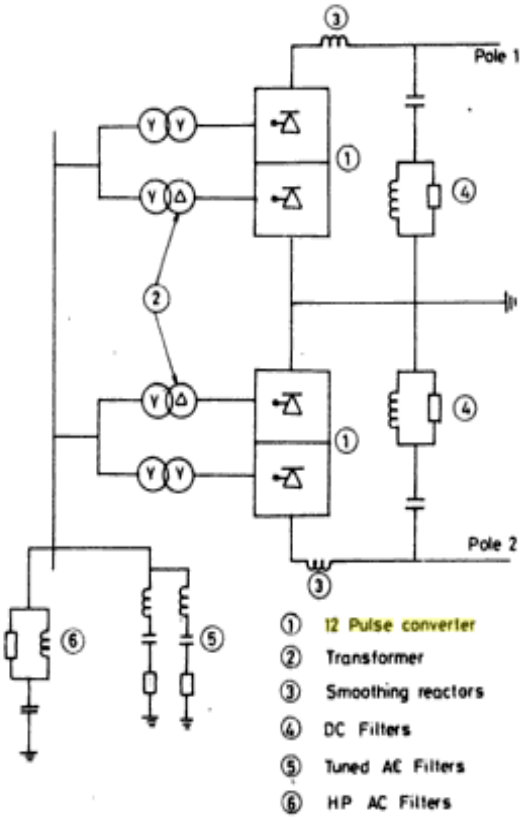
The equivalent circuit for harmonic current are



AC system represented by an equivalent circuit

21. Draw schematic diagram for 12- pulse converter ?

The schematic diagram for 12- pulse converter is



Schematic diagram of a typical HVDC converter station.

UNIT – V

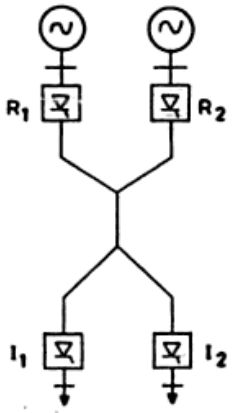
PART-A

1. **Define MTDC?**

A multi terminal DC (MTDC) system has more than two converter stations, some of them are operating as rectifiers and others as inverters. The simplest way of building a MTDC system from an existing two terminal system is to introduce tappings.

2. **Draw MTDC system configuration?**

The MTDC system configuration for bulk power transmission is given below:



MTDC system configuration for bulk power transmission

3. **Write the disadvantage of point to point system? or Why we are going for MTDC system ?**

HVDC transmission systems designed and operated so far are point to point systems with two terminals (converter stations) but in the multi-terminal DC (MTDC) system has more than two converter stations.

4. **What are the types of MTDC system?**

There are two possible types of MTDC systems. They are

i) Series

ii) Parallel

The parallel MTDC systems can be further subdivided into two categories:

a) Radial

b) Mesh

5. Define parallel MTDC system?

The current in all the converter stations except one are adjusted according to the power requirements. One of the terminals operates as a voltage setting terminal at constant angle or voltage.

6. Define series MTDC system?

In a series connected system, the current is set by one converter station and is common for all the stations. The remaining stations operate at constant angle(extinction or delay) or voltage control.

7. Compare series MTDC and parallel MTDC ?

The comparison between the series MTDC and parallel MTDC are given below

i) High speed reversal of power is possible in series systems without mechanical switching. This is not possible in parallel systems.

ii) Insulation coordination is a problem in series systems as the voltage along the line varies.

iii) There are increased losses in the line and valves in series systems, in comparison to parallel system. The system operation in series systems can be optimized by operating the largest inverter at rated voltage.

8. What are the control methods of MTDC systems ?

The control methods of MTDC systems are

i) Current margin method

ii) Voltage limiting control

iii) Use of Decentralized Current Reference Balancer (DCRB)

iv) Two ACR (Automatic Current Regulator) method.

9. What are the protection of MTDC system ?

The protection of MTDC system are

i) The system can be shut down following a fault in DC line or converter station and the faulted component isolated using high speed disconnect switches.

ii) System reliability considerations dictate the need for fast clearing of fault with minimum disturbance to the healthy part of the system.

iii) A major problem is the large drop in the DC voltage even for distance faults. This requires fast detection and clearing of faults to maintain power transfers.

10. What are the drawbacks of Voltage Limiting Control ?

The drawbacks of this scheme are

i) The disturbance in the AC system connected to an inverter station can result in other inverters getting unloaded (due to drop in the DC voltage). This may cause adverse effect on the AC system supplied by healthy inverter stations.

ii) Two or more terminals can operate in the voltage controlling mode forcibly, in the case of loss of a terminal resulting in indeterminate distribution of currents in those terminals.

iii) Currents during DC line fault or commutation failure are likely to be higher without additional measures.

11. What are the characteristics of DC breakers ?

The breaker is characterized by four variables of interest in its applications to the system. They are :

i) Voltage capability

ii) Current capability

iii) Energy capability

iv) Switching time

12. What are the applications of DC breakers ?

The applications of DC breakers is required mainly for fault clearing in MTDC systems. However, even for two terminal DC systems, the DC breakers can be useful in the following situations :

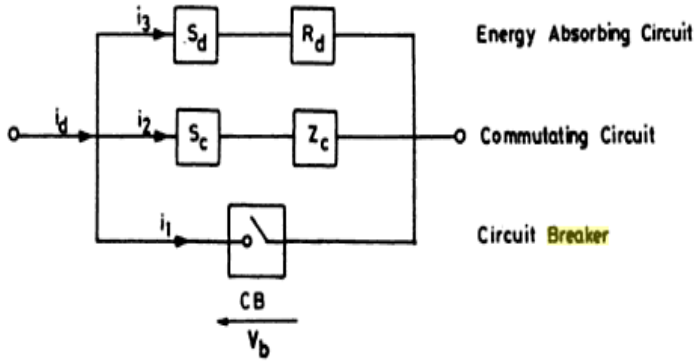
i) When the converters feed two parallel DC lines

ii) When parallel connected converters feed the same line.

iii) When current needs to be transferred from the ground return to the metallic return during the monopolar operation. The breaker for this application are termed as Metallic Return Transfer Breakers(MRTB).

13. Draw the arrangement of DC breakers ?

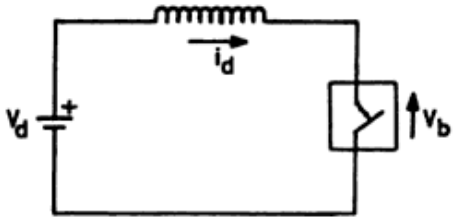
The general arrangement of a HVDC circuit breaker is shown below :



Arrangement of a DC breaker

14. Draw the simple representation of DC circuit with breaker ?

The simple representation of DC circuit with breaker is



Simple representation of DC circuit with breaker

15. Define critical withstand voltage ?

The critical withstand voltage (CWS) is defined as

$$\mathbf{CWS = CFO - 3\sigma}$$

Where

σ is the standard deviation.

The CWS represents a voltage level with 0.13 % probability of flashover.

16. Define transient overvoltage in DC line ?

The maximum overvoltage occurs at midpoint in a pole when the faults is also at the midpoint of the other pole. For off-centre faults, the maximum overvoltages occurs at a location which is a mirror image of the fault location (with respect to the midpoint).

17. What is critical flashover voltage (CFO) ?

The critical flashover voltage is defined as the statistical mean (with 50 % probability) of a data group (usually 20 % flashovers) on a specific insulator specimen.