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DEPARTMENT OF ELECTRICAL AND ELECTRONICS ENGINEERING
Year/Sem: IV/VIII

EE 6010 HIGH VOLTAGE DIRECT CURRENT TRANSMISSION

Unit-I INTRODUCTION
PART-A

1. **List out two merits of AC and DC transmission.**

DC Transmission

- It requires only two conductors as compared to three for a.c transmission
- There is no skin effect in a d.c system.
- A d.c line has less corona loss and reduced interference.

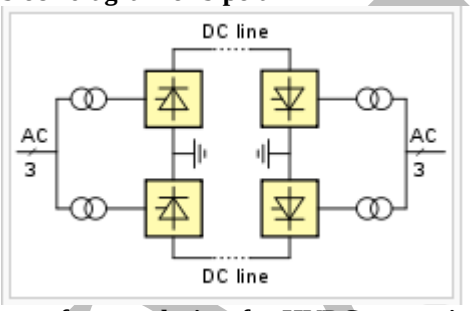
AC Transmission

- The power can be generated at high voltages
- The maintenance of a.c sub-station is easy and cheaper

2. **What are the types of DC link?**

- Mono polar link
- Bipolar link
- Homo polar link

3. **Draw the block diagram of bipolar link**



4. **List the types of power devices for HVDC transmission**

1. Thyristor
2. Insulated fiats bipolar transistor
3. GTO-gate turn-off thyristor
4. LTT- Light hissered thyrisor
5. Mos-controlled thyristo(MCT)

5. **Write the advantages and disadvantages of HVDC transmission?**

Advantages

1. Full control over power transmitted
2. The ability to enhance transient and dynamic stability in associated AC networks
3. Fast control to limit fault current in DC lines
4. Reduced transmission lines.
5. Interconnection of systems operating at different frequencies

Disadvantages

1. Inability to use transformer to change voltage levels
2. High cost of converter equipment
3. Generation of harmonics which requires AC and DC filters, adding to the cost of converters station
4. Complexity of control

6. **Mention the some of HVDC projects from abroad?**

1. Gotland 1 – 98km, 200kv, 20mw, 1954

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2. HVDC Gotland 2 – vastervik (Sweden) to yipne (Sweden) 92.9km, 150kv, 130mw, 1983

3. Nelson river bipole 2 – sundance(Canada) to rosser (Canada) 937km, ±500kv, 1800Mw, 1985

4. HVDC Tjaereborg - Tjaereborg (Denmark) – Tjaereborg 4.3km, ±9kv, 7.2mw, 2000(interconnection of wind power station)

5. HVDC back-to-back station – eagle pan (USA) - eagle pan (USA)(Texas) ±15.9kv,36mw, 2000

6. Caprivi link – Namibia (gerus) to Namibia zembari 970km, 500kv, 300mw, 2010

7. **What are the types of power losses in thristor?**

1. Forward conduction losses
2. Loss due to leakage current during forward & reverse blocking
3. Switching losses due to ton and toff
4. Gate triggering loss

8. **Define Reliability.**

The reliability of DC transmission system is quite good on exhaustive record of existing HVDC lines in the world in available from which the reliability statistics Can be computed the development of LTT is expected to improve reliability Because of elimination of high voltage pulse transformers and auxiliary supplies For turning on the devices.

9. **Energy Availability.**

It is defined as, Energy Availability=100 $\left[1 - \frac{\text{Equivalent outage time}}{\quad}\right]$

Where equivalent outage time is the product of the actual outage time and The fraction of system capacity lost to outage.

10. **Write down any two application DC transmission?**

- Long distance bulk power transmission
- Underground or underwater cables
- Asynchronous interconnection of A.C systems operating at different frequencies.

11. **What are the factors to be considered for planning HVDC transmission?**

The system planner must consider the factors are,

- Cost
- Technical performance
- Reliability

12. **What are the advantages of LTT over ETT?**

- Infinite gate isolation
- Total noise immunity for the control circuits
- Faster turn-on time
- Elimination if high voltage pulse transformers and auxiliary power supplies.

13. **Distinguish between AC & DC transmission.**

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S.No	AC Transmission	DC Transmission
1	It requires three conductors for transmission	It requires only 2conductors
2	There skin effect is present in AC	There is no skin effect in DC Transmission
3	More corona loss	Less corona loss
4	Stability problem occurs.	No stability problem.

14. **What is meant by MOS controlled thyristor?**

An MCT is a new device in the field of semiconductor-controlled devices. It is basically a thyristor with two MOSFETs built into the gate structure one MOSFET is used for turning on the MCT and other for turning off device. An MCT is a High – frequency, high power, low – conduction drop switching device.

15. **Define break even distance- give its range of value for overhead line**

The variation of costs of transmission with distance for AC and DC Transmission. For distances less them break even distance, AC tends to be economical then DC. And costlier for longer distances. The break even distances can vary from 500 to 800 km in overhead lines.

16. **What is meant by an Asynchronous tie?**

When two power system are connected through DC ties, there is no need of coordinated control. It is called asynchronous fie. The two systems which have different nominal frequencies.

17. **What is LASCR? How does it differ from a conventional SCR?**

Light activated thyristor, also called LASCR. It is turned on by throwing a pulse of light on the silicon wafer of thyristor. This is the major difference to others.

18. **State atleast four HVDC projects in India.**

S.NO	System/Project	Year of Commissioned	Supplier	Power Rating(mw)	Voltage (kv)
1.	National HVDC project-stage-I	1989	BHEL	100	100
2.	NHVDC-stage-II	2000	BHEL	100	200
3.	Rihand-Delhi	1991-92	ABB	750	±500
4.	Chandrapur-padghe	1998	ABB	1500	±500

19. **What are the types of commutation?**

Type of device	Commutation	Initiated by
Conventional Thyristor	Line	AC Line voltage
	Circuit (or capacitor)	Capacitor voltage
GTO, IGBT or MCT	Self	Gate drive

20.Why circuit turn off time should be greater than the thyristor turn-off time?

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Circuit turn off time should be greater than the thyristor turn-off time for re liable turn-off, otherwise the device may turn-on at an undesired instant, a process called commutation failure.

21. What is the turn-off time for converter grade SCRs and inverter grade SCRs?
Turn-off time for converter grade SCRs is 50 – 100 ms turn-off time for converter grade SCRs and inverter grade SCRs and for inverter grade SCRs is 3 – 50 ms.

PART-B

1 Explain in detail about the description of a HVDC transmission system.
2 Briefly explain the types of DC link in HVDC transmission.
3 Compare the AC and DC transmission and mention the applications of DC transmission.
4 Write the advantages and applications of HVDC TRANSMISSION?
5. Explain the planning of HVDC system.
6. Explain the modern trends in HVDC transmission system.

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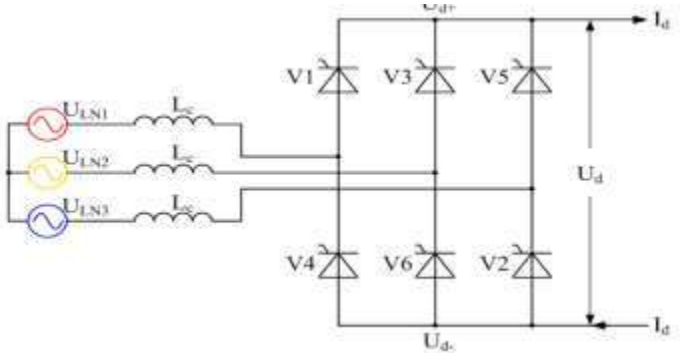
UNIT –II ANALYSIS OF HVDC CONVERTERS

1**. What is firing angle?**

The angle at which thyristor is triggered it is defined as the angle between the zero crossing of the input voltage and the instant the thyristor is fired

2. Draw the circuit of Graetz CIRCUIT.



3. What is meant by pulse number of a converter?

It is defined as the ratio of the base frequency of the DC voltage ripple To the fundamental frequency of the AC voltage is called pulse number.

= _____

4. List some of the converters in HVDC systems.

- Line commutated converter
  i. Six pulse converter
  ii. 12-pulse converter

- Voltage source converter
  i. Basic two level converter
  ii. Three level voltage source converter

5. Define value rating.

The value voltage rating is specified in terms of peak inverse voltage (PIV) it has to withstand. The ratio of PIV to the average dc voltage is an Index of the value utilization.

The average maximum dc voltage across the Converter is given by

$_{do} = \frac{sq}{\pi} EM \quad \frac{\pi}{q}$

6. **What are the merits of twelve or multibridge pulse converter?**

- Reduced filtering requirements and Harmonics are eliminated

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7. How can the converter confi 7. How can the converter configuration defined?

There are several configuration for a converter of a specified pulse Number, we have in addition to the graetz bridge, six phase diametric Connection, cascade of three single phase fall wave converters, cascade of two three phase converters.

8. List the assumption made to develop the equivalent circuit of a converter

Bridge used in dynamic simulation.

- All the values in a bridge have identical characteristics
- A value offers infinite impedance in the reverse direction
- The grading and damping circuits across the values are ignored
- The current id is assumed to be continuous and non zero.
- L/R of each phase of the converter transformer in the same.

9. Define overlap and overlap angle.

Overlap is the phenomenon due to the effect of source inductance on the a.c. side.

The current commutation is delayed due to the source inductance which is normally the leakage reactance of a transformer. The waveforms with commutation period, denoted by μ during which both the outgoing diode and incoming diode are conducting. This period is also known as “overlap” period.

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Or

The commutation period, when outgoing and incoming thyristors are conducting, is also known as the overlap period. The angular period both devices share conduction is known as the commutation angle / overlap angle.

10. Write the assumptions for analysis of 6 pulse converter?

To consider the theoretical analysis of a conventional 6-pulse bridge , the following assumptions are made:

- DC current is constant (i.e. the smoothing reactor is infinite),
- Valves are ideal switches, and
- AC system is infinitely strong (i.e. the 3 phase emfs are balanced and perfectly sinusoidal).

11. Write the average direct voltage expression for graetz circuit?

Vd = Vd0[cosα + cos(α+u) and Vd = Vd0 cosα - RcId

Where; Rc = 3/πωLc = 3/πXc = equivalent commutation resistance

12. Mention the various modes of operation of rectifier characteristics.

Mode I : 2 and 3 valve conduction (u<60)
Mode II : 3 valve conduction only α < 30 deg, u = 60deg
Mode III : 3 and 4 valve conduction mode α > 30 deg,(60<u<120deg)

14. **Mention the various modes of operation of inverter characteristics.**

Mode I : β <60 deg for values of u <60-£ , the characteristics are linear
60deg<β,90deg ; u=60deg - £ = 60deg – gamma = constant
The characteristics are elliptical

Mode II : For u>60deg corresponding to β> 90deg +gamma zero
the characteristics are linear

15. **Mention the various modes of characteristics of 12 pulse converter.**

Mode I : 4 and 5 valve conduction 0 <u < 30deg
Mode 2: 5 and 6 valve conduction; 30deg < u < 60deg
Mode 3: 6 valve conduction 0 < α < 30deg, u = 60deg
Mode 4 : 6 and 7 valve conduction 60deg< u <90deg
Mode 5: 7 and 8 valve conduction, 90deg<u<120deg

16. Draw the equivalent circuit of rectifier.

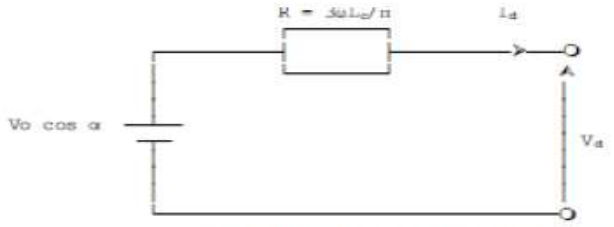

Figure 11.9 - Equivalent circuit for Rectifier

17. Draw the thyristor voltage waveform for inversion for 6 pulse converter.

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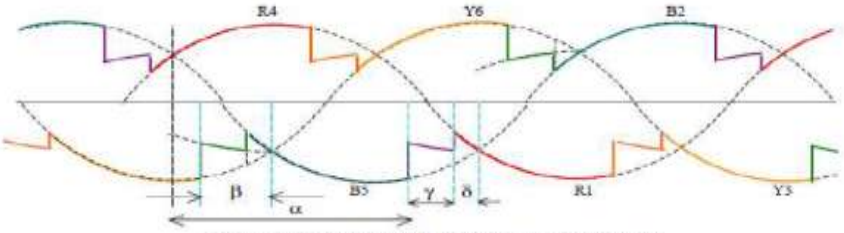


Figure 11.16 - Thyristor voltage waveforms for inversion

18. **Draw the a.c current waveform.**
When star to star connected transformer

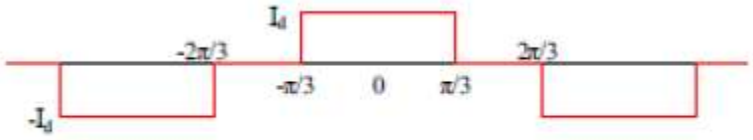


Figure 11.14 - Current waveform on a.c. system

19. When star to delta star connected transformer

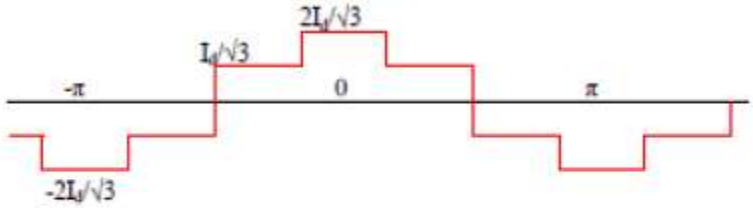
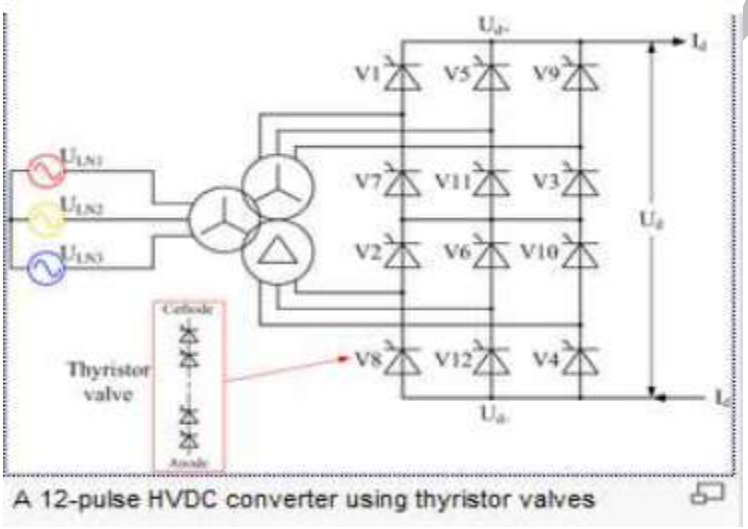


Figure 11.15 - Primary current waveform

20. Draw the circuit diagram of 12 pulse converter.



A 12-pulse HVDC converter using thyristor valves

21. Why series and parallel operation of thristor in HVDC TRANSMISSION?

For higher voltage rating use series operation of thyristor
For higher current rating use parallel operation of thyristor.

22. What is mean by snubber circuits?

A Snubber circuits consists of a series combination of resistance Rs and Capacitance e_s in parallel with the thyristor. A capacitor e_s in parallel with the Device is sufficient to prevent unwanted $\frac{dv}{dt}$triggering of the SCR.

PART – B

1 Explain in detail about the choice of Converter configuration with valve rating and transformer rating
2 Explain the complete characteristics of 12 pulse converter
3 Draw the 6 pulse Greatz converter and analysis the circuit with overlap for mode-1 overlap angle <60deg
4. Explain the parameter and converter bridge characteristics
5. Explain the detailed analysis of HVDC converter.

UNIT III CONVERTER AND HVDC SYSTEM CONTROL

1. What is meant by firing angle control?
The current or extinction angle controller generates a control signal vc, Which is related to the firing angle required. The firing angle controller Generates gate pulses in response to the control signal vc.

2. **Write the features control?**
i) Current order setting can be quickly and reliably changed depending on the requirement
ii) Power reversal can be done easily and quickly
iii) Fault current levels are limited to rated values.

3. **Why the necessity of control in a DC link?**
The expression for current through a DC link it can be observed that the denominator has only resistances, which are small when compared with the reactance of the AC system. Hence, current is sensitive to change in voltage resulting in large fluctuations which can damage the thyristors,

4. **What is the principal of control in DC link?**
The control of power in a DC link can be achieved through the control of current of voltage. From minimization of loss considerations, it is important to maintain constant voltage in the link and adjust the current to meet the required power.

5. What is meant by current and extinction control?

1. The current controller is invariably of feedback type the controller which is PI type.
2. The extinction angle controller can be of predictive type or feedback type With EPC control. The predictive controller is considered to be less Prone to commutation failure.

6. State any four important reasons why the current control is desirable in the Rectifier station under normal operating conditions?

i. The increase of power in the link is achieved by reducing αr, which improves the power factor at the rectifier.

ii. The inverter can now be operated at minimum ע thereby minimize the reactive power consumption.

iii. The operation at minimum extinction angle at the inverter and current control at the rectifier results in better voltage regulation them the operation with minimum delay angle at the rectifier & current control at the inverter.

iv. The current during line fault are automatically limited with rectifier station in current control.

7. How power is reversed in HVDC link?

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The power reversal in the link can take place by the reversal of the DC Voltage. This is done easily by increasing the delay angle at the station initially operating as the rectifier, while reducing the delay angle at the station initially operating as the inverter.

8. Define current margin.

The difference between the current controller settings of the two stations is called current margin(Im). In order to avoid conflict between the two current controllers at the both ens, the rectifier current controller is provided with a higher current order.

Idi = Idr – Im

Where Idi – current order of the inverter

Idr - current order of the rectifier

Im usually about 10% of rated value

9. **Draw backs of constant current control(CCC**).

- Increase in the converter valve voltage stress due to the voltages across the series capacitors
- Increase in the magnitude of AC harmonics as the overlap angle is the reduced for a specified DC current

10. What are the parameters to change current and power transfer in DC link?

i) Control angle of rectifier α

ii) Control angle of inverter β

iii) Tap changer on rectifier side

iv) Tap changer on inverter side

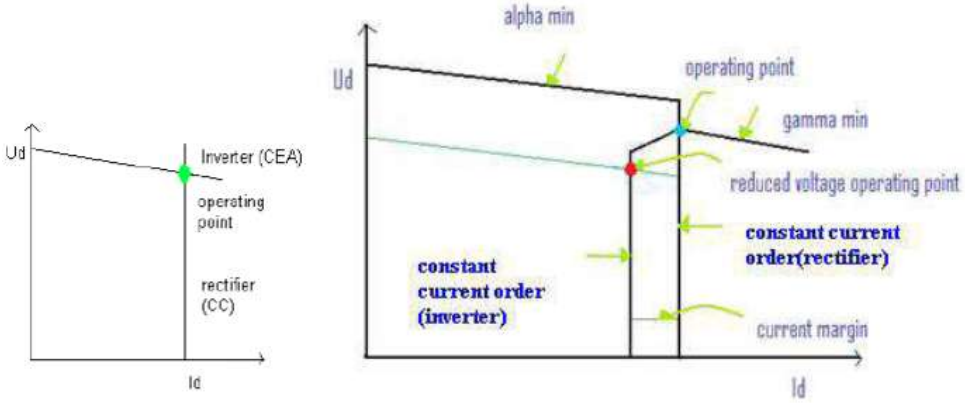
11. What is meant by compounding?

The term compounding a converter implies selection of converter characteristics in order to meet the requirements of regulation and protection

12. Define required regulation.

Converter valves should be operated strictly within their current rating, since there is substantial rise of damage if the current is increased beyond the rated value for a even a short time. Therefore constant current regulation is thus clearly desirable.

13. Draw the characteristics of compounding of inverter.



14. What is the use of transformer tap changer control at the inverter side of an HVDC system?

The on-load tap changer control at the inverter is used mainly to maintain a constant DC voltage. The tap changer control at the rectifier is designed to maintain delay angle within the limits (say 10deg to 20deg) in order to maintain certain voltage margin for the purpose of current control.

15. What is the use of tap changing transformer in HVDC systems?

The tap changing transformer used to increase the power factor obtained in the ac side and maintain the operating point at point A or B in the Vd , id characteristics of rectifier and inverter use tap changing transformer.

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16. Draw the communication link of the HVDC transmission.

A communication link is necessary to carry information from the receiving end to the rectifier regulator and may also be needed for protective purposes, starting purposes and reversal of the direction of power flow

There are 3 main possibilities:

1. Short wave radio link
2. Pilot wires
3. The use of carrier frequency on the power conductors.

17. What is meant by compounding a converter?

The term compounding a converter implies selection of converter characteristics in order to meet the requirements of regulation and protection.

18. What is the need for transformer tap changer control of HVDC converter?

The tap changing transformer used to increase the power factor obtained in the ac side and maintain the operating point at point A or B in the Vd , id characteristics of rectifier and inverter use tap changing transformer.

PART B

1 Briefly explain the principle of DC link control and the converter control basic characteristics.
2 Draw and explain the basic V-I characteristics of HVDC converter control.
3 Explain the operation of inverter compounding and uncompounded inverter.
4. Describe the operation of current regulation from the inverter side
5 Explain the operation of rectifier compounding.
6. Explain the operation of transformer tap changing.
7. Explain in detail the rectifier and inverter compounding with appropriate diagram and expressions
8 Write short notes on the following: a. Transmission characteristics in the rectifier and inverter compounding (4) b. Necessity of communication link in HVDC power transmission

UNIT IV REACTIVE POWER AND HARMONIC CONTROL

1. Mention the performance criteria for selection of harmonic filter

1. Harmonic distortion 2. Telephone influence factor
3.Telephone Harmonic form factor 4. IT product

2. **Mention the Types of filters**

There are basically two types of filters

- Passive filters ---- tuned filters and damped filter; single and double tuned , high pass filters
- Active filters

3. **Differentiate characteristic and non-characteristic harmonics.**

s.no	Characteristics harmonics	Non-characteristics harmonics
1.	It's always presents even under ideal operation, balanced AC voltages, equidistant pulses	Unbalance and distortion in AC voltages
2.	Equal transformer leakage reactance	Unequal transformer leakage impedances
3.	DC current is assumed to be constant h=np±1	DC current is varied h=np

4. State the ill effects of harmonics injected into the AC line?

- Telephone interference
- Extra power looses & consequent heating in machines
- Over voltages due to resonances

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- Instability of converter controls
- Interference with ripple control system used in load management.

5. **What is radio interference?**

The radio interference is mainly due to the positive conductor. This is because of the fact that the corona discharges from the negative conductor are in the form of triple pulses which are uniformly distributed ever the conductor surface.

6.What are the sources of harmonics?

• Arcing devices and Electronic and medical test equipment
• PCs and office machines , Induction Heaters
• Semiconductor based power supply system
• Inverter fed A.C. drives , Thyristor controlled reactors

7. What are the effects of trouble caused by harmonics?

1.Resonance 2. Poor Damping 3. efficiency of motor reduced 4. Overheating of cable 5. Trip of protection 6. Overheating at winding. 7.Increase magnetic losses.

8. **Define THD.**

The THD is a measure of the *effective value of the harmonic components* of a distorted waveform. That is, it is the potential heating value of the harmonics relative to the fundamental. This index can be calculated for either voltage or current

9. What are the means to reduce harmonis?

Using filter (passive and active filters)circuit and increasing pulse number

10. List the causes of non-characteristics harmonis.

a) Imbalance in the operation of two bridges forming 12 pulse converter
b) Firing angle errors
c) unbalance and distortion in AC voltage and
d) unequal transformer leakage impedances

11. Write the effects of unbalanced voltages.

The presence of the negative sequence component in the AC voltages shifts the zero crossing of the commutation voltages.

12. Mension the criteria for selection of DC filter.

a) Maximum voltage TIF on DC high voltage bus

b) maximum induced noise voltage in mv/km in a particular test line one km away from the HVDC line

c) maximum permissible noise to ground in dB in telephone lines close to the HVDC lines.

13. Define short circuit ratio(SCR)

The short circuit ratio is defined as

$= \frac{h}{\qquad\qquad}$

14. What are the factors depends commutation failure?

The recovery from a commutation failure depends on the following Factors

- The response of the gamma controller at the inverter
- The current control in the link
- The magnitude of AC voltage

15. Function of smoothing reactor

A sufficiently large series reactor is used on DC side to smooth DC current and also for protection. The reactor is designed as a linear reactor and is connected on the line side, neutral side.

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PART-B

1. Explain the generation of Harmonics in HVDC system
2. Explain detail about the analysis of single and double tuned AC filters and write the design criteria for AC filters.
3. Explain in detail about the passive and active DC filters with the design criteria.
4. Discuss criteria of design of a.c. filters. Also mention various types of a.c. filters and show their circuit configuration and impedance characteristics
5. Explain the characteristics and non- characteristics harmonics in HVDC converter system.
6. Write short note on the following terms: 1. Harmonic distortion 2.TIF 3. THFF
2. IT and KIT
7. What are the types of AC filters? Also explain with waveforms
8. Write criteria for design of AC filters.

UNIT- V POWER FLOW ANALYSIS IN AC/DC SYSTEMS

1. What is HVDC simulator?
HVDC simulator is similar to transient network analyzer (TNA) which is Used to determine over voltages in AC systems due to switching surges and load refection.

2. What are the requirements of a good simulation tool?
The requirements of good simulation tool are as follows,

1. Easy maintenance 2. Accuracy of solution
2. Flexibility of use
3. Reduced cost
4. Real time simulation 6. Easy monitoring and control

3. **List some tools used for the simulation of HVDC simulation.**
1. Physical simulator
2. Parity simulator
3. Analog computer
4. Digital computer
5. Hybrid computer

4. Application of HVDC transmission

- Long distance bulk power transmission
- Underground or under water cables
- Asynchronous interconnection of AC systems operating at different Frequencies
- Control and stabilization of power flows in AC ties

5. What is parity simulator?
A parity simulator is essentially a synthetic breadboard which Electronically simulates the physical terminal characteristics of Each network element rather than its mathematical input/output

6. **List the assumption made to develop the equivalent circuit of a converter**
Bridge used in dynamic simulation.

- All the values in a bridge have identical characteristics
- A value offers infinite impedance in the reverse direction
- The grading and damping circuits across the values are ignored
- The current id is assumed to be continuous and non zero.
- L/R of each phase of the converter transformer in the same.

8**. What are the applications of DC simulator?**
The application of DC simulator are,

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1. Insulation coordination
2. Testing of controllers and their optimization
3. Evaluation of surge arrestor ratings
4. Harmonic analysis

9**. State the advantages of parity simulator?**

It avoids drawback of an analog computer simulationThe advantages of an analog computer interms of change in Time scaling are retained while eliminating the drawbacks
The principle of parity simulation permits hybrid structure.

10. Write the system studies required for design of HVDC system.

i) Dc power transfer under various normal and contingency conditions
ii) Reactive power requirement
iii) DC terminal arresters
iv) AC and DC filter design
v) Controller requirements under various normal and faulted system conditions

11. Write the advantages of digital dynamic simulation.

- Easy transportability and maintenance
- Reduced cost of simulation
- Flexibility interms of representing any components of the system**.**

12. Write the disadvanges of digital dynamic simulation.

1. Increased simulation time 2. Lack of adequate mathematical models
3. Numerical problems and Lack of interactive capability

13. Mention the types of valve model.

3 types are:
Time varying imdedance, ideal switch which is controllable and ideal switch in series with a constant voltage source.

14. What are the approaches used for transient analysis of electrical network?

1. The use of trapezoidal rule of integration to tramsform the energy storage elements to resistive elements with current sourse across them which represent the past history
2. Formulation of stage equation for network

15. What are two types of programs used for HVDC system studies?

i) AC/DC load flow analysis
ii) AC/DC transient stability analysis

16. What are advantages of EMPT representation of elements in DC system?

i) Easy of obtaining solutions particularly for piecewice linear components
ii) Inclusion of models for distributed lossless elements such as long transmission lines.

17**. Write the equations representing the equivalent circuit of lumped element.**

For Inductor: $i(t) = (1/L)\int v(t)\,dt + i(t-h)$
Apply trapezoidal rule $I(t) = (h/2L)\,[\, v(t) + v(t-h) + i)\, t-h)$
For capacitor $I(t) = -(2C/h)\,[\, v(t) + v(t-h) + i(\, t-h)$

18. Drawbacks of parity simulation.

The problem of offset voltages and currents of OP-AMP used. Each component of a parity simulator is electrically isolated, there could be problems of interconnection and EMC.

19. Mention the some problems studied for DC simulator.

The development of concepts and equipment for control and protection of HVDC
systems.
i) Control of power, current and extinction angle in 2 terminal system

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ii) Evaluation of the control performance under AC and DC faults
iii) Evaluation of overcurrent and over voltages stresses in various components.
iv) Analysis of various AC/DC system interations
v) Anlysis of AC and DC harmonics

20. Comparison between insulation characteristics of DC and AC cable.

1. In the ac cable case, the radial dielectric stress distribution is dependent upon the perttivity of the dielectric. Where in the case of dc the stress distribution determined by insulation resistance.
2. In the case of an ac cable the maximum stress always appears at the conductor surface, but with dc the maximum sress may appear at the conductor surface or at the outer boundary of the dielectric, depending on the temperature.
3. The dc strength of a dielectric is much higher than tha ac strength
4. With ac cables the temperature limitations are set by the physical behavious of the materisl and the method of construction whereas with dc cable the temperature limitations are set by the physical behavious of the materisl and the method of construction but also by variations in dielectric stressing arising from temperature effects.

21. Write practical dielectrics used in HVDC cables.

Impregnated paper and polythene

22. Compare the DC and AC cables from economic point of view.

DC is particularly applicable to long submarine cable transmission where the cost ratio is high. The cost of DC cable is only a fraction of those for the AC cable and in addition much less physical space tends to be required in the waterway involved. IN DC cable the problems such as migration of impregnating compound, movement of the bales on the sea-bed, under the effects of currents which may affect the economic considerations.

PART-B

1. Brief about the various types of system studies in design of HVDC system.
2. Explain the modeling of HVDC systems for digital dynamic simulation.
3. Describe the operation of physical simulator.
4. Explain the various problems studies using DC simulator.
5. Describe the operation of parity simulator
6. Discuss about the advantages and disadvantages of digital dynamic simulation.
7. Write short on valve model and firing pulse generation.
8. Explain the practical dielectric used in hvdc cables.
9. Explain the operation of dielectric stress considerations.
10 Explain the thermal consideration and losses in dc cables.

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