

Electrical Engineering

Power System



HVDC (One Shot)

By- Ajay Gupta Sir



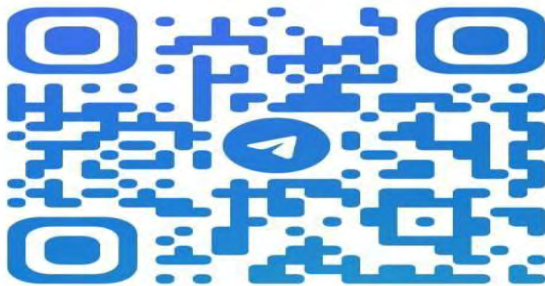
Recap Of previous class

1. Bifurcated line
2. Thevenin equivalent model
3. Line terminated by capacitor
4. Line terminated by inductor
5. Questions



Topics to be Covered

1. Why HVDC
2. Type of DC LINK
3. Equipment in HVDC station
4. Advantage of HVDC
5. Disadvantage of HVDC

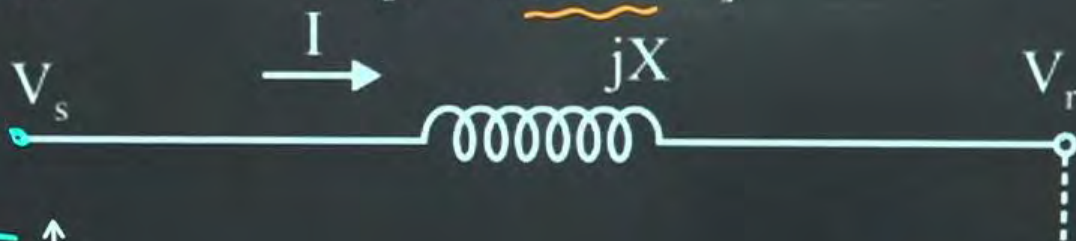


@AJAYGUPTASIRPW

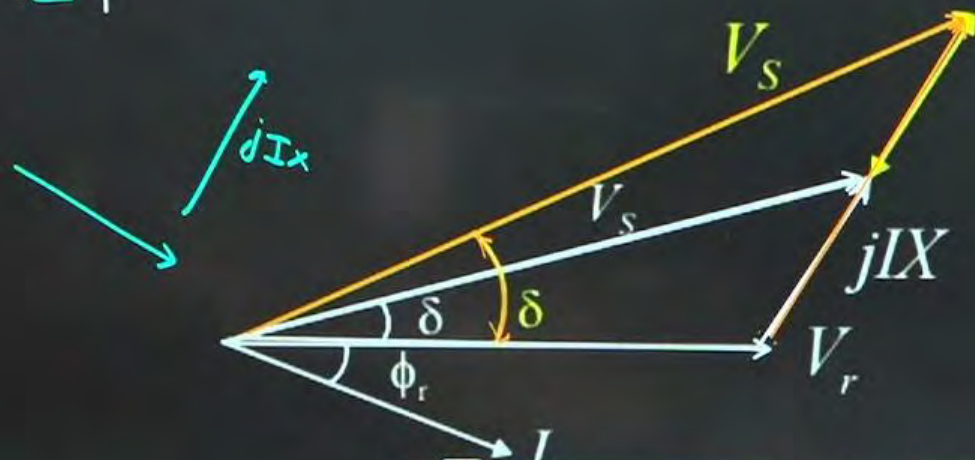
H.V.D.C

$$P = \frac{V_s V_r}{X} \sin \delta$$

$$[\delta = 25^\circ - 30^\circ]$$



$$\underline{V}_s = \underline{V}_r + jI\underline{X}$$



length ↑

↓
L ↑

↓
X ↑

↓
 jIX ↑

↓
 δ ↑

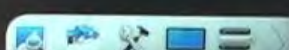
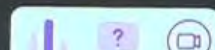
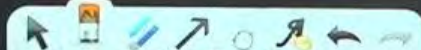
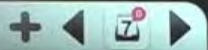
↓
Stability ↓



➤ The first power plant was commissioned in 1882 new York (110 V DC)

➤ Later A.C system was used due to transformer and induction motor

➤ But D.C. transmission has several advantage than A.C. transmission so for power transmission over a long distance, We start using HVDC transmission.

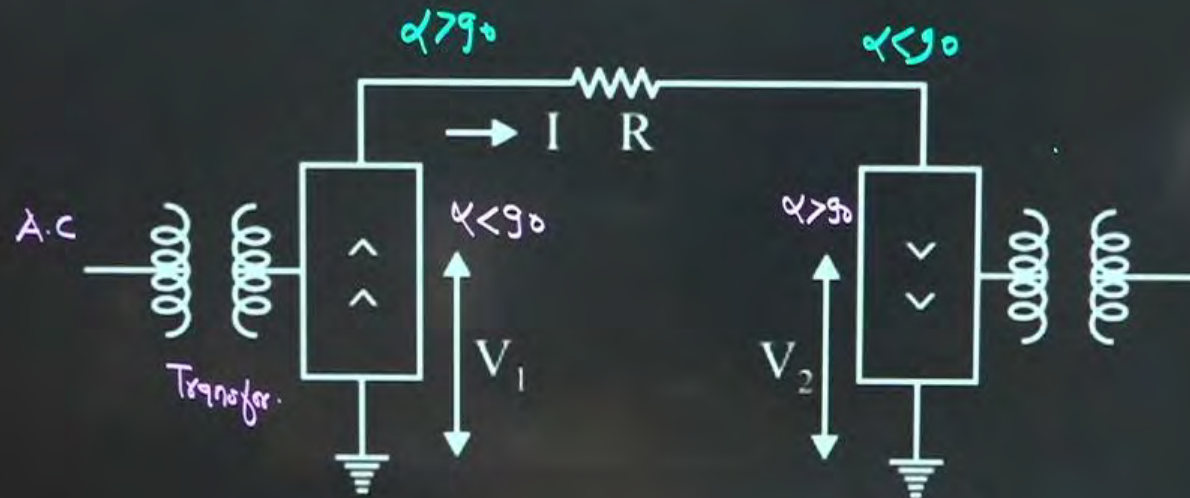




- Generation is done in AC. But at the sending end substation, first A.C is step up by mean of transformer.
- Then A.C. power is converted into D.C. by use of phase controlled rectifier.
- Then power is transferred through HVDC line.
- Now at the receiving end substation D.C power is again transfer into A.C. and D.C power is step down by transformer
- Now these AC power can be used by consumers.

- For rectification $\alpha < 90$ is used.
- for Inversion $\alpha > 90$ is used.

- So by exchanging firing angle, role of both converter will be change. So power can flow in both direction



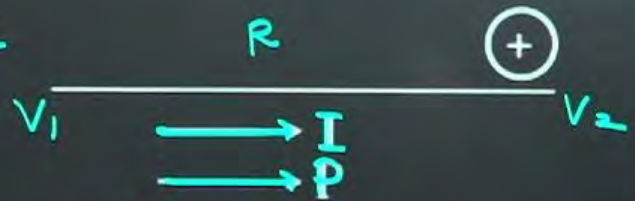
$$I = \frac{V_1 - V_2}{R}$$

$$P = VI$$

If voltage is positive, ($V_1 > 0, V_2 > 0, V_1 > V_2$)

$$P = \oplus I$$

So power is flowing in the direction of current



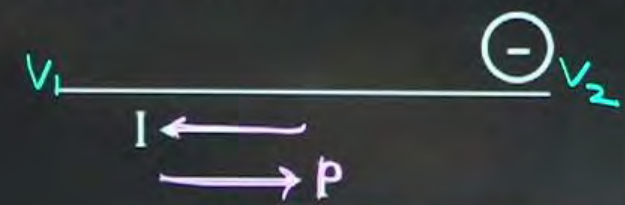
$3 > 2$
 $-3 < -2$

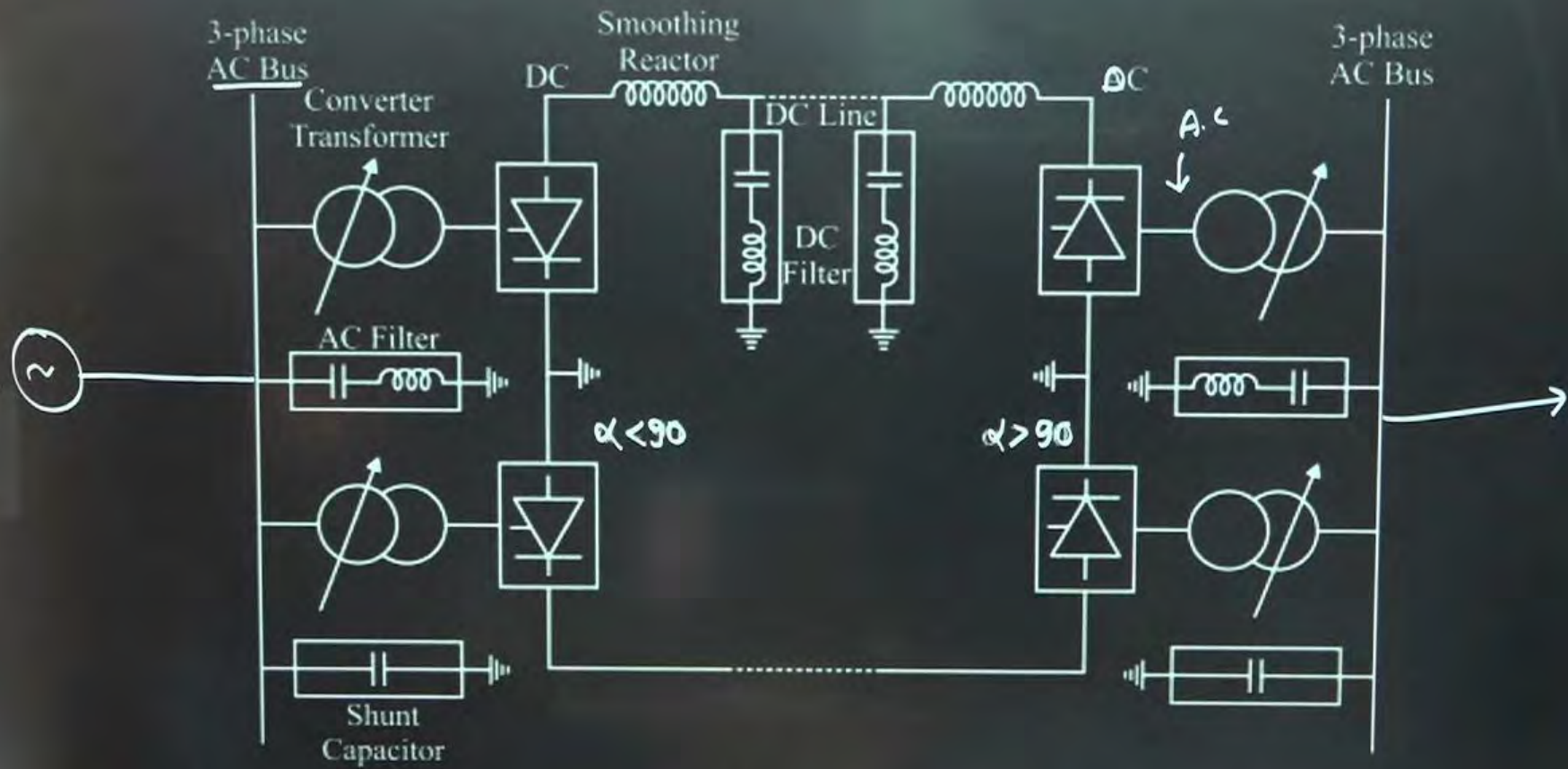
If voltage is Negative, ($V_1 < 0, V_2 < 0, |V_1| > |V_2|$)

$$P = VI$$

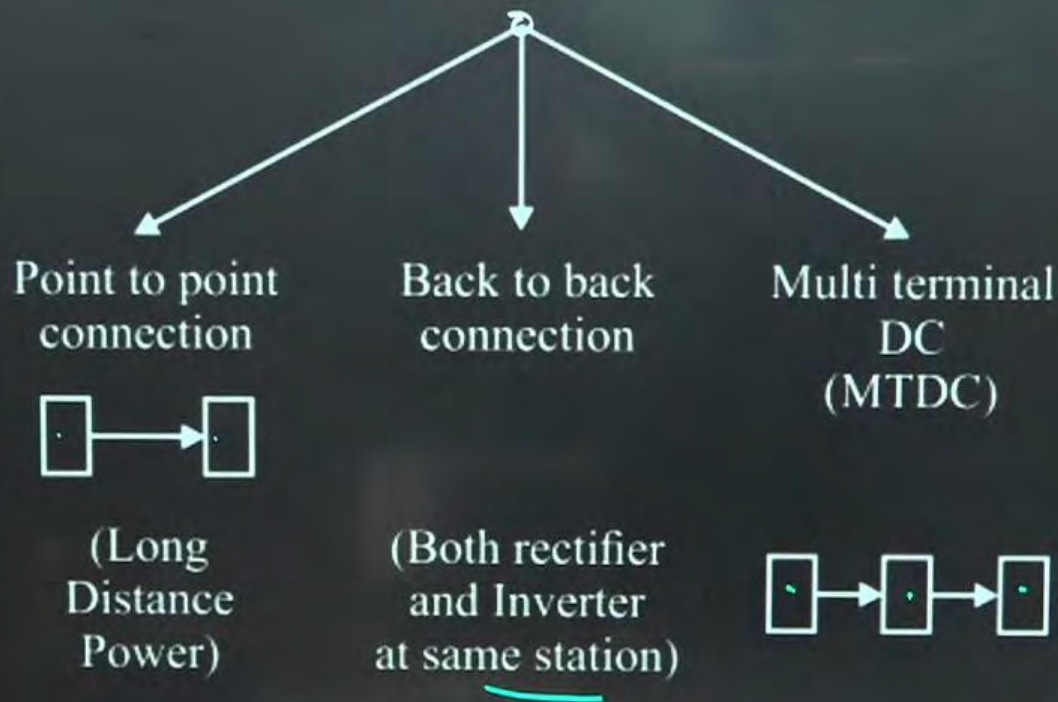
$$P = \ominus I$$

So power is flowing opposite to direction of current





Type of DC link

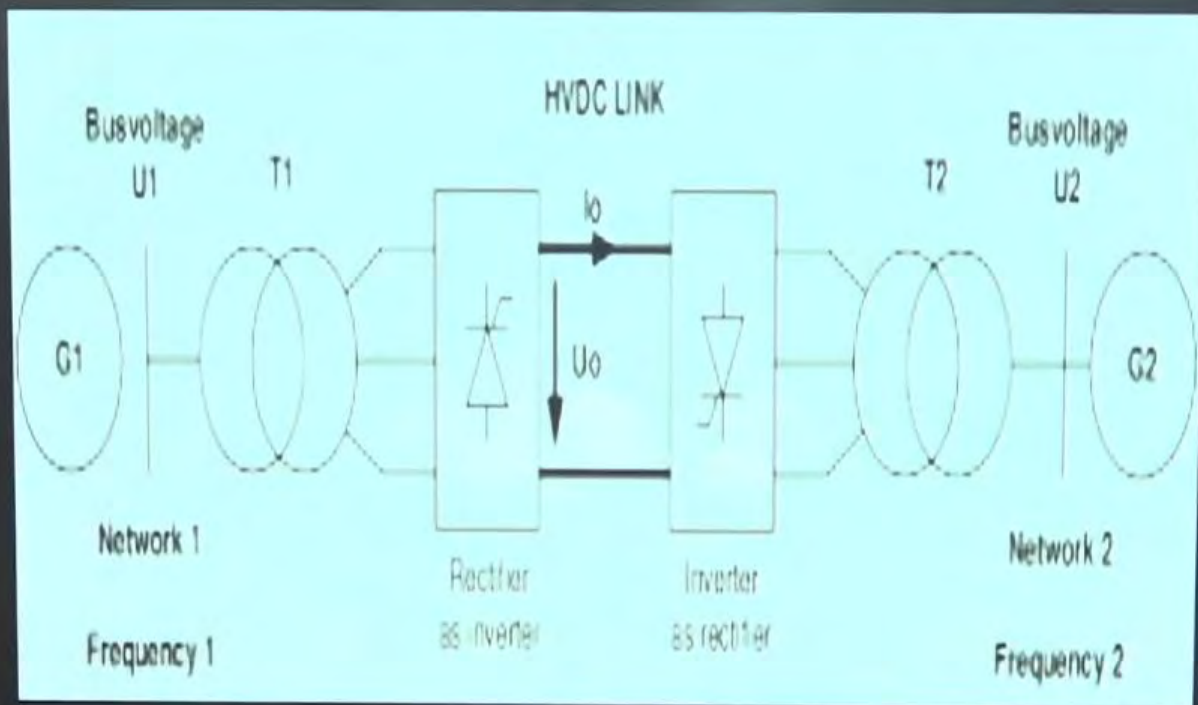


Point to point DC connection:



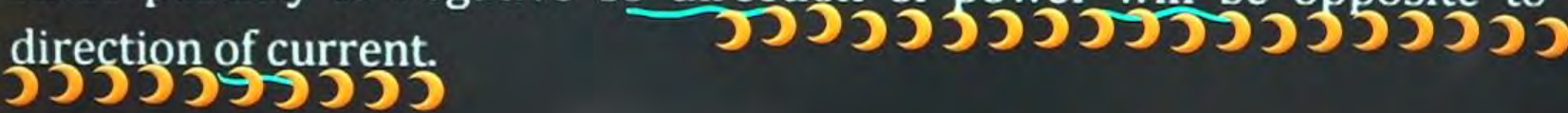
There may be three types of point-to-point connection

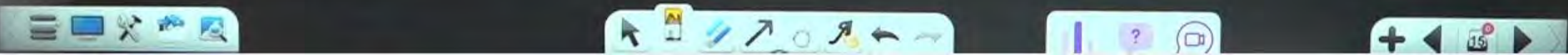
1. Monopolar link
2. Bipolar link
3. Homopolar link

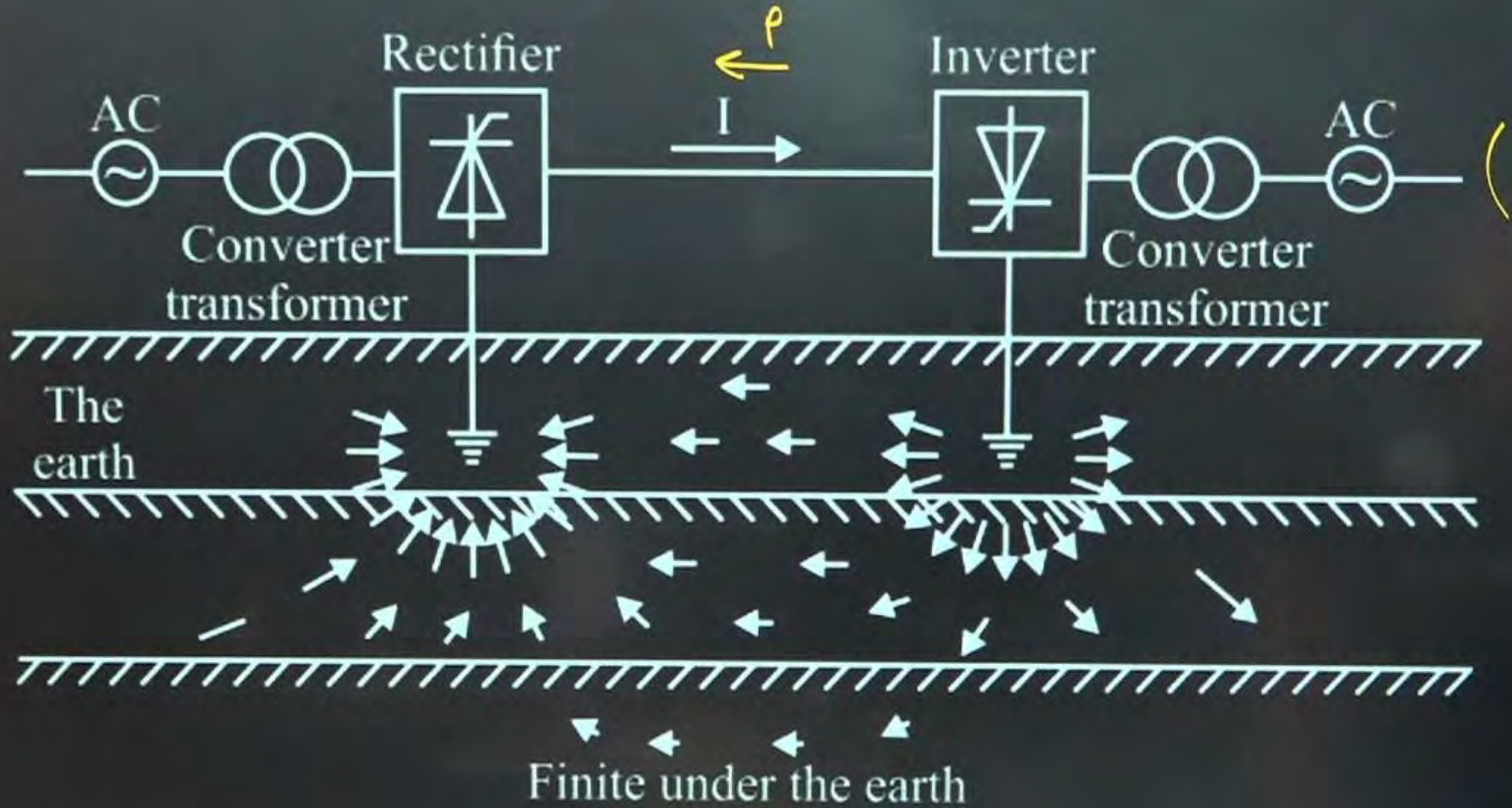


Monopolar Link

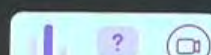
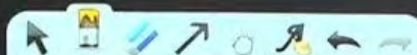
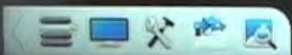
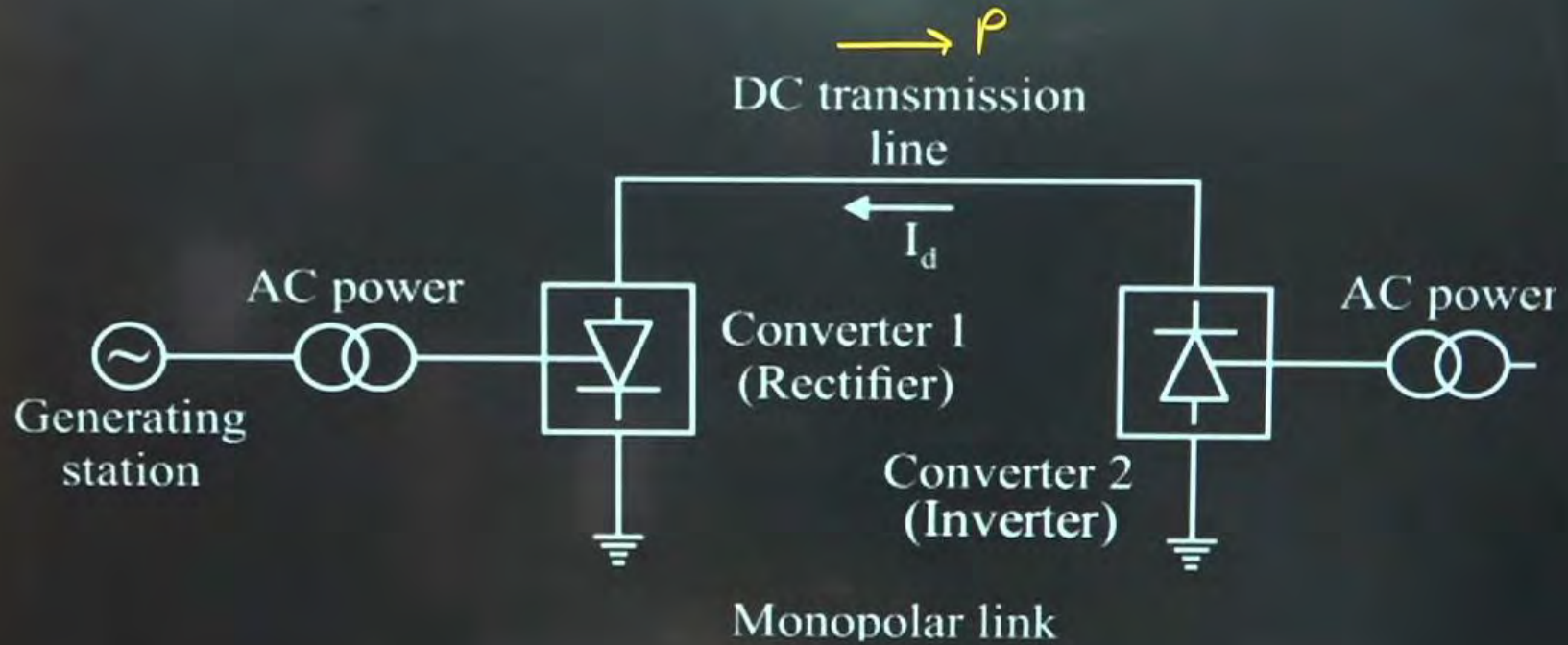


1. Only one conductor is used, usually of negative polarity and uses ground or sea water as a return.
2. Negative polarity is used to reduce corona loss and radio interference.
3. Since polarity is negative so direction of power will be opposite to direction of current.
A series of orange crescent-shaped icons arranged in two rows, pointing to the right, used as a decorative element.
4. This method is mostly used for power transmission using cables, because it saves the cost of laying one cable. When the ground resistance is too high, a metallic return path is preferred instead of using the ground

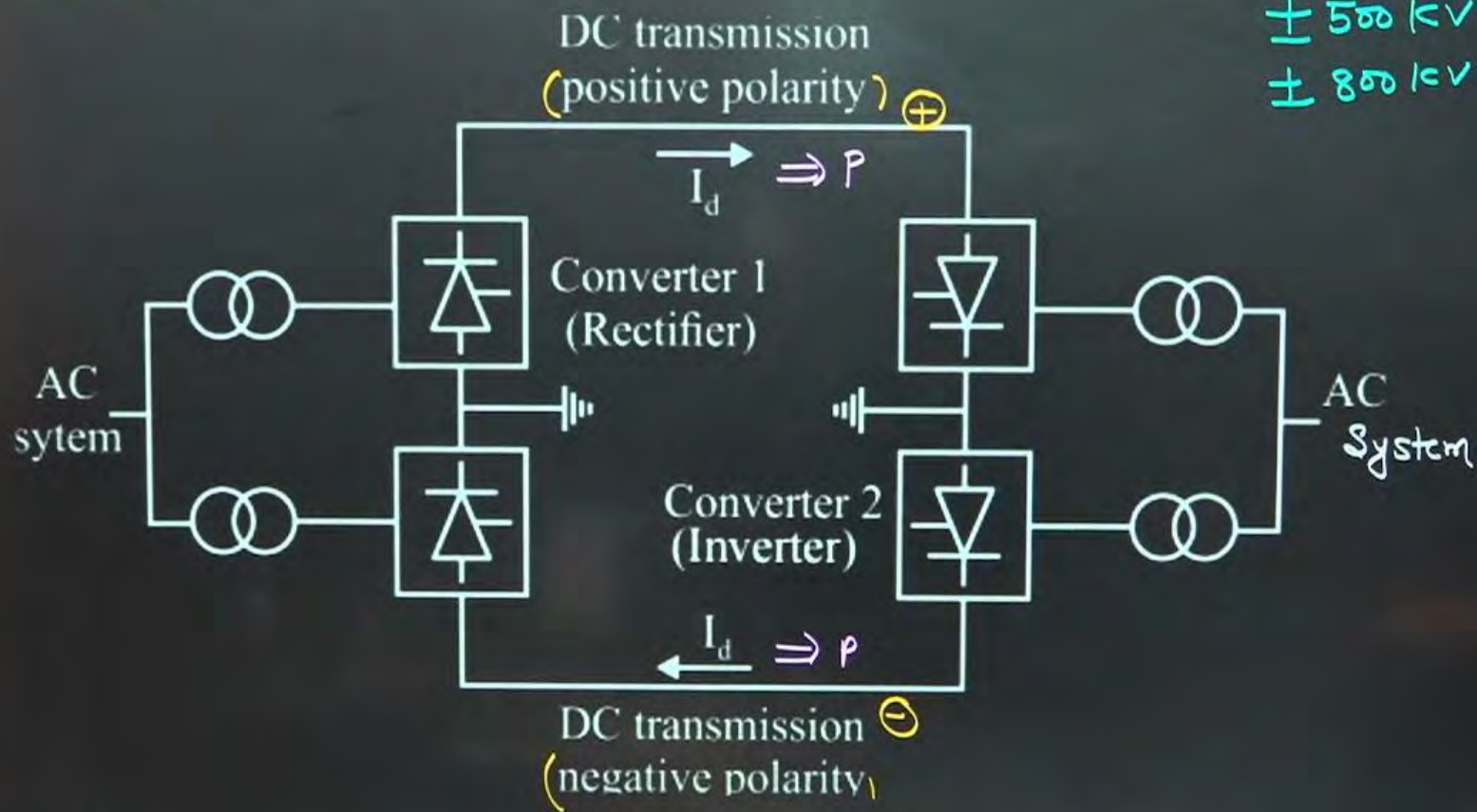




Monopolar



Bipolar link



Bipolar link



- It has two conductor one is positive and second is negative.
- At each substation, two converter use in series and neutral point (junction between two terminal) is grounded.
- Normally current in both conductor are equal so ground current will be zero

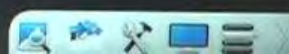
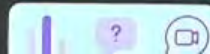
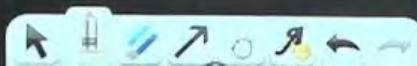


➤ If fault developed in one conductor other conductor can supply half of power (the return current will flow through ground).

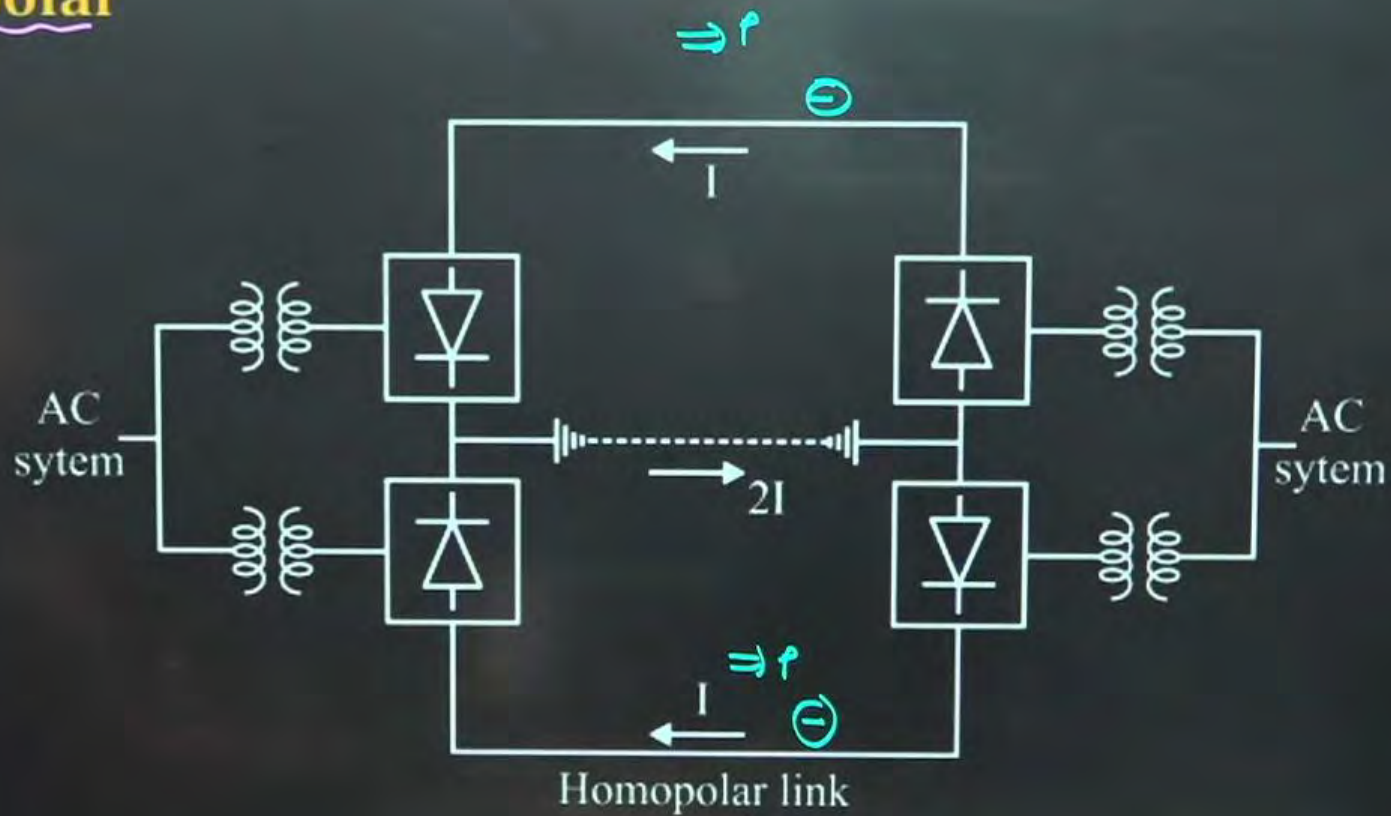
➤ The total capacity of bipolar link will be 2 times of monopolar link.

➤ In both conductor direction of current is opposite but direction of power flow is same

± 500 kV, ± 800 kV



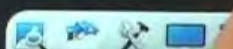
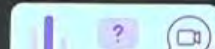
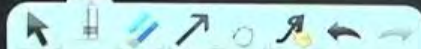
Homopolar





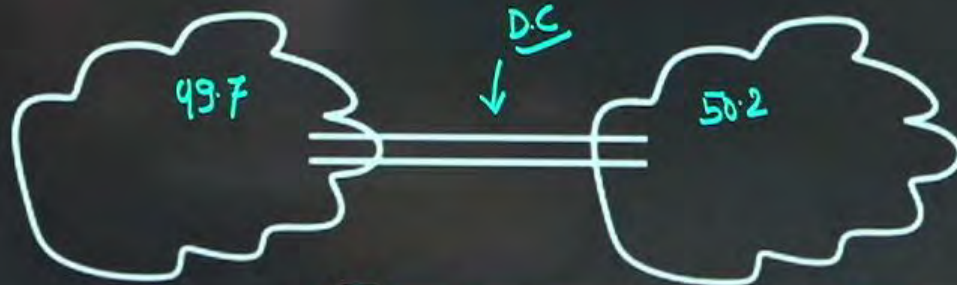
➤ It has two conductors of same polarity. (Mostly negative) and use ground as a return path

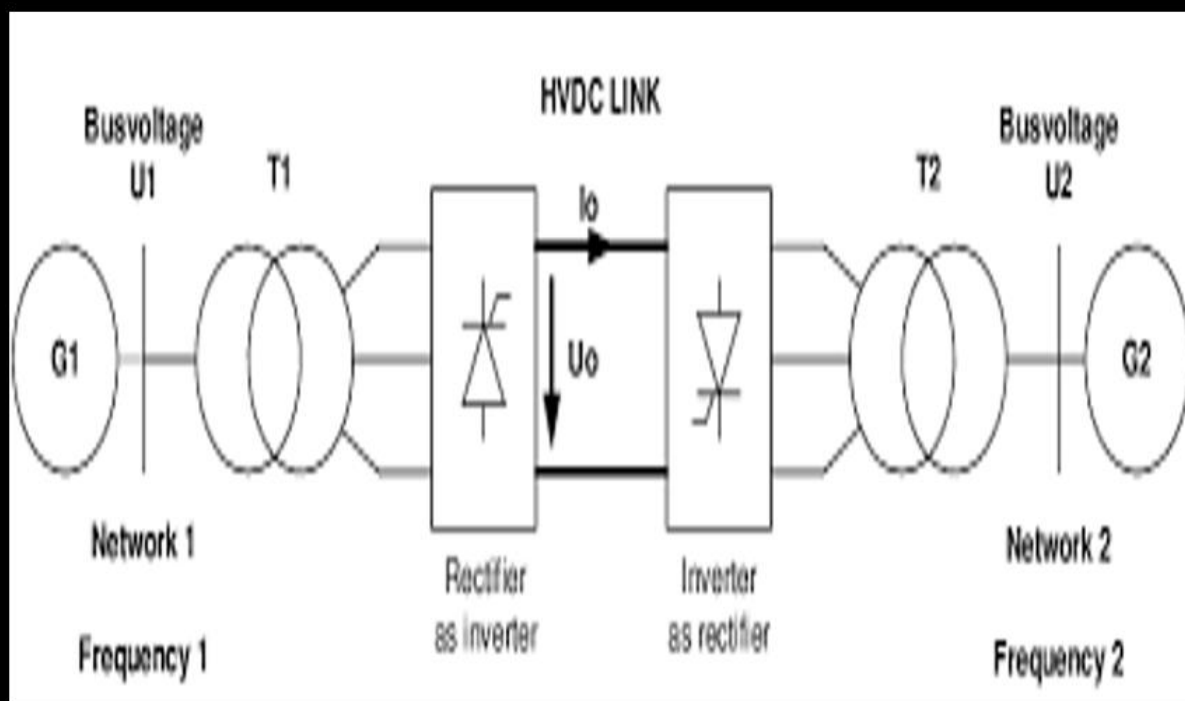
➤ If fault is developed in one conductor the converter equipment can be reconnected, so healthy conductor (having over load capacity) can supply more than half of rated power



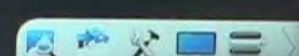
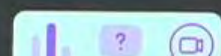
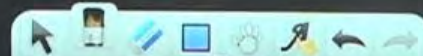
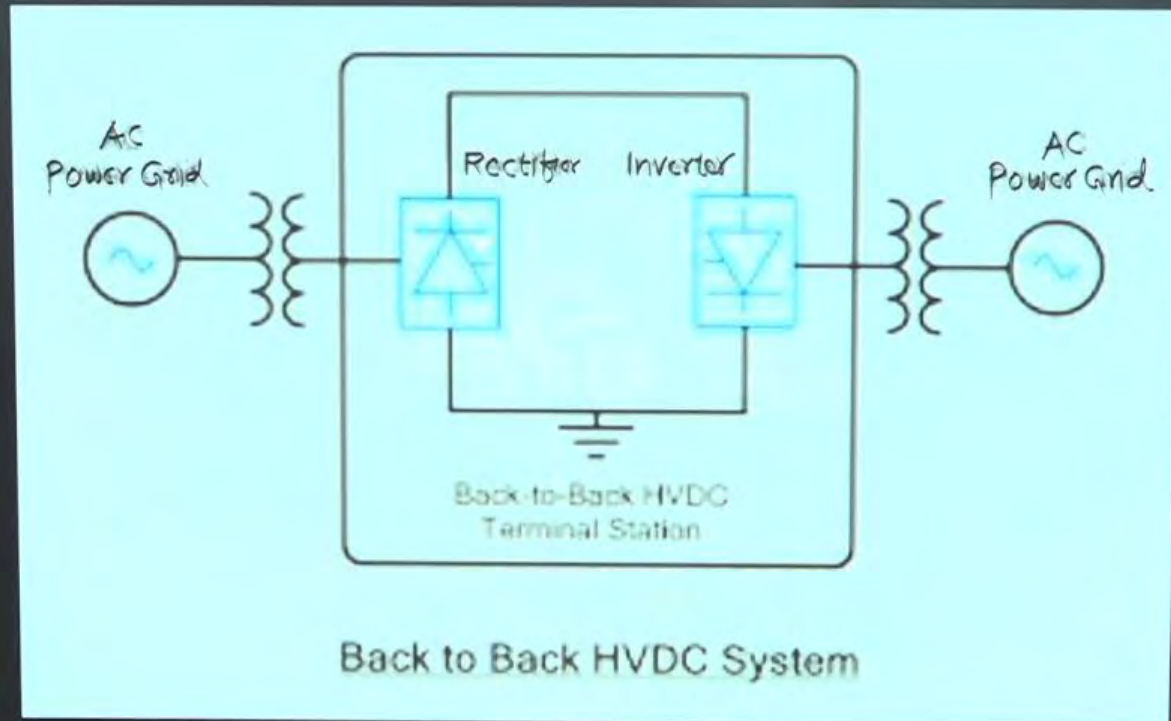
Back to Back connection

- This connection is used to connect two A.C system operating at different frequency.
- Because DC link is an asynchronous link
- The effective length of HVDC B/B connection is zero

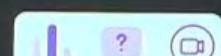
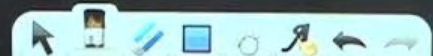
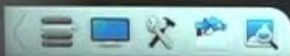
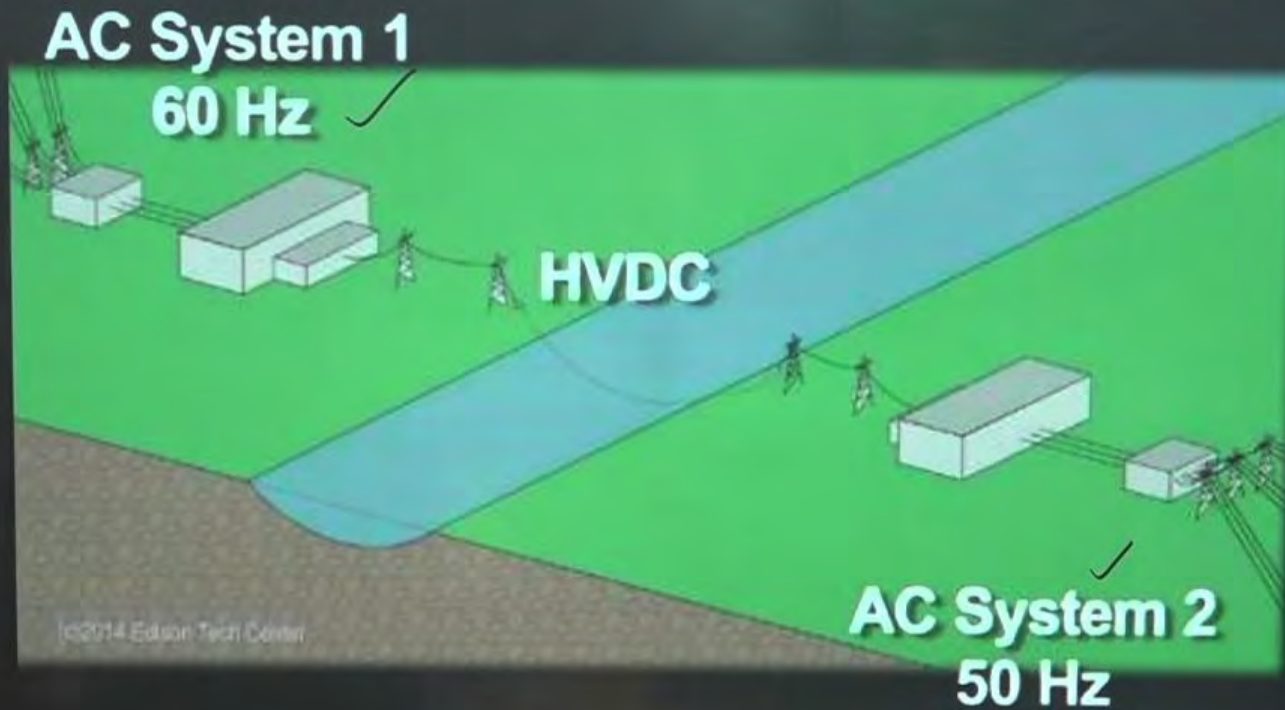




Back-to-Back Connection:



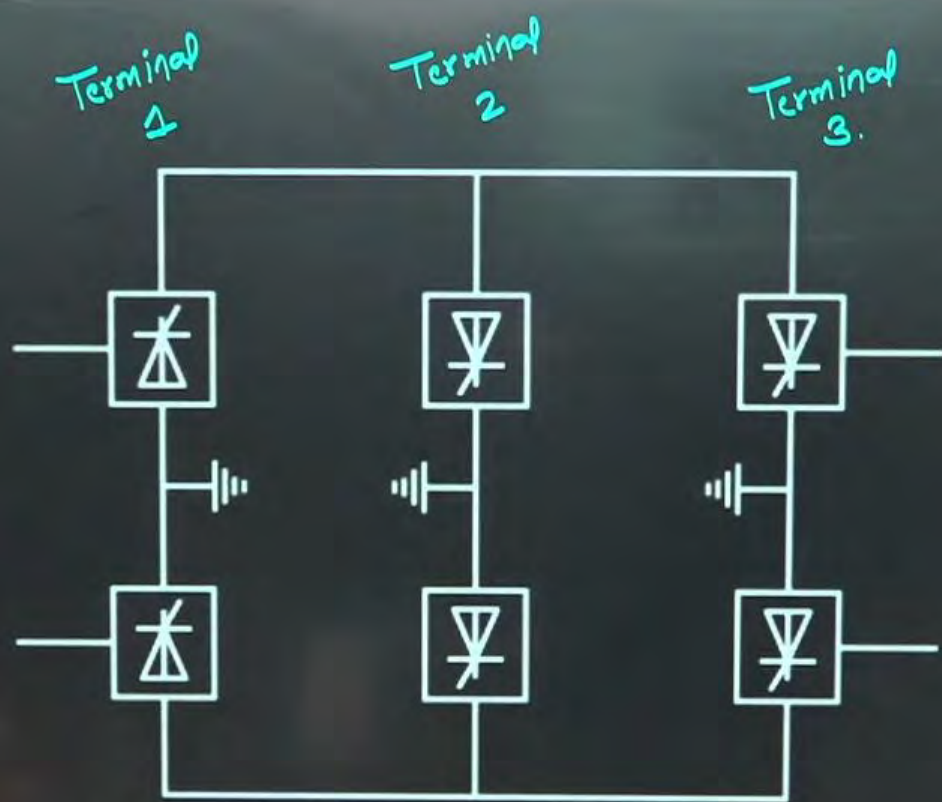
Back to Back Connection:



It is a DC link, which is connecting more than 2 terminal through HVDC

MAP OF THE HVDC MULTITERMINAL LINE



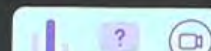
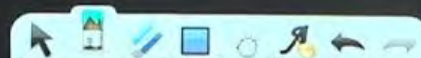
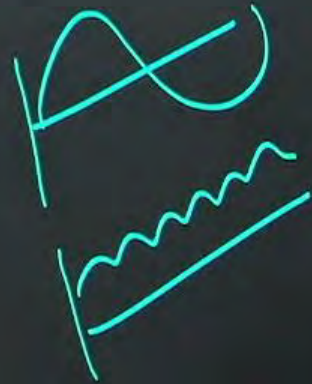
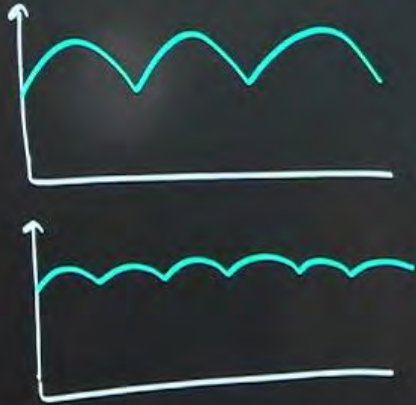


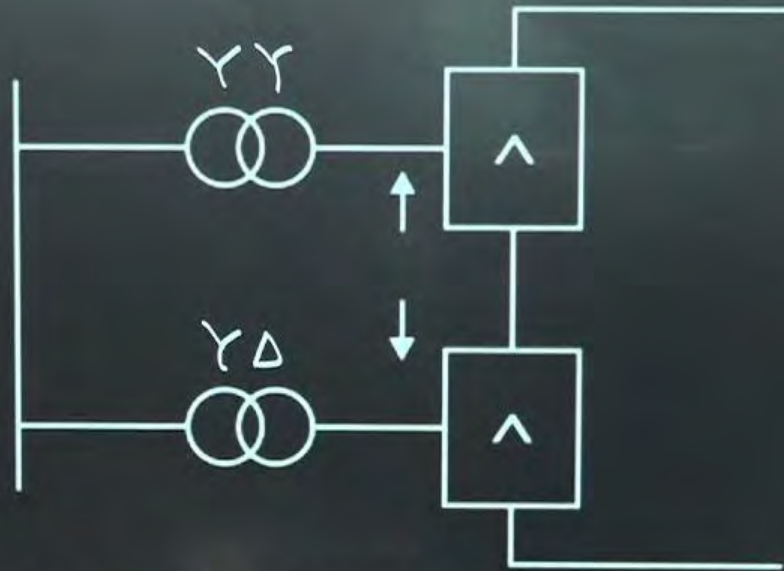
Converter station equipment



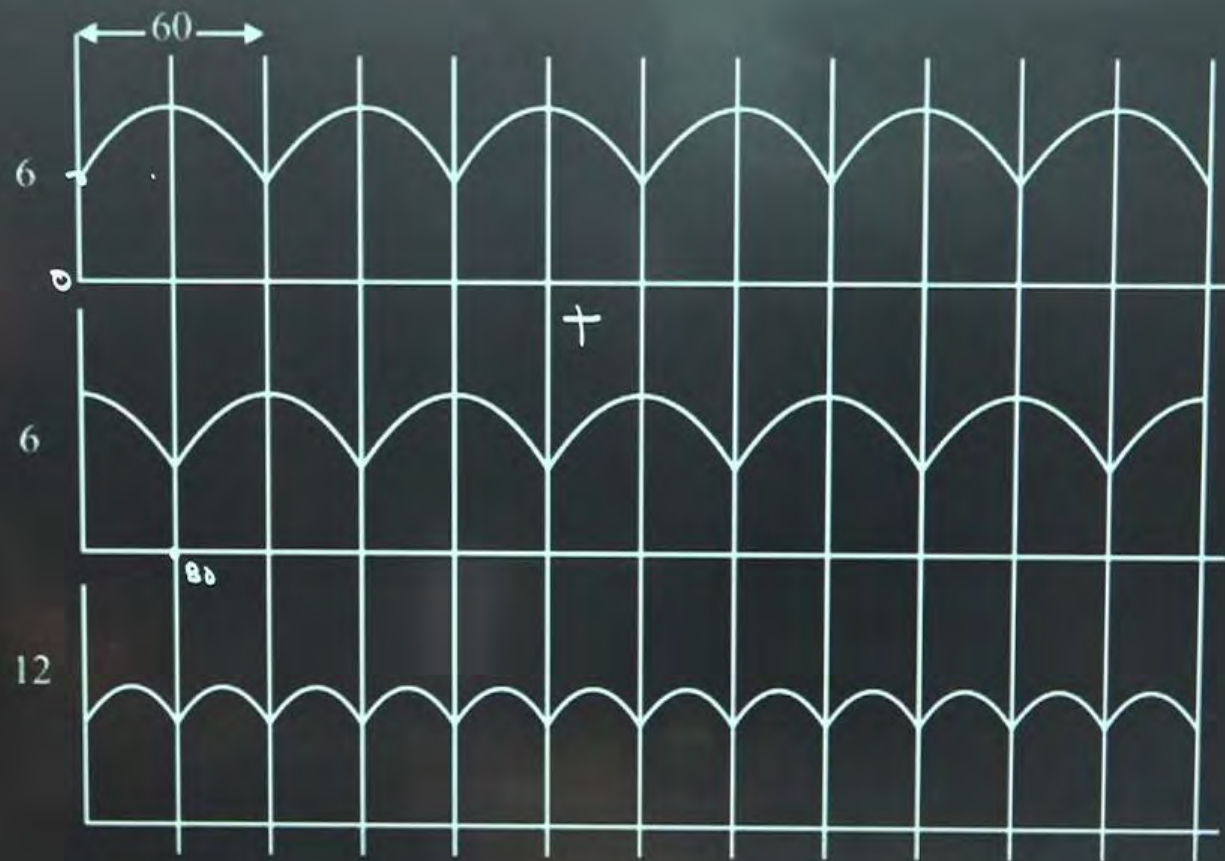
1. Thyristor valve $\rightarrow$ (phase-controlled rectifier) (3 ϕ full Converter)

- Now a days, we use 12 pulse converter to reduce harmonic
No of pulse $\uparrow \rightarrow$ harmonic





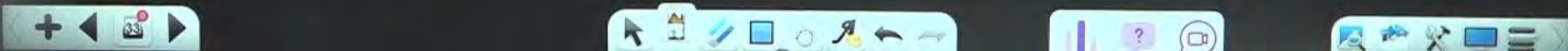
- For this two 6 pulse converter are connected in series one is fed from Y-Y transformer, and another is fed from Y-Δ.



Transformer, so A 30° phase shift is created in upper and lower pulse converter.



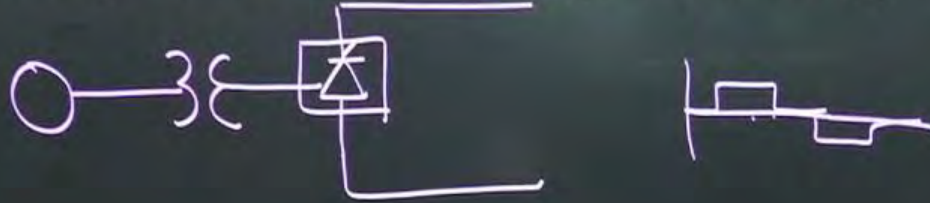
- The converter which have $\alpha < 90^\circ$ will act as an rectifier and converter which have $\alpha > 90^\circ$ will act as inverter
- We use Ionized water to cool thyristor valve.



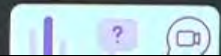
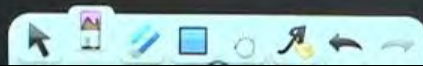
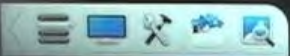
Converter Transformer



- It convert A.C voltage into suitable voltage for feeding.



- Its design is somewhat different from normal transformer. it handle high harmonics so care must be taken to reduce high eddy current loss, its insulation should also be able to withstand D.C voltage

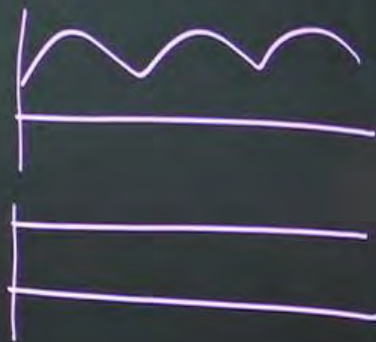




Smoothing Reactor



- It reduce the harmonic voltage and current in DC line.
- It makes DC current almost ripple free and constant
- It also limits the high magnitude current
- If prevent commutation failure in inverter.



AC and DC Filter



- Power electronic converter introduce harmonic both in source side and load side (AC side and DC side)
- If no of pulse = $n = \underline{12}$
 - A.C side = $(\underline{2n \pm 1}) = (23, 25, \dots)$
or $(\underline{n \pm 1}) = (11, 13, \dots)$
 - DC side = $(2n) = (24)$
or $(n) = (12)$

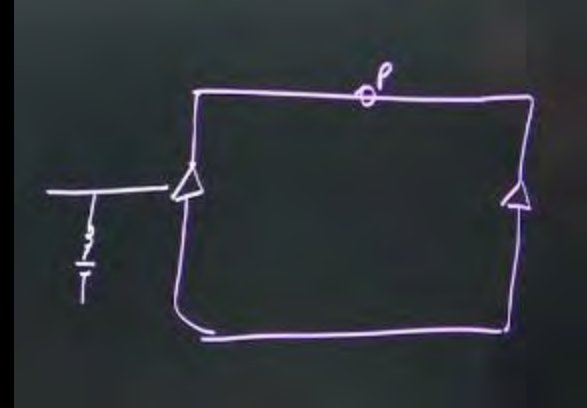


- AC filter reduce harmonics, it also provide reactive power to converter.



$$Q = P \tan \alpha$$

- DC filter only reduce the harmonic.

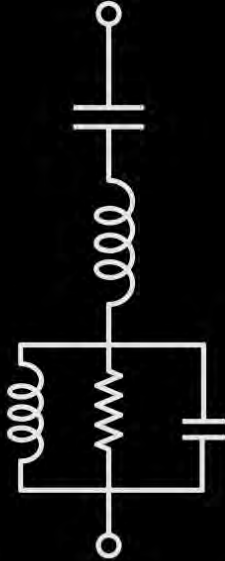




- It shows the different types of three-phase RLC harmonic filter



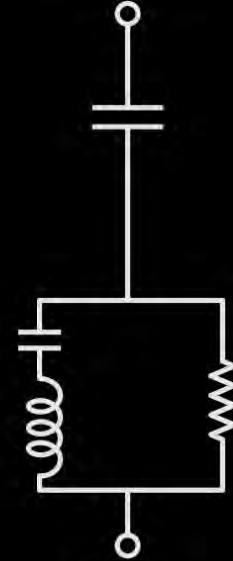
Single-tuned



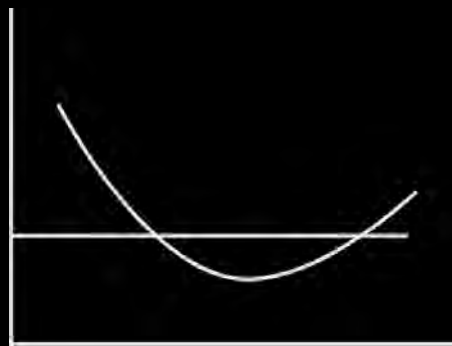
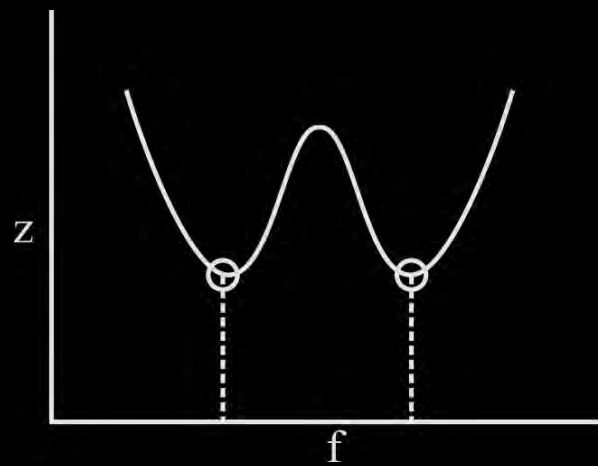
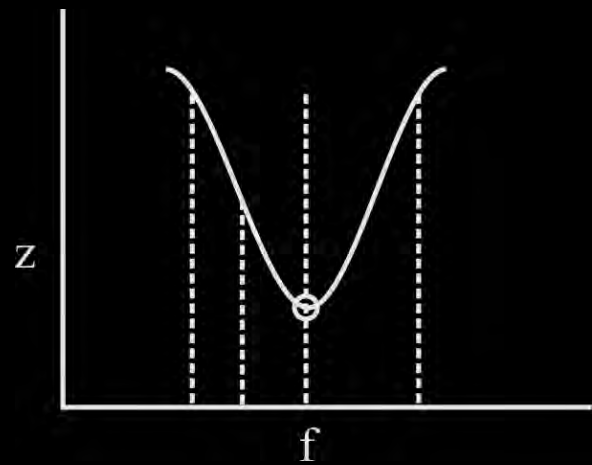
Double-tuned



High-pass



C-type
High-pass



Reactive power compensator

- No reactive power flow over DC line but converter draw reactive power from AC side.
- It is supplied by AC filter, shunt capacitor, synchronous condenser, static VAR compensator (TSC, TCR)

→ Thyristor switch Capacitor, Thyristor controlled reactor

Reactive power depend on firing angle and active power

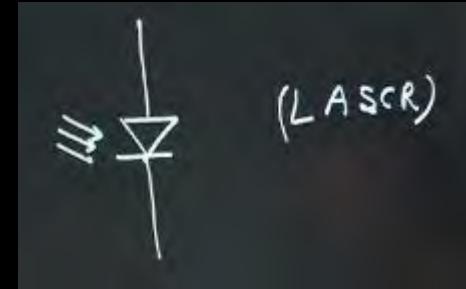
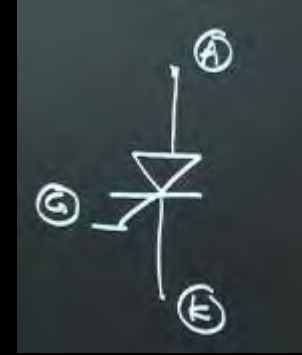
$$\sqrt{Q} = \sqrt{P} \tan \alpha$$

Control Equipment



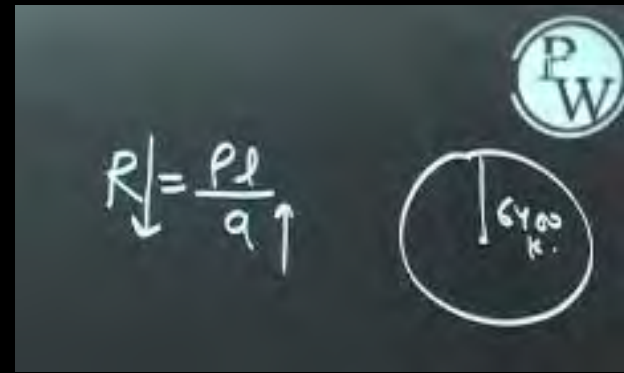
➤ Control of firing angle is Important in HVDC system

➤ It is fired through optical fiber cable(light triggering).



Ground Return

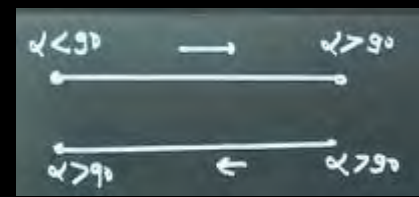
- The ground has low resistance so low power loss.
- Unlike AC current, it does not follow route of line
But it spread through out large cross section area
- for earthing, each electrode is use (Straight electrode, ring electrode, radial electrode).



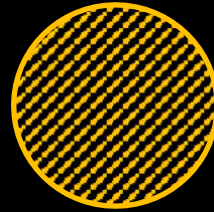


- Graphite electrode is used, which is provide in pit filled with coke.
- The electrode is buried about 3 km to 50 km from terminal station.

Advantage of HVDC



- The Direction as well as Magnitude of power flow can easily be controlled.
- No skin effect in D.C line, so current Distribution is uniform in the conductor.



Effective area $a \uparrow$, $R \downarrow = \frac{\rho l}{a}$

So effective resistance & ohmic loss will reduce.

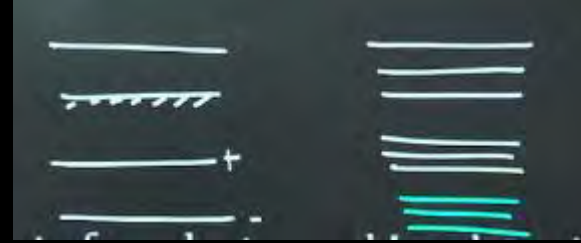
- Corona loss & associated Radio Interference is reduce. $P_c \propto (f + 25)$
- We can Interconnect two AC system operating at different frequency because $P_c \propto (0 + 25)$ became D.C like is a asynchronous link.
- With DC interconnection, the fault level is not increased.
- HVDC is preferred for underground & submarine cable even for long distance because No continuous charging current occur in D.C line.
- There will be continuous charging at AC line due to shunt capacitance effect. So, reactive power in a line is continuously changing. Therefore Intermediate sub-station are installed for every 200 km and 300km to compensate reactive power.

➤ But in HVDC, no such Intermediate sub-station is required.

➤ Reliability of line

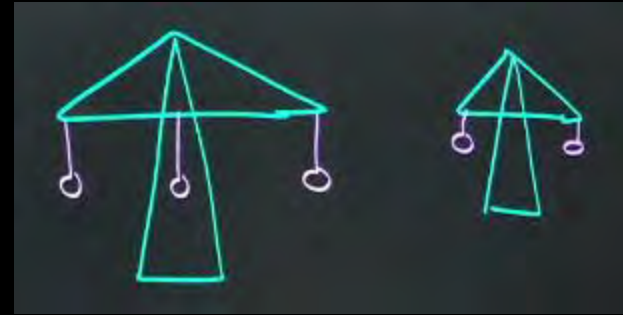
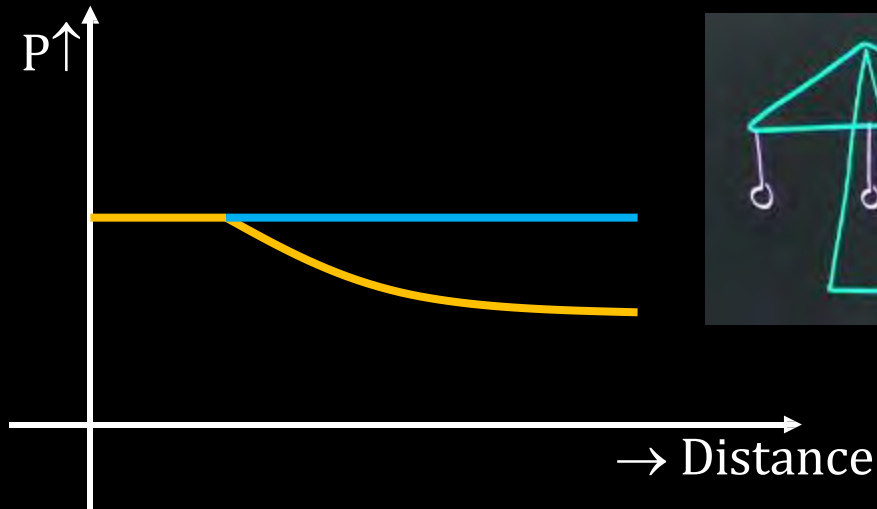
Monopolar link = Single circuit AC line

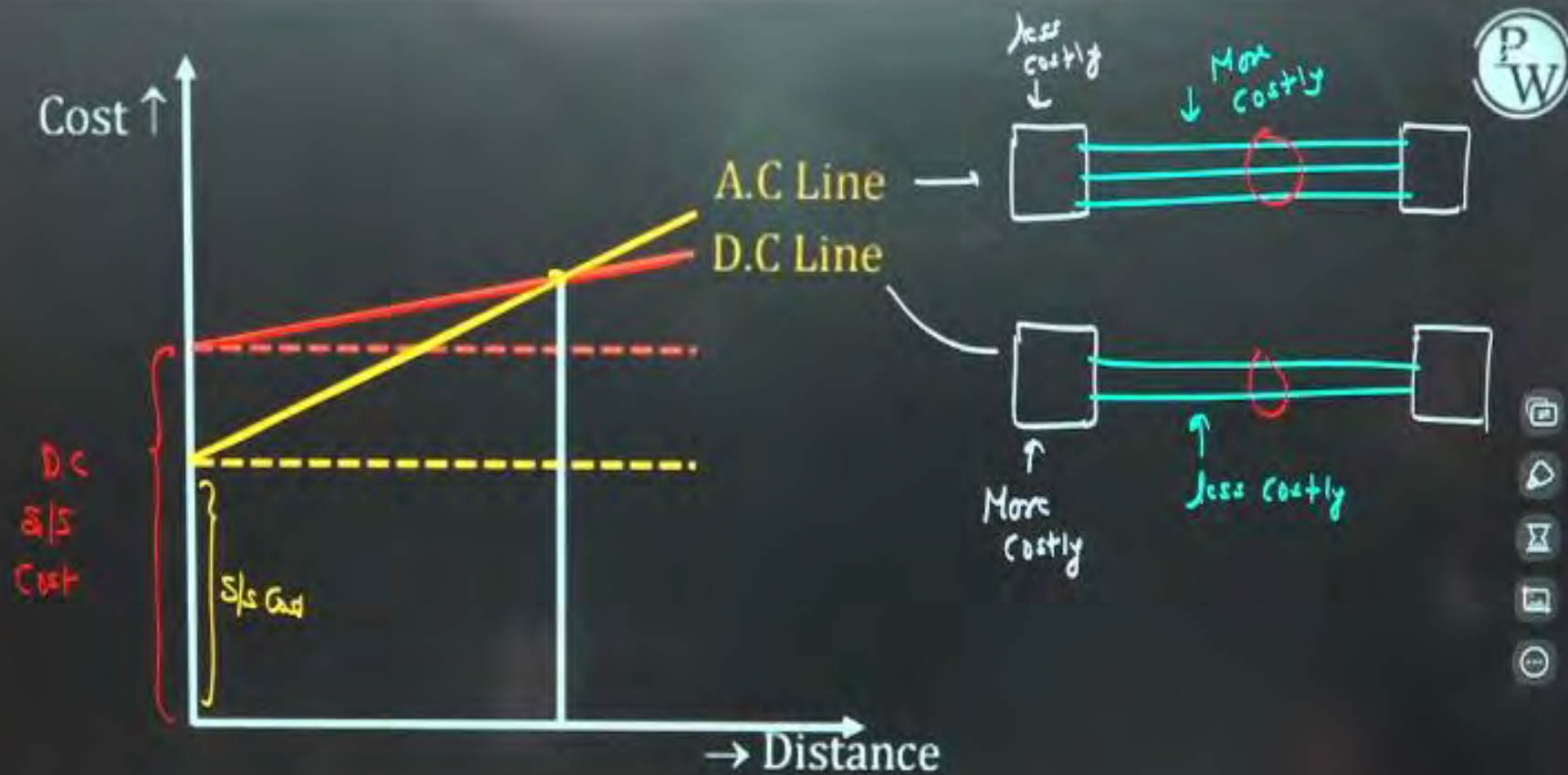
Bipolar Line = Double Circuit AC Line



➤ It has only two conductor so less amount of conductor and Insulator is required in HVDC

- “Right of way” Requirement is less
- The length of uncompensated AC line cannot be more than 500 km due to stability problem. The DC transmission does not have any such limit.





For long distance bulk power transmission DC system is most economical

Disadvantage of HVDC

- 1) The cost of D.C circuit breaker is very high. Arc quenching in D.C current is difficult. 
- 2) Thyristor valve create harmonics in both source & load side.
- 3) The overload capacity of power converter is limited.
- 4) Huge reactive power requirement at the converter terminal.
- 5) Cost of terminal equipment & it's maintenance is very costly.
- 6) The control circuit for firing of SCR is also very complicated.

Q. HVDC transmission is preferred to EHV – AC because

- A.** HVDC terminal equipment are inexpensive
- B.** VAR compensation is not required in HVDC system
- C.** System stability can be improved 
- D.** Harmonics – Problem is avoided

Q.

Bulk power transmission over long HVDC lines are preferred, on account of

- A. Low cost of HVDC terminals
- B. No harmonics problems
- C. Minimum line power losses
- D. Simple protection

$\equiv = R \downarrow$

Q. Out of the considerations (i) to (iv) listed below:

- (i) No distance limitation related to steady state stability ✓
- (ii) No reactive power requirement from the system are the two terminals. ✗
- (iii) No substantial effect on fault level of the two systems at the terminals in spite of the inter connection ✓
- (iv) No corona problems (less corona) (6+25)

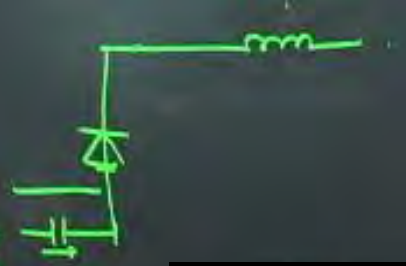
The considerations which constitute advantages of HVDC transmission are

- A** All of the above
- B** (i) and (iii) ✓
- C.** (iii) and (iv)
- D.** (ii) and (iv)

Q.

Choose the appropriate auxiliary components of HVDC transmission system from the following

1. D.C. line inductor ✓
2. A.C. line inductor ✗
3. Reactive power sources ✓
4. Distance relays on D.C. line ✗
5. Series capacitance on A.C. line ✗



A 1 and 2

B ✓ 1 and 3

C. 2 and 4

D. 4 and 5

Q. High voltage DC (HVDC) transmission is mainly used for

- A.** Bulk power transmission over very long distances
- B.** Inter-connecting two systems with the same nominal frequency
- C.** Eliminating reactive power requirement in the operation
- D.** Minimizing harmonics at the converter stations

Q.

An HVDC link consists of rectifier, inverter transmission line and other equipment's. Which one of the following is true for this link?

- A The transmission line produces/supplies reactive power.
- B The rectifier consumes reactive power, and the inverter supplies reactive power from/to the respective connected AC systems.
- C Rectifier supplies reactive power and the inverter consumes reactive power to/from the respective connected AC systems.
- D Both the converters (rectifier and inverter) consume reactive power from the respective connected AC systems.

$\alpha < 90^\circ$

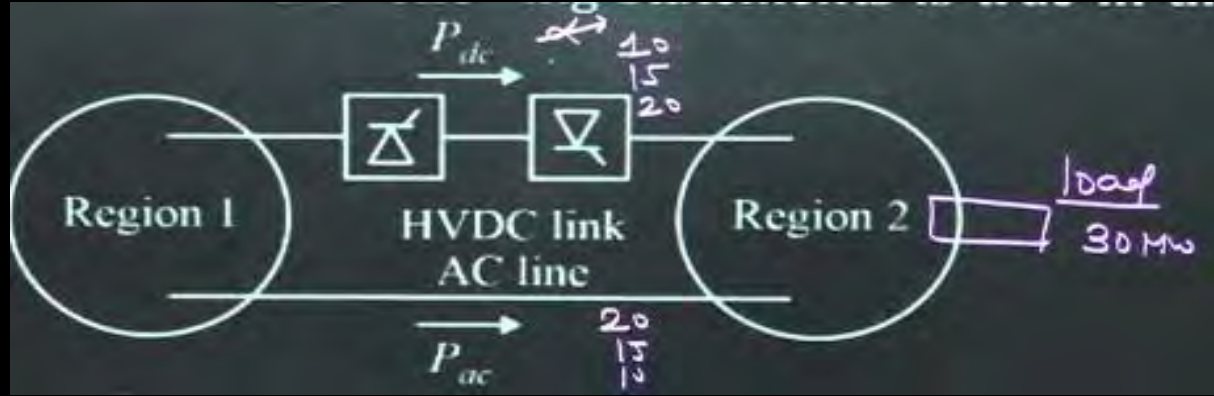
Rectifier $Q = P \tan \alpha$
 $= \oplus \oplus = \oplus$

Inverter $Q = -P \tan \alpha$
 $= \ominus \ominus = \ominus$

$\frac{P}{W}$

Q.

Two regional systems, each having several synchronous generators and loads are interconnected by an ac line and a HVDC link as shown in the figure. Which of the following statements is true in the steady state?



A Both regions need not have the same frequency.

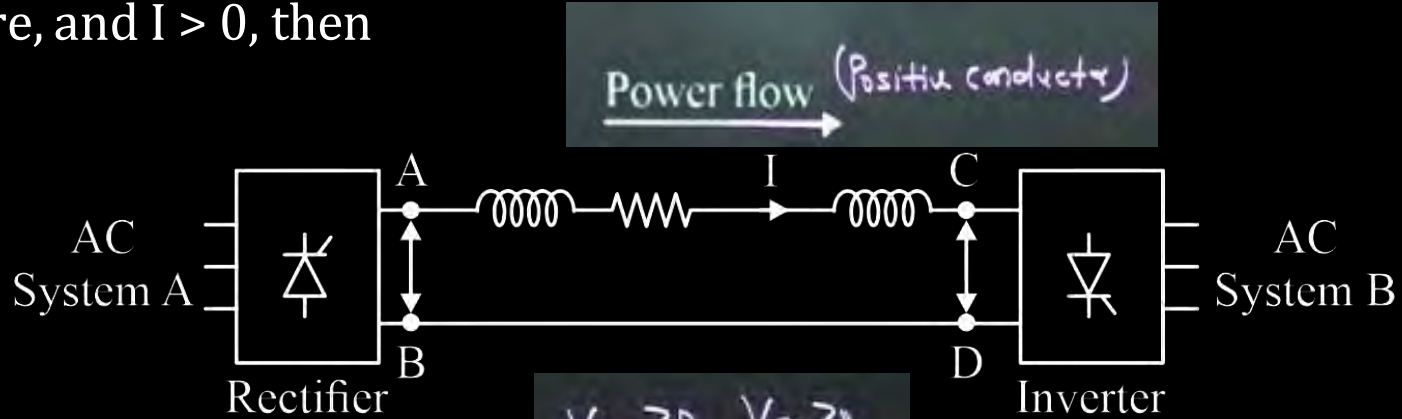
B The total power flow between the regions ($P_{ac} + P_{dc}$) can be changed by controlling the HDVC converters alone.

C The power sharing between the ac line and the HVDC link can be changed by controlling the HVDC converters alone.

D The directions of power flow in the HVDC link(P_{dc}) cannot be reversed.

Q.

Power is transferred from system A to system B by an HVDC link as shown in the figure. If the voltages V_{AB} and V_{CD} are as indicated in the figure, and $I > 0$, then



- A. $V_{AB} < 0, V_{CD} < 0, V_{AB} > V_{CD}$
- B. $V_{AB} > 0, V_{CD} > 0, V_{AB} < V_{CD}$
- C. $V_{AB} > 0, V_{CD} > 0, V_{AB} > V_{CD}$
- D. $V_{AB} > 0, V_{CD} < 0$



#Q. Which of the following is correct regarding the advantages of DC transmission over AC transmission? [ESE-2024]

- ☐ A Power per conductor is more, more corona loss and possibility of higher operating voltages
- ☐ B Power per conductor is more, less corona loss and possibility of higher operating voltages
- ☐ C Power per conductor is more, no skin effect and possibility of lower operating voltages
- ☐ D Power per conductor is more, there is charging current and possibility of higher operating voltages

#Q. Consider the following conditions :

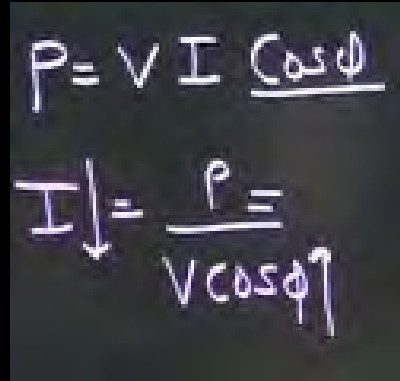
In HVDC transmission, high power factor of the system is maintained for the following reason(s):

1. For a given current and voltage of the thyristor and transformers, the power rating of the converters is equal.
2. The stresses on the thyristors and damping circuits are reduced.
3. For the same power to be transmitted the current rating of the system is reduced and also the copper losses in the ac lines are reduced.

Which of the above conditions is/are correct?

[ESE-2023]

- ☐ A 1 only
- ☐ B 2 only
- ☐ C 3 only
- ☐ D 2 and 3 only



$$P = V I \cos \phi$$

$$I = \frac{P}{V \cos \phi}$$

#Q. In an HVDC transmission, the DC output voltage can be controlled to get inverter operation when the firing angle α is [ESE-2020]

- A** $\alpha = 0^\circ$
- B** $0^\circ < \alpha < 90^\circ$
- C** $90^\circ < \alpha < 180^\circ$
- D** $0^\circ < \alpha < 180^\circ$

#Q. In an HVDC transmission mode, the link which has two circuits that are almost independent of each other is called [ESE-2020]

- ☐ A Monopolar link
- ☐ B Bipolar link
- ☐ C Homopolar link
- ☐ D Dualpolar link

#Q. Which one of the following is used for communication with the aim of achieving high figure of merit of HVDC circuit breakers?
[ESE-2019]

- ☐ A Oil interrupter
- ☐ B Air interrupter
- ☐ C Vacuum interrupter
- ☐ D SF_6 interrupter



#Q. Vacuum interrupter are used to achieve high figure of merit is HVDC breaker.
The HVDC system uses [ESE-2019]

- A** Rectifier station at sending end and inverter station at receiving end.
- B** Inverter station at sending as well as at the receiving end.
- C** Rectifier station at sending end as well as at the receiving end.
- D** Inverter station at sending end and rectifier station at receiving end.

#Q. Statement (I): In an HVDC system, the steadystate power transfer from a generator to the infinite bus is dependent on the power angle and the line impedance intervening between them.

Statement (II): In an HVDC system, the power transfer between the two stations connected by a dc link is much larger than that in a corresponding EHV ac system.

[ESE-2018]

- A** Both Statement (I) and Statement (II) are individually true and Statement (II) is the correct explanation of Statement (I).
- B** Both Statement (I) and Statement (II) are individually true but. Statement (II) is not the correct explanation of Statement (I).
- C** Statement (I) is true but Statement (II) is false.
- D** Statement (I) is false but Statement (II) is true.



#Q. Bulk power transmission over long HVDC lines is preferred because of [ESE-2017]

- A** Low cost of HVDC terminal
- B** No harmonic losses
- C** Minimum line power losses
- D** Simple protection

#Q. **Statement (I):** Limiting factor of DC transmission is the high cost of conversion equipment.

Statement (II): Generation of harmonics is used for reactive power transfer only which has the ability to alter voltage levels.

[ESE-2017]

- A** Both Statement (I) and Statement (II) are individually true and Statement (II) is the correct explanation of Statement (I).
- B** Both Statement (I) and Statement (II) are individually true but. Statement (II) is not the correct explanation of Statement (I).
- C** Statement (I) is true but Statement (II) is false.
- D** Statement (I) is false but Statement (II) is true.



#Q. Consider the following advantages with respect to HVDC transmission:

1. Long distance transmission
2. Low cost of transmission
3. Higher efficiency

Which of the above advantages are correct?

[ESE-2016]

A 1 and 2 only

B 1 and 3 only

C 2 and 3 only

D 1, 2 and 3

#Q. **Statement (I):** HVDC transmission is advantageous over HVAC for large power transfer over long lines.

Statement (II): HVDC requires conversion equipment at two ends of the transmission line. [ESE-2015]

- A** Both Statement (I) and Statement (II) are individually true and Statement (II) is the correct explanation of Statement (I).
- B** Both Statement (I) and Statement (II) are individually true but. Statement (II) is not the correct explanation of Statement (I).
- C** Statement (I) is true but Statement (II) is false.
- D** Statement (I) is false but Statement (II) is true.

#Q. Which of the following will be provided to reduce the harmonics on the ac side of an HVDC transmission line? [ESE-2015]

- ☐ A Synchronous motors in over excited condition
- ☐ B Shunt capacitor
- ☐ C Static compensator
- ☐ D Shunt filters



#Q. The power transmission capability of bipolar lines is approximately [ESE-2014]

- A** half that of 3-phase single circuit
- B** same as that of 3-phase single circuit line
- C** twice that of 3-phase single circuit line
- D** thrice that of 3-phase single circuit line

#Q. **Statement (I):** No compensation is needed in HVDC lines, unlike EHV-AC system where series and/or shunt compensation is required.

Statement (II): Charging current is absent in HVDC system.

[ESE-2013]

- A** Both Statement (I) and Statement (II) are individually true and Statement (II) is the correct explanation of Statement (I).
- B** Both Statement (I) and Statement (II) are individually true but. Statement (II) is not the correct explanation of Statement (I).
- C** Statement (I) is true but Statement (II) is false.
- D** Statement (I) is false but Statement (II) is true.

#Q. The following is not an advantage of dc transmission:

- A** No charging current
- B** No skin effect
- C** No stability problem
- D** Cheap converters

#Q. The method used to implement an asynchronous link is

- A** dc back to back connected converter
- B** $0 - 360^\circ$ static phase shifter
- C** rotary transformer
- D** static VAR compensator

#Q. In an HVDC system

- A** Both generation and distribution are d.c.
- B** Generation is a.c. and distribution is d.c.
- C** Generation is d.c. and distribution is a.c.
- D** Both generation and distribution are a.c.



#Q. Consider the following statements:

The suitable configuration of HVDC converter is decided on the requirements

1. of high pulse number
2. of converter transformer utilization factor should be near to unity.

Which of these statements is/are correct?

[ESE-2010]

- A** 1 only
- B** Both 1 and 2
- C** Neither 1 nor 2
- D** 2 only



#Q. Consider the following statements:

HVDC transmission is superior to HVAC transmission due to

1. Lack of reliable DC circuit breakers.
2. Lesser number of conductors for same power carrying capacity.
3. Non synchronous link between two different systems simplifying the problem of voltage stability and frequency control.
4. No costly terminal equipment's such as converts and inverters are required.

Which of these statements is/are correct?

[ESE-2009]

A 4 only

B 4 and 3

C 1 and 2

D 2 and 3

#Q. **Assertion (A):** In HVDC systems, the voltage should be as high as possible and the rectifier control angle α should be as low as possible.

Reason (R): Control of dc voltage is exercised by the rectifier and inverter control angles α and γ respectively.

[ESE-2009]

A

Both A and R are true and R is the correct explanation of A

B

Both A and R are true but R is NOT the correct explanation of A

C

A is true but R is false

D

A is false but R is true



#Q. Consider the following statements regarding HVDC power transmission:

1. The modern HVDC systems use 12-pulse converters.
2. DC systems never use ground or sea return.
3. Most of present-day d.c. schemes are two-terminal links.

Which of these statements is/are correct?

[ESE-2008]

- A** 1, 2 and 3
- B** 1 only
- C** 2 and 3 only
- D** 1 and 3

#Q. What is the DC output voltage for a 6-pulse Graetz bridge converter for HVDC transmission?
[ESE-2007]

A $V_d = \frac{3E_m}{\pi} \cos \alpha$

B $V_d = \frac{3\sqrt{2}E_m \cos \alpha}{\pi}$

C $\frac{3\sqrt{3}E_m \cos \alpha}{\pi}$

D $V_d = \frac{3\sqrt{3}E_m \cos \alpha}{2\pi}$

#Q. High voltage d.c. transmission requires filters for

- A** current harmonics on a.c. side and voltage harmonics on d.c. side
- B** voltage harmonics on a.c. side and current harmonics on d.c. side
- C** voltage harmonics on both a.c. and d.c. sides
- D** current harmonics on both a.c. and d.c. sides

#Q. If p is the pulse number and n is an integer, what is the order of harmonics on a.c. side and d.c. side of an HVDC converter? [ESE-2006]

A $(np + 1)$ and $(np - 1)$, respectively

B $(np - 1)$ and np , respectively

C $(np + 1)$ and np , respectively

D $(np \pm 1)$ and np , respectively

#Q. Consider the following statements regarding the suitable choice of HVDC converter configuration:

1. Pulse number should be high
2. Ratio of peak inverse voltage to no load d.c. output voltage should be as high as possible
3. Transformer utilization factor should be nearly unity

Which of these statements are correct?

[ESE-2004]

A 1 and 2

B 1, 2 and 3

C 2 and 3

D 1 and 3



[ESE-2003]

#Q. In HVDC transmission there are predominant

- A** Voltage harmonics on d.c. side and current harmonics on a.c. side of converters
- B** Current harmonics on d.c. side and voltage harmonics on a.c. side of converters
- C** Current harmonics only on the d.c. side of converters
- D** Voltage harmonics only on the a.c. side of converters

#Q. Match List-I (Different Configurations for Asynchronous Interconnection) with List-II (Corresponding Figures) and select the correct answer: [ESE-2003]

List-I

- A. Two-terminal DC link
- B. Back to back HVDC Link along with AC feeder
- C. Back to back HVDC Link at border

Code:

- A** A-3, B-2, C-1
- B** A-3, B-3, C-1
- C** A-3, B-1, C-2
- D** A-2, B-1, C-3

List-II

1. 
2. 
3. 



#Q. In the HVDC system, the ac harmonics which gets effectively eliminated with 12 pulse bridge converters, are [ESE-2001]

- A** triplen harmonics
- B** triplen and 5th harmonics
- C** triplen, 5th and 7th harmonics
- D** 5th and 7th harmonics



2 Minutes Summary

→ Why HVDC

→ Different link of HVDC

→ Equipment in HVDC Converter station

→ Advantage & Disadvantage

Thank you

GW
Soldiers !



PRACTICE SHEET-1

EE

POWER SYSTEMS

Transient in power system and HVDC

- Q1** A surge of 150 kV is propagating from an overhead line of surge impedance 300Ω into a cable of surge impedance 100Ω . The coefficient of current reflection at the junction of overhead line & cable is
 (A) 0.4 (B) -0.4
 (C) 0.5 (D) -0.5
- Q2** A 10 km long 3ϕ , 3 core cable has the capacitance measured between any two conductors is $0.2 \mu\text{F}/\text{km}$ when other conductor connected to sheath. It is connected to 11 kV, 50 Hz, busbar. The kVA taken by the cable is _____ kVA.
- Q3** Calculate the most economic size (diameter) of a single core cable working on 121 kV, 3-phase system, if dielectric stress of 15 kV/cm can be allowed.
 (A) 11.55 mm
 (B) 13.17 mm
 (C) 17.33 mm
 (D) 18.4 mm
- Q4** For a lossless line terminated by its surge impedance, the natural reactive power loading is
 (A) $\frac{V^2}{X}$ (B) $\frac{V^2}{Z}$
 (C) $\frac{V^2}{Z_c}$ (D) zero
- Q5** A 3 - Φ , 420 kV transmission line has $Z_s = 500 \Omega$. If the line is compensated with series capacitor and shunt reactor of 30 % and 20 % respectively, the new values of surge impedance and surge impedance loading are
 (A) 374.21Ω and 429.26 MW
 (B) 419.66Ω and 382.39 MW
 (C) 352.28Ω and 460.76 MW
 (D) 467.7Ω and 377.16 MW
- Q6** A surge of 20 kV magnitude travel along a cable toward its junction with an overhead line. The inductance and capacitance of the cable are 0.36 mH and $0.45 \mu\text{F}$ per mm respectively and those of overhead line are 2 mH, $0.015 \mu\text{F}$ per respectively. The voltage rises at the junction due to the surge will be _____ kV.
- Q7** A travelling wave due to lightning with an incident voltage 220 V travels through the overhead line of surge impedance 360Ω and enters a cable of surge impedance of 40Ω . The voltage entering the cable at the junction is
 (A) 55 V (B) 66 V
 (C) 44 V (D) 23 V
- Q8** High voltage d.c. transmission requires filters for
 (A) current harmonics on a.c. side and voltage harmonics on d.c. side
 (B) voltage harmonics on a.c. side and current harmonics on d.c. side
 (C) voltage harmonics on both a.c. and d.c. sides



(D) current harmonics on both a.c. and d.c. sides

Q9 In an HVDC system

- (A) Both generator and distribution and d.c.
- (B) Generation is a.c. and distribution is d.c.
- (C) Generation is d.c. and distribution is a.c.
- (D) Both generation and distribution are a.c.

Q10 The following is not an advantage of dc transmission

- (A) No charging current
- (B) No skin effect
- (C) No stability problem
- (D) Cheap converters

Q11 In an HVDC transmission mode, the link which has two circuits that are almost independent of each other is called

- (A) Monopolar link
- (B) Bipolar link
- (C) Homopolar link
- (D) Dualpolar link

Q12 Which of the following will be provided to reduce the harmonics on the ac side of an HVDC transmission line ?

- (A) Synchronous motors in over excited condition
- (B) Shunt capacitor
- (C) Static compensator
- (D) Shunt filters



Answer Key

Q1 (C)

Q2 151.9~152.1

Q3 (B)

Q4 (D)

Q5 (D)

Q6 37~38

Q7 (C)

Q8 (A)

Q9 (D)

Q10 (D)

Q11 (B)

Q12 (D)



Electrical Engineering

Power Systems



Practice Sheet Discussion – 01

Transient in Power System And HVDC



By- Ajay Gupta Sir

Q.

A surge of 150 kV is propagating from an overhead line of surge impedance 300Ω into a cable of surge impedance 100Ω . The coefficient of current reflection at the junction of overhead line & cable is



A 0.4

B -0.4

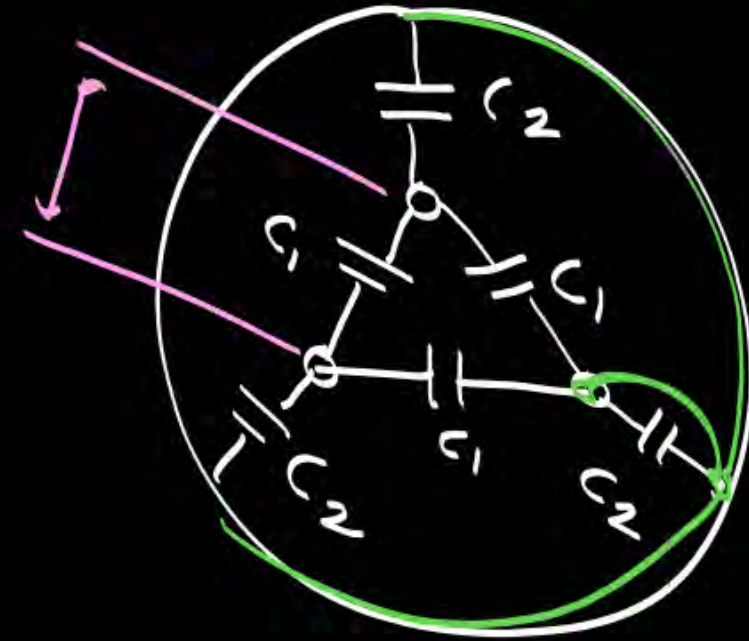
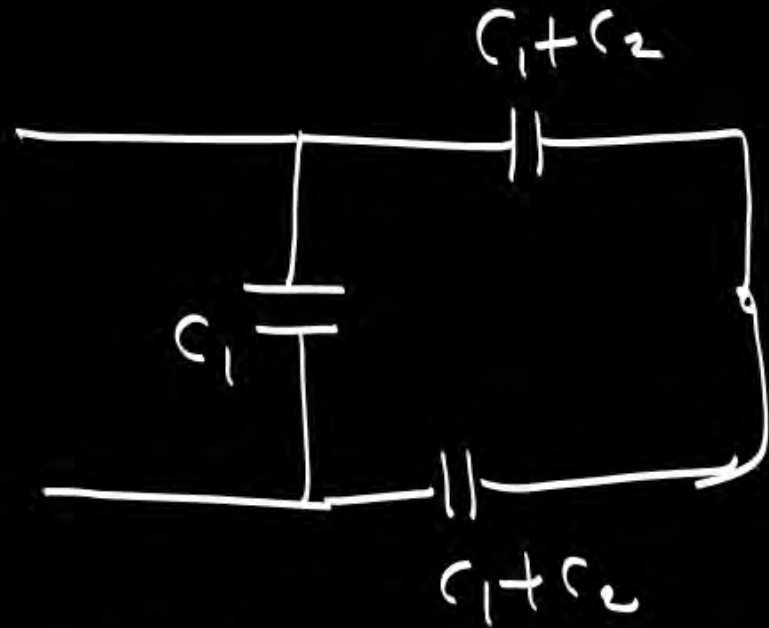
C 0.5 ✓

D -0.5

$$= - \left(\frac{Z_2 - Z_1}{Z_2 + Z_1} \right) = - \left(\frac{100 - 300}{100 + 300} \right) = \frac{200}{400} = 0.5$$

Q.

A 10 km long 3 ϕ , 3 core cable has the capacitance measured between any two conductors is $0.2 \mu\text{F}/\text{km}$, when other conductor connected to sheath. It is connected to 11 kV, 50 Hz, busbar. The kVA taken by the cable is ____ kVA.



$$C_1 + \frac{C_1 + C_2}{2} = \frac{1}{2} (3C_1 + C_2) = 0.2 \times 10^{-6} \text{ F/km}$$

$$3C_1 + C_2 = 0.4 \times 10^{-6} \text{ F/km}$$

$$C_{ph} = 3C_1 + C_2$$

$$\begin{aligned} P=0 \quad Q=Q &= \frac{V^2}{X_c} = V^2 \omega C = (11 \times 10^3)^2 \times (100 \pi) \times 0.4 \times 10^{-6} \\ &= 152.05 \text{ kVAR} \end{aligned}$$

Q.

Calculate the most economic size (diameter) of a single core cable working on 121 kV, 3-phase system, if dielectric stress of 15 kV can be allowed.

- A** 11.55 mm
- ☒ **B** 13.17 mm
- C** 18.17 mm
- D** 18.4 mm

$$E = \frac{V_{max}}{\gamma}$$

$$15 \times 10^3 = \frac{121 \times 10^3 \sqrt{2}}{\sqrt{3} \gamma}$$

$$\gamma = 6.586 \text{ mm}$$

$$D = 2\gamma = 13.17 \text{ mm}$$

Q.

For a lossless line terminated by its surge impedance, the natural reactive power loading is

- A** V^2/X
- B** V^2/Z
- C** V^2/Z_c
- D** Zero ✓

For SIL $Q=0$

Q.

A 3 - ϕ , 420 kV transmission line has $Z_s = 500 \Omega$. If the line is compensated with series capacitor and shunt reactor of 30 % and 20 % respectively, the new values of surge impedance and surge impedance loading are

- A** 374.21 Ω and 429.26 MW
- B** 419.66 Ω and 382.39 MW
- C** 352.28 Ω and 460.76 MW
- D** 467.7 Ω and 377.16 MW

$$Z_s' = Z_s \sqrt{\frac{1 - k_{se}}{1 - k_{sh}}}$$

$$= 500 \sqrt{\frac{1 - 0.3}{1 - 0.2}} = 467.7$$

$$S_{IL} = \frac{V^2}{Z_s'} = \frac{(420)^2}{467.7} = 377.16 \text{ MW}$$

Q.

A surge of 20 kV magnitude travel along a cable toward its junction with an overhead line. The inductance and capacitance of the cable are 0.36 mH and 0.45 μ F per mm respectively and those of overhead line are 2 mH, 0.015 μ F per km respectively. The voltage rises at the junction due to the surge will be ____ kV.

Cable Surge Impedance

$$= \sqrt{\frac{0.36 \times 10^{-3}}{0.45 \times 10^{-6}}} = 28.28$$

Surge Impedance of OH line

$$= \sqrt{\frac{2 \times 10^{-3}}{0.015 \times 10^{-6}}} = 365.14$$

$$V'' = 20 \times \frac{2 \times 365.14}{28.28 + 365.14}$$
$$= 37.124 \text{ kV}$$

Q.

A travelling wave due to lightning with an incident voltage 220 V travels through the overhead line of surge impedance 360Ω and enters a cable of surge impedance of 40Ω . The voltage entering the cable at the junction is

A 55 V

B 66 V

C 44 V

D 23 V

$$V'' = 220 \times \frac{2 \times 40}{360 + 40}$$

$$= 220 \times \frac{2 \times \cancel{40}}{\cancel{400} 10} = 440$$

Q. High voltage d.c. transmission requires filters for

- A** ✓ current harmonics on a.c. side and voltage harmonics on d.c. side
- B** voltage harmonics on a.c. side and current harmonics on d.c. side
- C** voltage harmonics on both a.c. and d.c. sides
- D** current harmonics on both a.c. and d.c. sides

Q. In an HVDC system

- A** Both generator and distribution and d.c.
- B** Generation is a.c. and distribution is d.c.
- C** Generation is d.c. and distribution is a.c.
- D** ✓ Both generation and distribution are a.c.

Q. The following is not an advantage of dc transmission

- A** No charging current
- B** No skin effect
- C** No stability problem
- D** Cheap converters ✓

Q. In an HVDC transmission mode, the link which has two circuits that are almost independent of each other is called

- A** Monopolar link
- B** Bipolar link ✓
- C** Homopolar link
- D** Dualpolar link

Q. Which of the following will be provided to reduce the harmonics on the ac side of an HVDC transmission line?

- A** Synchronous motors in over excited condition
- B** Shunt capacitor
- C** Static compensator
- D** Shunt filters ✓

Thank
you