



**R. C. Patel College of Engineering and Polytechnic,
Shirpur**

Class: SYEE (EE3K)

Course:

**ELECTRICAL POWER GENERATION,
TRANSMISSION AND DISTRIBUTION**

(Course Code: 313333)

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Academic Year: 2026–27

Unit - IV

Extra High Voltage Transmission (HVAC and HVDC) (12 Marks)

Course Outcome:

**CO4: Interpret the parameters of the
extra high voltage transmission
system.**

* Introduction:

Importance of EHV Transmission:

- EHV (Extra High Voltage) transmission is used for transmitting a large amount of electrical power over long distances.
- As transmission voltage increases, current decreases for the same power.
- Copper loss $\propto I^2$, therefore, copper loss decreases.
- More power can be transmitted through a single line.
- Fewer transmission lines are required, reducing the overall project cost.
- Transmission efficiency increases.
- However, EHV transmission requires careful consideration of
 - Electrostatic field
 - Corona effect
 - Corona loss
 - Noise
 - Conductor interference
 - Radio interference
 - Conductor design
 - line height
 - phase spacing.

* 765 kV lines in India:

Examples of 765 kV transmission lines:

1. Tiruda-Koradi line
2. Akola-Aurangabad line

3. Anpara - Unnao line
4. Kishnepur - Moga L-1 (W) and L-2 (E)
5. Tehri - Meerut line-1 and line-2
6. Sipat - Seoni line-1 and line-2

* Necessity of EHV Transmission:

1. Reduced current:
 - For the same power and power factor, higher voltage requires lower current.
2. Reduced conductor size:
 - Lower current reduces the required cross-sectional area of the conductor.
3. Reduced copper loss:
 - Lower current results in lower I^2R loss, thereby improving transmission efficiency.
4. Interconnection of large power systems:
 - EHV transmission is useful for interconnecting large power system.
5. Higher power handling capacity:
 - Power handling capacity increases approximately in proportion to V^2 .
6. Economical for long distances:
 - EHV transmission is economically advantageous for bulk power transmission over long distances.
7. Improved voltage regulation,

* High voltage substation Equipment and their functions:

1. Busbar:

- A busbar is a common conductor.
- Incoming and outgoing lines are connected to it.

2. Insulator:

- Insulator is used to isolate conductor from tower structure.
- Functions:
 1. Provides mechanical support to the conductor.
 2. Restricts the flow of electric current to the required conductor/path.
- Common material: porcelain.



Fig. Insulator

3. power Transformer/Main Transformer:

- Function: Used in substation for stepping up or stepping down voltage.
- Step-up transformers increase voltage for transmission.
- Typical transmission voltage may be 132 kV, 220 kV or higher.

4. Auxiliary Transformer:

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function: provides supply for auxiliary loads such as:

- control room
- Area lighting
- staff quarters.
- It steps down 11 kV, 3 phase supply to 400V, 3 ϕ , 4 wire supply.

5. Instrument Transformer:

- substation lines operate at high voltage and high current.
- Instrument transformers are used to step down these quantities for measurement and protection.

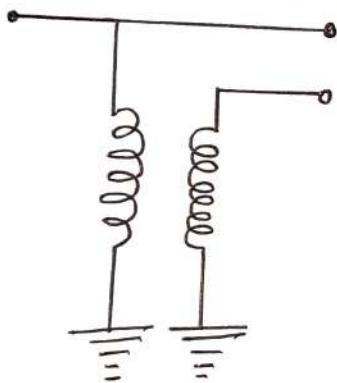


Fig. Potential Transformer. (PT)



Fig. Current Transformer (CT)

- Types of Instrument Transformer:

1. CT
2. P.T.

- standard outputs mentioned:

CT: 1A or 5A

PT: 110V

6. Lightning Arrester:

function: protects the insulation and conductors of the electrical power transmission system from harmful effects of lightning.

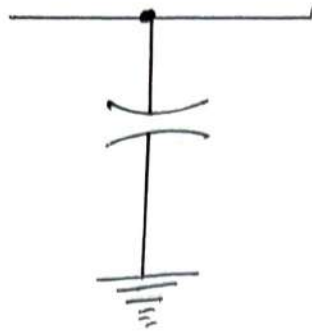


Fig. lightning Arrester.

- Connected betn the line and earth,
- Installed at the starting / entry point of the substation.

7. Circuit Breaker:

- A circuit breaker is a protective device.



Fig. Circuit breaker.

- Functions:

- Interrupts the circuit during a fault
- protects electrical equipment
- Can be operated,
- Manually
- By remote control,

8. Relay:

- A relay detects faults and sends a signal to the trip circuit of the circuit breaker.

- Types of Relays:

- overcurrent relay
- Earth fault relay
- phase to phase fault relay
- Thermal relay.

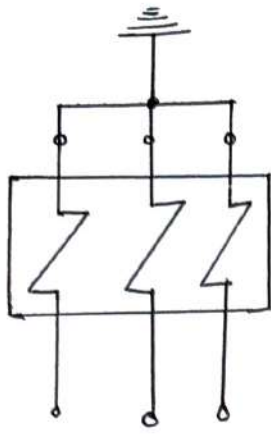


fig. Overcurrent Relay

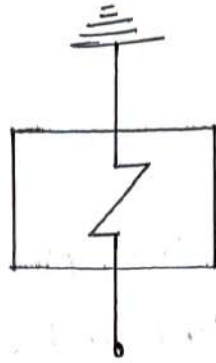


fig. Earth Fault Relay.

9. Earth switch:

- During maintenance, a line is opened using an isolator.
- The earth switch is used for ground capacitance discharge.
- Main function: Discharges the stored / ground capacitance charge to earth.

10. Isolator: (No load switch):

Function: Used to connect or disconnect a circuit only under no load condition.

* FACT Devices:

- FACT = Flexible AC Transmission Line Devices.
- In Conventional AC transmission systems, power transfer capability is limited due to various factors.
- Main purpose of FACT Devices :
 - FACT devices provides: - lagging as required by the system.
- This helps in improving power transmission and making active power and apparent power nearly equal under the ideal

- Transmission condition described in the source.
- FACT devices use static power electronic equipment.

* Types of FACTS Controller:

1. Series Compensation Controller:

- TCSR - Thyristor Controlled Series Reactor
- TCSC - Thyristor Controlled Series Capacitor.

2. Shunt Compensation Controller:

- STATCOM - Static synchronous compensator
- SVC - Static VAR compensator.

* High Temperature low sag (HTLS) conductor:

* Defn/Features:

- HTLS Conductor can operate at temperature up to 210°C
- They can carry more current and power than conventional conductor,
- They have low sag, even at high operating temperature.
- Used where installation of new or taller towers is restricted and clearance problems exist.

* Construction:

- Conventional ACSE uses a stranded steel wire core.
- HTLS Conductor uses a lightweight, high-strength carbon fibre composite core.
- They have higher current carrying capacity.

* Limitation:

- conductor cost and operating cost are high.

* Effect in High voltage Transmission lines:

* Ferranti Effect:

* Condition for Ferranti effect:

- Ferranti Effect occurs when:

1. Transmission line is unloaded or lightly loaded.
2. load is suddenly removed.
3. sudden load shedding occurs.
4. Transmission line becomes open-circuited due to load failure.

* Defn: When receiving end voltage become greater than sending end voltage under no-load or light load condition. This phenomenon is called as Ferranti effect.

— under no load or light load condition;

$$V_R > V_S$$

where V_R = Receiving end voltage
 V_S = Sending end v_{tg}.

* Causes:

- Mainly due to line capacitance.
- In long transmission lines, capacitance and inductance are important parameters.
- For lines of about 240 km or more, capacitance is distributed along the entire line.
- At no load, the capacitive charging current I_c becomes significant.

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— This causes the receiving end v_t to become greater than the sending end v_s.

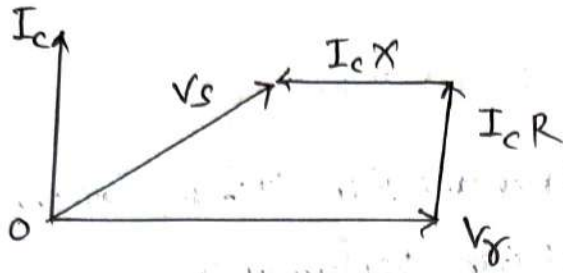


Fig: Ferranti Effect ~~is~~ phasor diagram.

* Corona Effect:

* Defn: When the voltage betn two conductors exceeds the breakdown strength of air (approximately 30 kV/cm), the surrounding air gets ionized. This phenomenon is called corona effect.

* observations during Corona:

1. Violet glow around the conductor
2. Hissing noise is produced
3. Ozone gas is formed.

* Advantages of Corona:

1. Ionization of air increases the effective diameter of the conductor.
2. Effective conductor resistance decreases.
3. Electrostatic stress is reduced.
4. Provides protection against lightning overvoltage.
5. Reduces transient effect due to surges.

* Disadvantages of Corona:

1. Causes power loss, reducing transmission efficiency.
2. Produces ozone, which may cause ~~coro~~ corrosion of conductor and hardware.

3. Causes radio interference and harmonics.

4. produces electromagnetic and electrostatic interference.

* Line Compensation: Need and Benefits:

- In long distance EHVAC transmission system, Compensation is required to improve transmission performance.
- Main devices used
 - Series Capacitor
 - shunt Reactor.

Need / Benefit of line compensation:

1. Control reactive VAR Flow.
2. Increases power transmission capacity.
3. Improves power factor.
4. Improve voltage regulation.
5. Improve system stability
6. Improve voltage control.
7. Increases transmission efficiency.
8. Reduces temporary and transient overvoltages.

* Types of Line compensation:

- There are two main types:

1. Series Compensation
2. shunt Compensation.

1. Series Compensation:

- Series capacitors are used to increase transmission capacity.
- Economical for transmission distance of less than 300 km.
- The source gives

$$P = \frac{V^2}{X_L - X_C}$$

where P = power transmitted

X_L = Inductive reactance

X_C = Capacitive reactance.

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2. Shunt Compensation:

- shunt compensation is performed by connecting a compensating element in parallel (shunt) with the transmission line.
- Types:
 - a) shunt Capacitive Compensation
 - b) shunt Inductive Compensation.

a) shunt Capacitive Compensation:

- Used for power factor improvement
- When an inductive load is connected, it draws lagging current
- Therefore, the power factor becomes lagging.
- A shunt capacitor is connected to provide compensation.
- Main purpose: Correct lagging power factor.

b) shunt Inductive Compensation:

- Used when the transmission line is lightly loaded or unloaded.
- shunt capacitance of a long transmission line can increase receiving end V_{tg} .
- This results in the Ferranti Effect.
- A shunt reactor is connected to compensate for this capacitive effect.
- Main purpose: Control overvoltage in lightly loaded or no load transmission lines.

* HVDC Transmission Network in India:

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HVDC Link	Distance	Power	Voltage	Type
Rihand-Dadri	814 km	1500 MW	± 500 kV	Bipolar
Talcher-Kolar	1376 km	2000 MW	± 500 kV	Bipolar
Chandrapur-Padghe	752 km	1500 MW	± 500 kV	Bipolar
Barsoor-Lower Subansiri	—	100 MW	100 kV	Monopolar
Sasaram-Pusaoli	0 km	500 MW	140 kV	Back-to-back link
Vindhyachal-Western Region	0 km	2×250 MW	70 kV	Back-to-back link
Chandrapur-Southern Region	0 km	2×500 MW	140 kV	Back-to-back link
Visakhapatnam-Eastern Region	0 km	500 MW	140 kV	Back-to-back link

* HVDC Transmission:

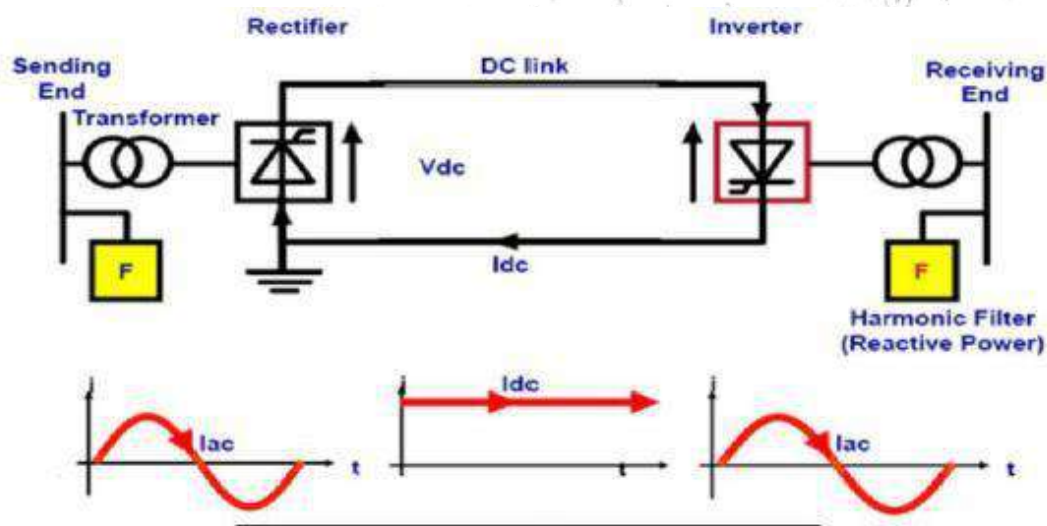


Fig. Block Diagram of HVDC Transmission

* Basic function of HVDC:

HVDC = High voltage Direct current transmission

- Basic Process:

AC supply $\rightarrow$ Rectifier $\rightarrow$ DC Transmission $\rightarrow$ Inverter $\rightarrow$ AC supply

- Rectifier: Converts AC vtg into DC

- Transmission: DC power is transmitted over a long distance.

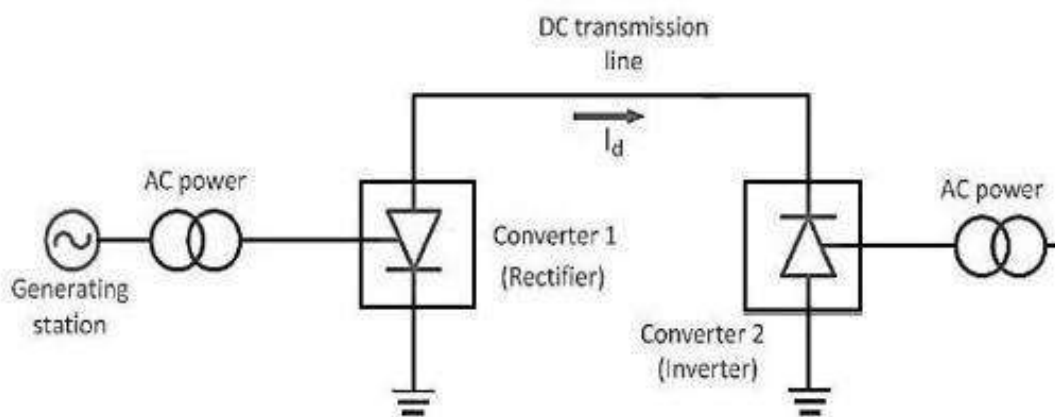
- Inverter: Converts transmitted DC back into AC.

* Classification of HVDC Transmission:

- There are 3 types:

1. Monopolar HVDC
2. Bipolar HVDC
3. Homopolar HVDC.

1. Monopolar HVDC Transmission:



Monopolar HVDC transmission system

* Defn: / Features:

- A single conductor is used for HVDC transmission.
- Generally negative polarity is used.
- power and current flow in one direction.
- Earth / ground may be used as the return path.
- current rating: approximately 200 A to 100 A.

* Advantages:

- Simple design
- less maintenance
- Economical
- suitable for lower-power transmission
- High charging current makes it technically suitable in some cases.

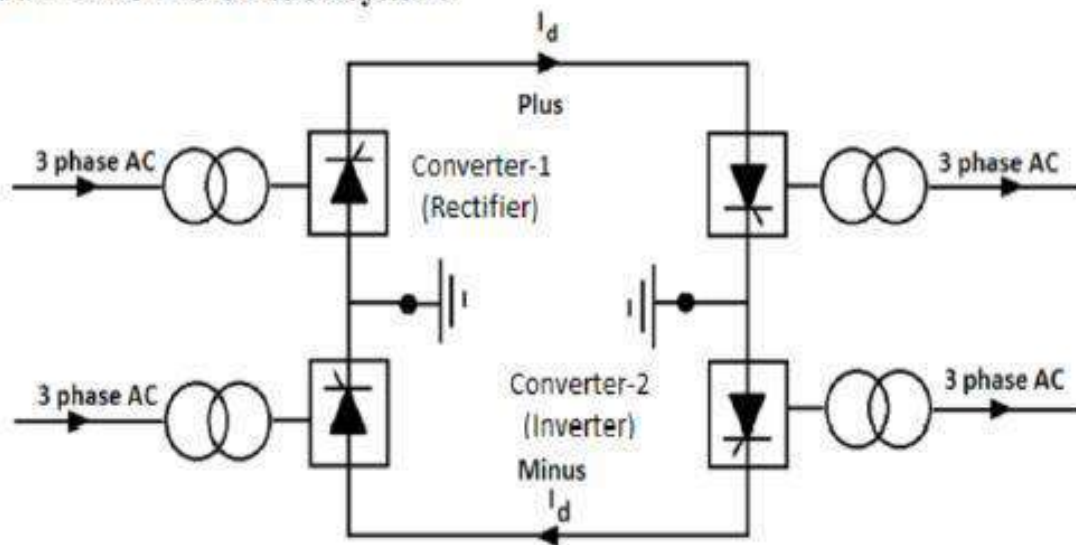
* Disadvantages:

- Failure of conductor can stop the complete transmission system.
- Mainly suitable for low power/cable transmission links.

* Mono polar = 1 conductor

2. Bipolar HVDC Transmission:

Bipolar HVDC Transmission System:



Defn/Features

- A bipolar HVDC link uses two conductors.
- one conductor: positive (+)
- one conductor: negative (-)
- It is commonly used for HVDC power transmission.

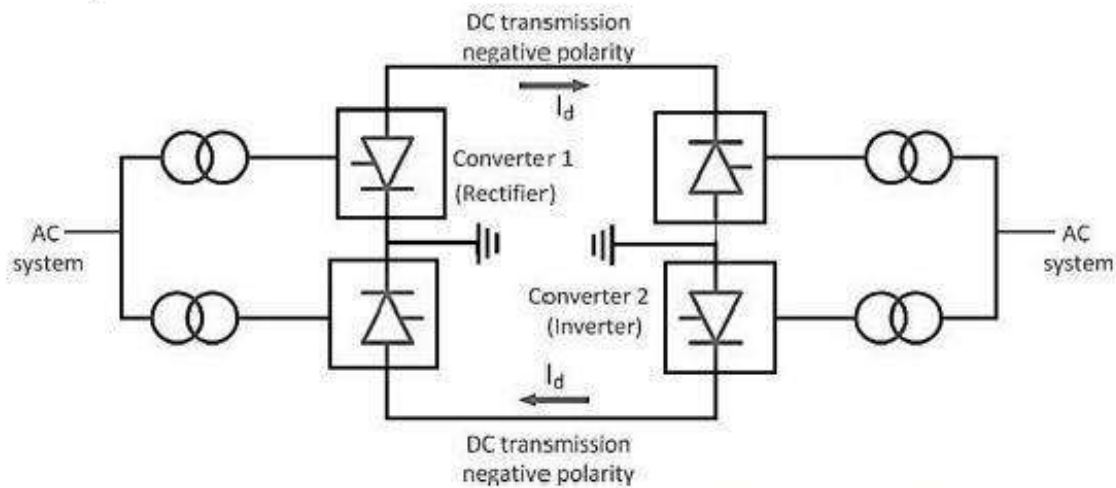
* Advantages:

1. power transmission can continue both two stations.
2. Fault in one line does not necessarily affect the other line.
3. During fault conditions, it can operate as a monopolar link.
4. current direction can be changed by changing the polarity of the two poles.

5. Bipolar v_{tg} is approximately twice the monopolar pole to earth v_{tg} .

* Bipolar = 2 conductors (one +ve & one -ve)

3. Homopolar HVDC Transmission:



- Defn: A homopolar HVDC link uses two or more conductors having the same polarity.
- Earth is generally used as the return conductor/path.
- If one conductor develops a fault, healthy conductors can continue supplying the remaining conductor through converters.
- During fault conditions, it can also operate as a monopolar link.
- * Homopolar = Multiple conductors + same polarity.

A EHVAC VS HVDC Transmission?

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Point	EHVAC	HVDC
Voltage level	220, 400, 765 kV	±500 kV
Main equipment	Step-up & step-down transformers	Transformer + Rectifier + Inverter
Economical for	Large power, long distance	Very large power & very long distance
Typical economical distance	≥ 500 km	≥ 800 km
Single circuit conductors	3 (R, Y, B)	1 conductor + earth return
Double circuit conductors	6	2 conductors + return path
Tower	Heavy	Light
Intermediate substation	Required around every 250 km	Not required
Substation cost	Less	More
Transmission line cost/km	More	Less
Earth return	Not possible	Possible
Skin effect	Present	Absent
Proximity effect	Present	Absent
Ferranti effect	Present	Absent
Corona loss	Present	Absent
Radio interference	Present	Absent
L & C effect	Present	Absent
Copper loss	More	Less
Right of way	Less	More
Voltage drop	More	Less
Voltage regulation	Good	Better
Charging current	Present	Absent

* Wireless Transmission of Electrical Power:

* Concept of Wireless Transmission of Electrical Power:

- Wireless power Transfer (WPT) works on the principle of Inductive power transfer.
- In a conventional transformer, the two coils are placed close together and a ferite core is used to improve magnetic coupling.
- In wireless power transfer, there is air gap betn the transmitter and receiver coils, hence there is no direct electrical connection betn them.
- Electrical power is transferred from the transmitter coil to receiver coil through a magnetic field.
- Basic Principle:
Electrical energy $\rightarrow$ Magnetic field $\rightarrow$ Electrical energy.

* Features of Wireless Transmission of Electrical power:

1. AC Conversion:
 - Voltage is converted into AC, generally high-Frequency AC.
2. High-Frequency Transmission:
 - High Frequency AC is transmitted through the transmitter coil
3. Induced current:
 - The alternating magnetic field induces current in the receiver coil.
4. Magnetic Coupling:
 - Transmitter and receiver coils are magnetically coupled.

5. Small magnetic field Range:

- The effective magnetic field region is relatively small, therefore, power regulation and efficiency are affected.

6. Resonant operation:

- For efficient power transfer, the transmitter and receiver coils should have the same resonant frequency.

7. Applications:

- Wireless power transfer can be used for charging mobile phones, electric vehicles and other electronic devices.