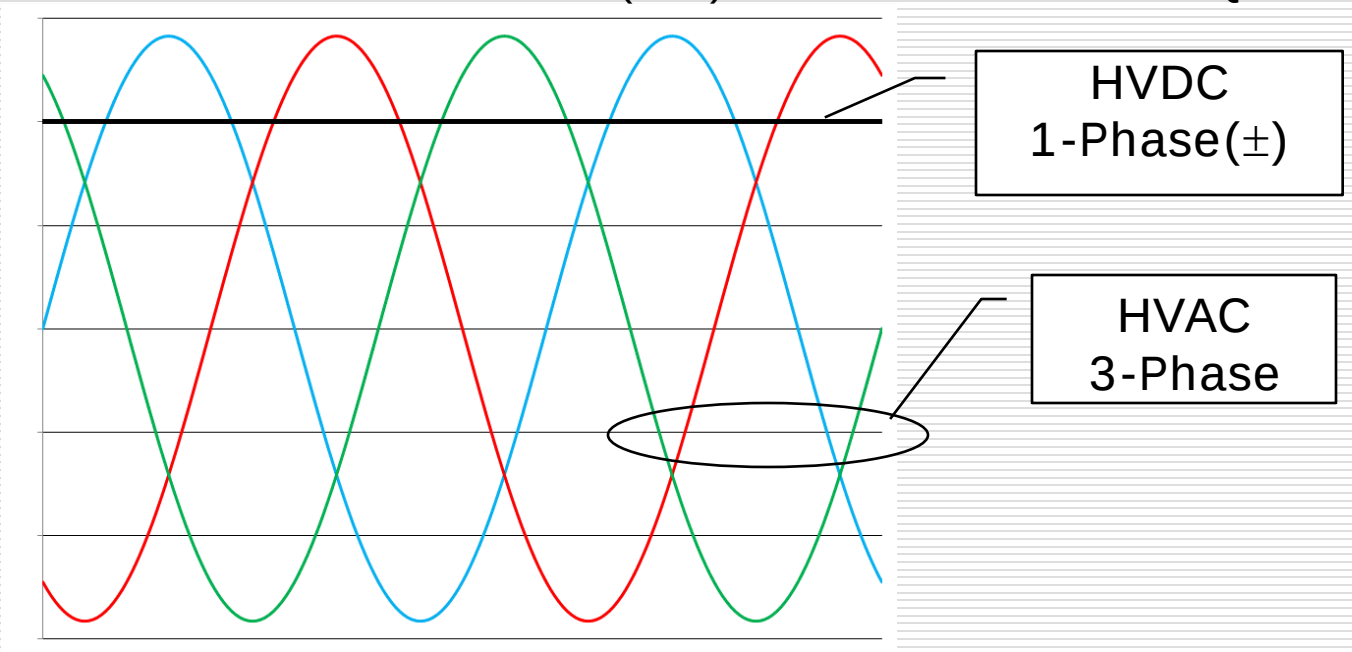
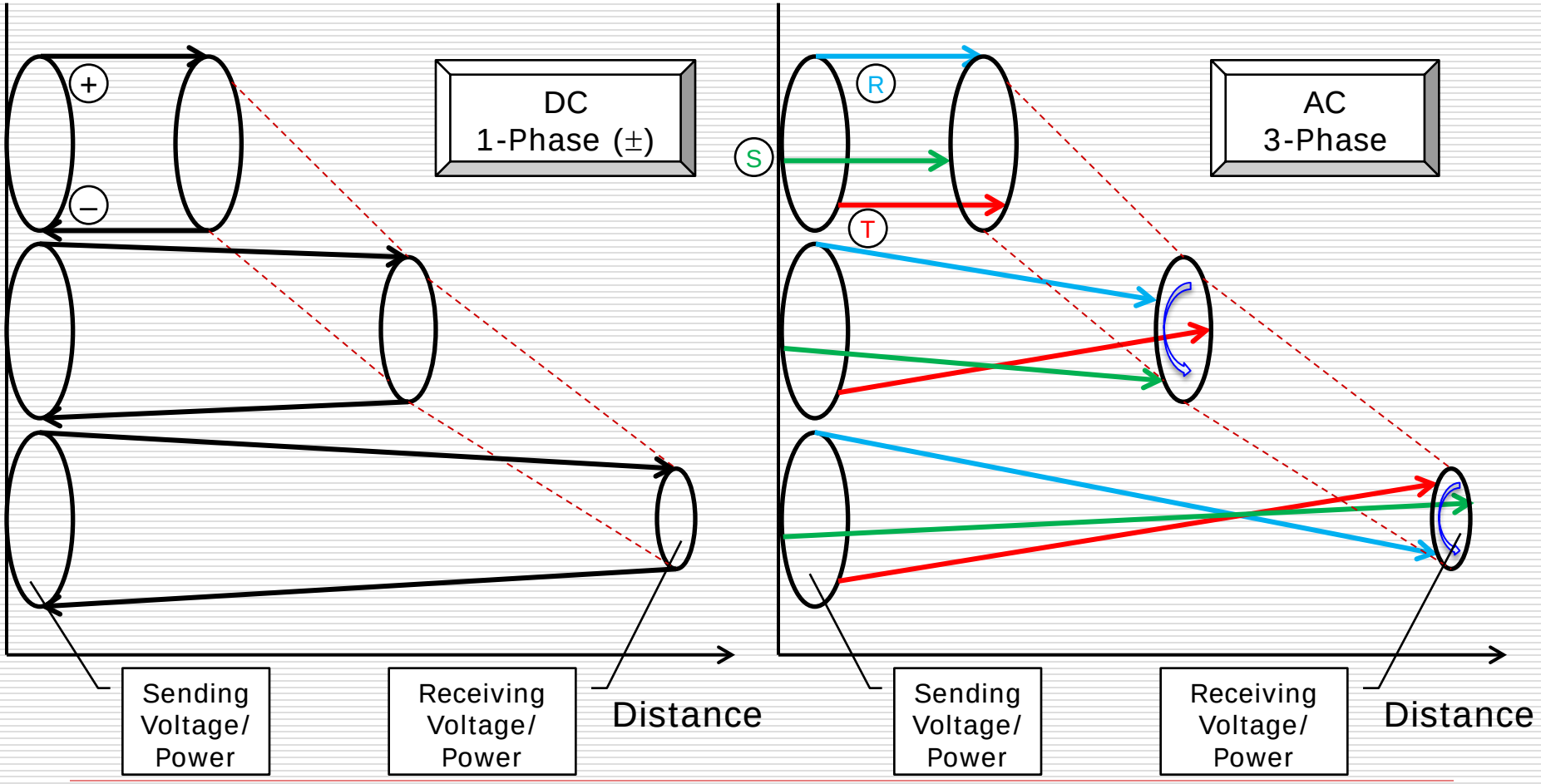
General Overview of HVDC Transmission System

WHAT IS HVDC ?

- High Voltage Direct Current Transmission
  - Only Active Power Flow is associated with HVDC: P.
- High Voltage Alternative Current Transmission
  - Both Active and Reactive Power (Var) Flows with AC: P and Q



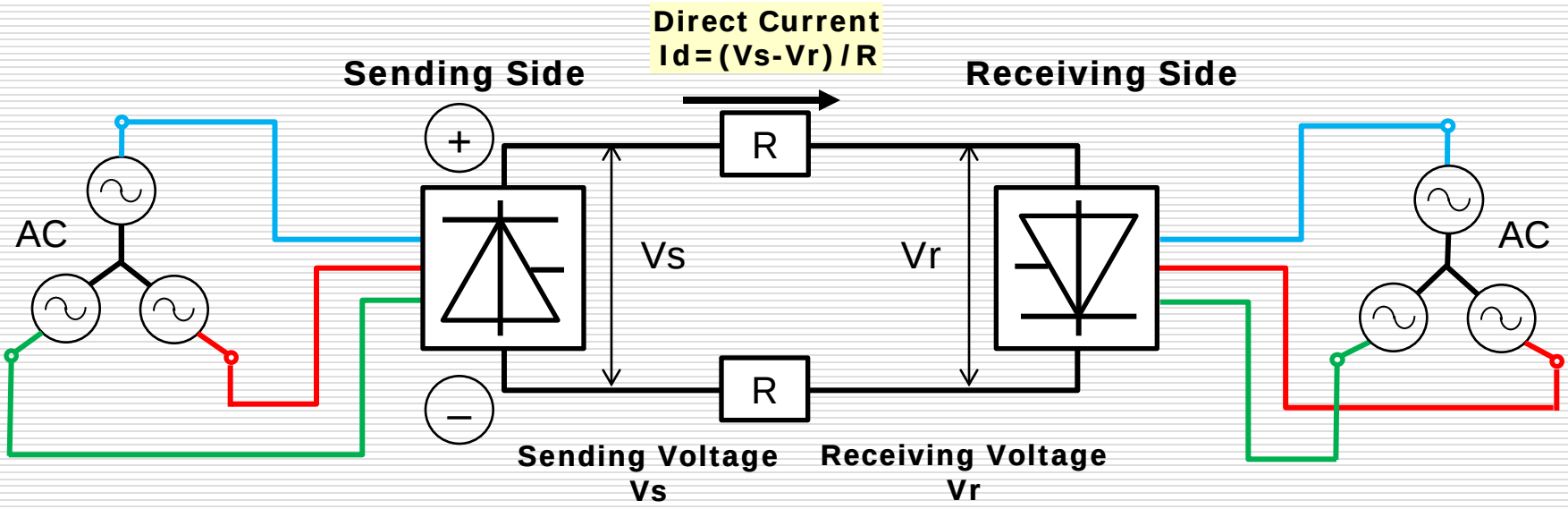
What is HVDC ?
Basic Image : DC vs. AC Transmission



- Voltage/Power – Decrease (Loss)
- Angle – No Change

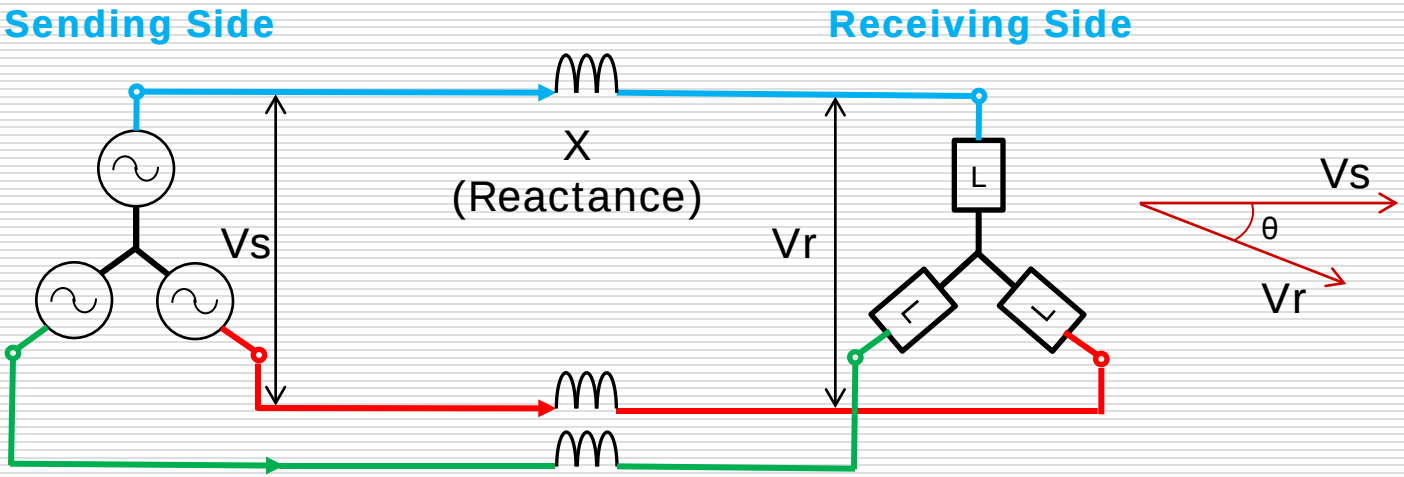
- Voltage/Power – Decrease (Loss)
- Angle – Change (Reactive Power)

WHAT IS HVDC ?



- Basic Power Flow Equations $Power = \frac{V_s(V_s - V_r)}{R}$
  - Only Governed by Ohm's Law

WHAT IS HVAC ?



- Basic Power Flow Equations $Power = \frac{V_s \cdot V_r}{X} \sin\theta$

  - Governed by Reactance
    - Var from Inductance & Capacitance

HVDC Advantages (1)

- Long-Haul Over Head Line (>500 ~ 1000km)

Bulk Power Transmission (>1 ~ 2 GW)

  - No limitation of stability (Free from stability & capacitance limitation)

- HVDC transmission line has less right of way requirement & less expensive in construction (HVDC 2-phase; HVAC 3-phase)

- Lower transmission loss because of no reactive loss

- Lower insulation/clearance of conductor (DC Voltage is about 71% of the AC Peak Voltage. AC is defined by RMS)

- Power transmission between asynchronous AC systems

HVDC Advantages (2)

- Fast Power Flow control
- Enhancement of AC system stability
- Supplying more active power where AC system is at the limit of its Short Circuit Capability

HVDC Disadvantages

- HVDC is generally less reliable and has lower availability than HVAC.
  - Mainly due to the extra conversion equipment and maintenance difficulty.
- Tapping for Multiple grids is difficult.
- HVDC circuit breakers are difficult
  - Some mechanism must be included in the circuit breaker to force current to zero
- Pollution deterioration of Outdoor Insulator is faster
  - Static Charge effect
- AC Filters are required to absorb harmonic component
- Clean room (Dust free) for Thyristor Valve is necessary

Comparison HVDC with HVAC

#	Item	HVDC	HVAC
1	Long-Haul OHL Bulk Transmission Capacity	High (> 1~2GW)	Limited
2	Long-Haul Transmission Stability	No Limit	Limited
3	Right-of-Way for Bulk Transmission OHL	Low	High
4	Long-Haul Transmission Loss	Low	High
5	Insulation / Clearance	Low	High
6	System Connection	Asynchronous	Synchronous
7	Power Flow Control	Easy and Fast	Difficult
6	Multiple terminal (Tapping)	Difficult and Costly	Simple and Easy
7	Short Circuit Limitation	Effective	Not Effective
8	Pollution Effect	• More Pronounced • Higher insulator creepage is required	Relatively less

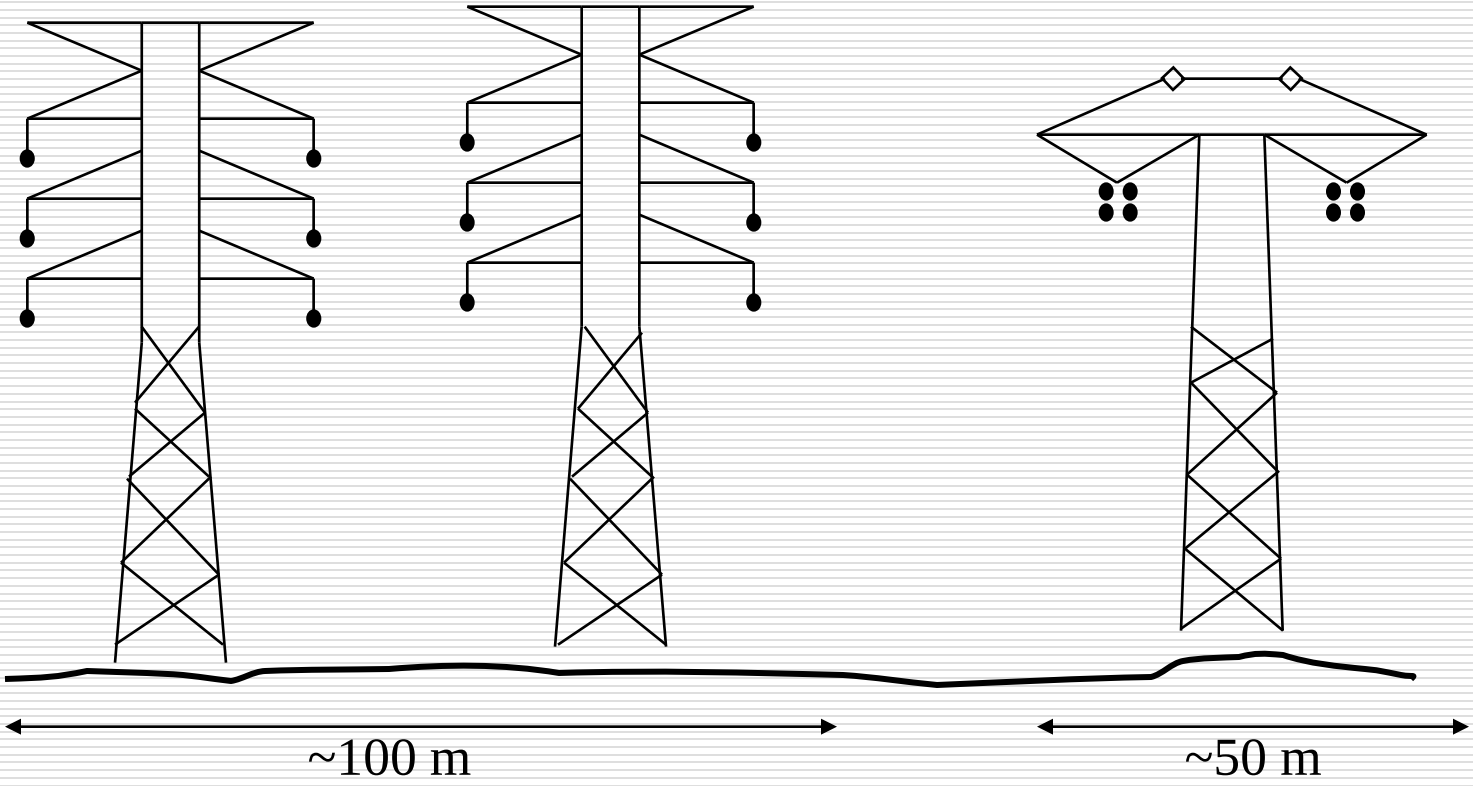
Why HVDC rather than HVAC ?

- Cheaper in Long-Haul Bulk Power transmission
- Asynchronous link
- Accurate Control of power flow – both magnitude and direction
- Fault isolation
- Improved link stability

Comparison of Right of Way for 2 GW

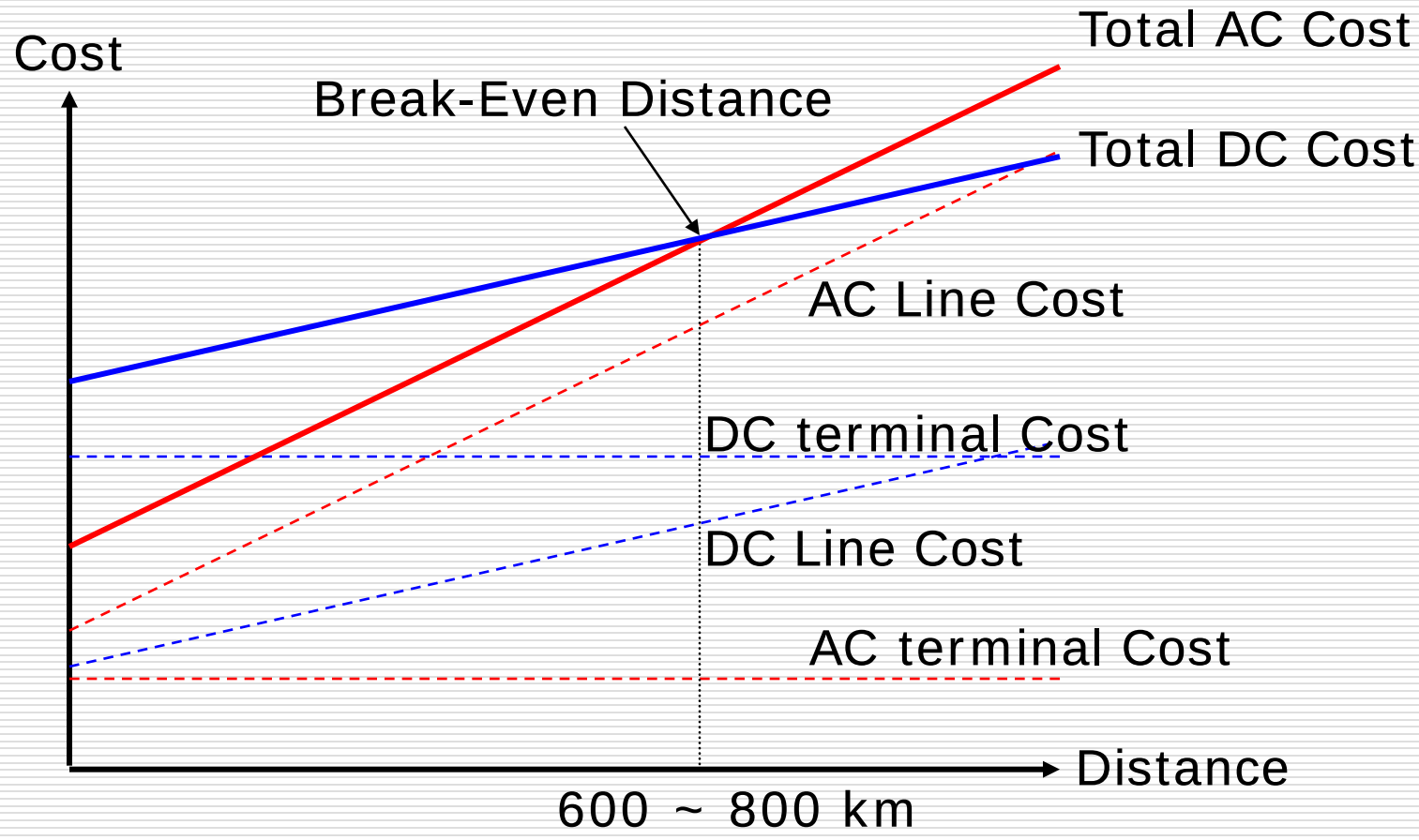
400~500 kV AC Lines

400~500 kV DC Line



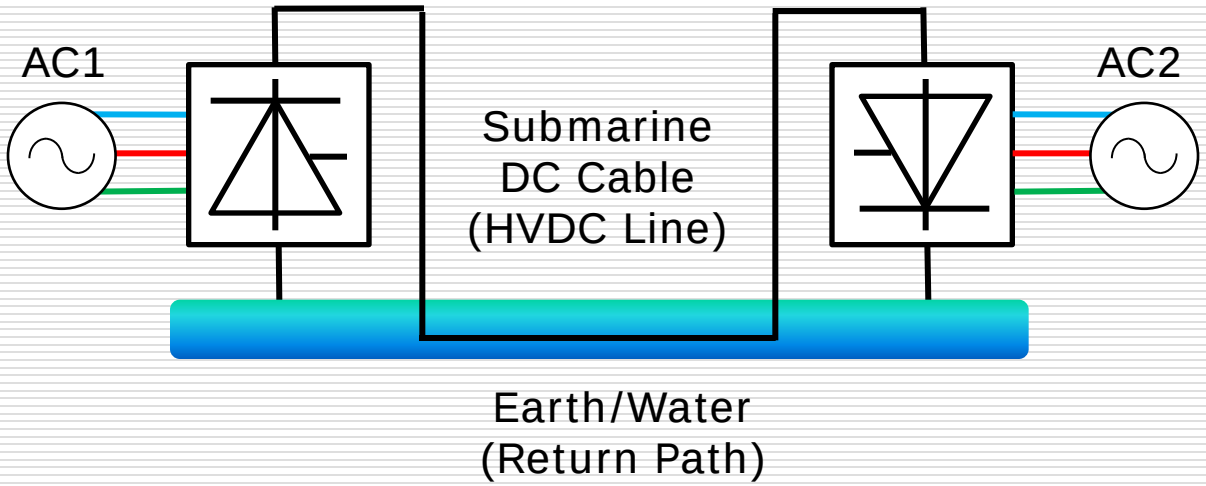
1~2GW Bulk Power Transmission

Cost comparison of HVDC & HVAC OHL Transmission



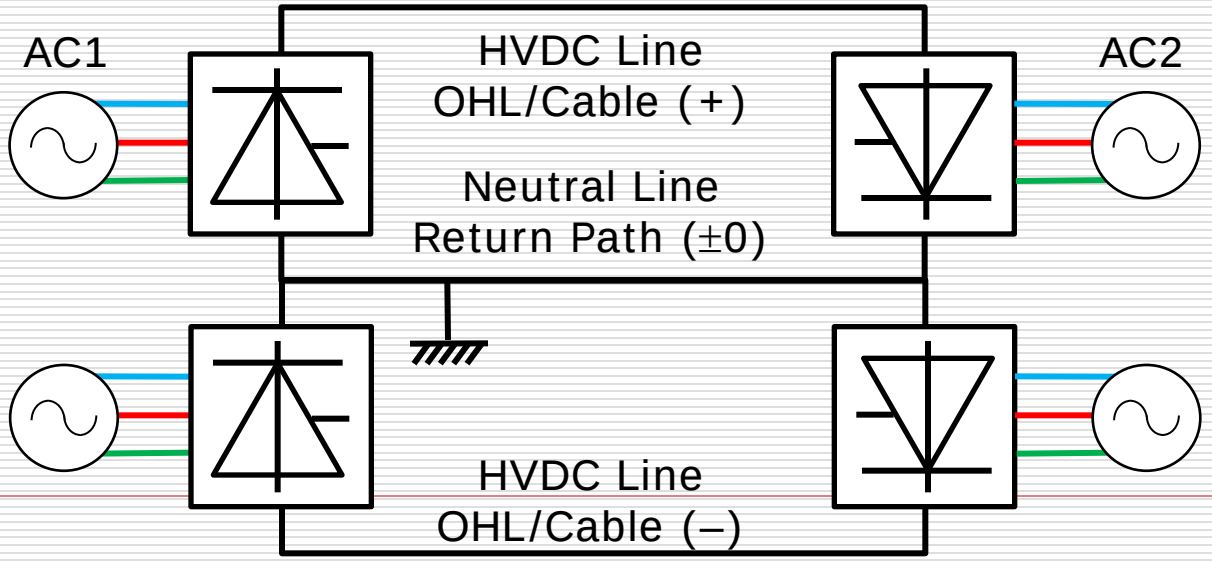
Types of HVDC Transmission system

- Monopole System:
  - One pole, one set of conductor for transmission and current return path is through earth.
  - Mainly used for submarine cable transmission.



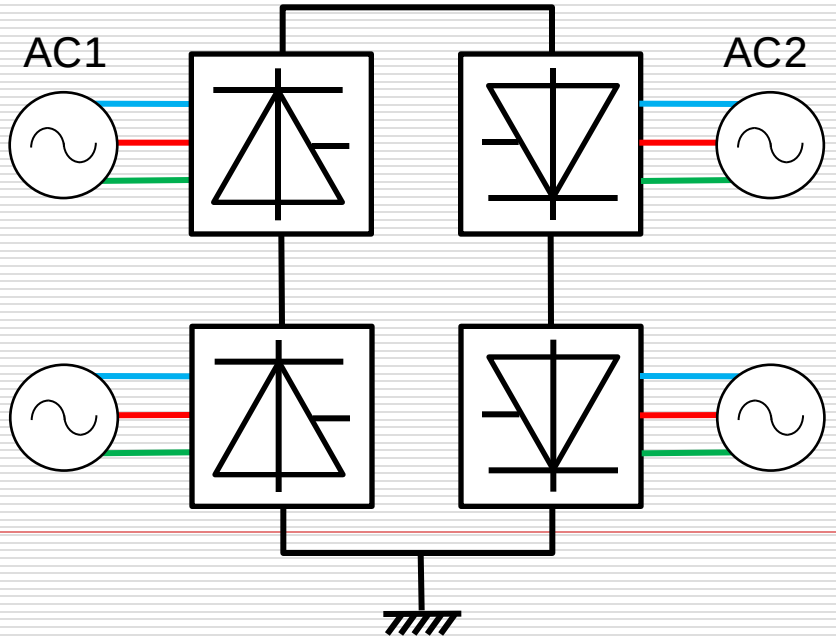
Types of HVDC Transmission system

- Bipolar System:
  - Two poles, two set of conductors in transmission line, one positive with respect to earth & other negative
  - The mid point of Bi-poles in each terminal is earthed via an electrode line and earth electrode.
  - In normal condition power flows through lines & negligible current through earth electrode. (in order of less than 10 Amps.)



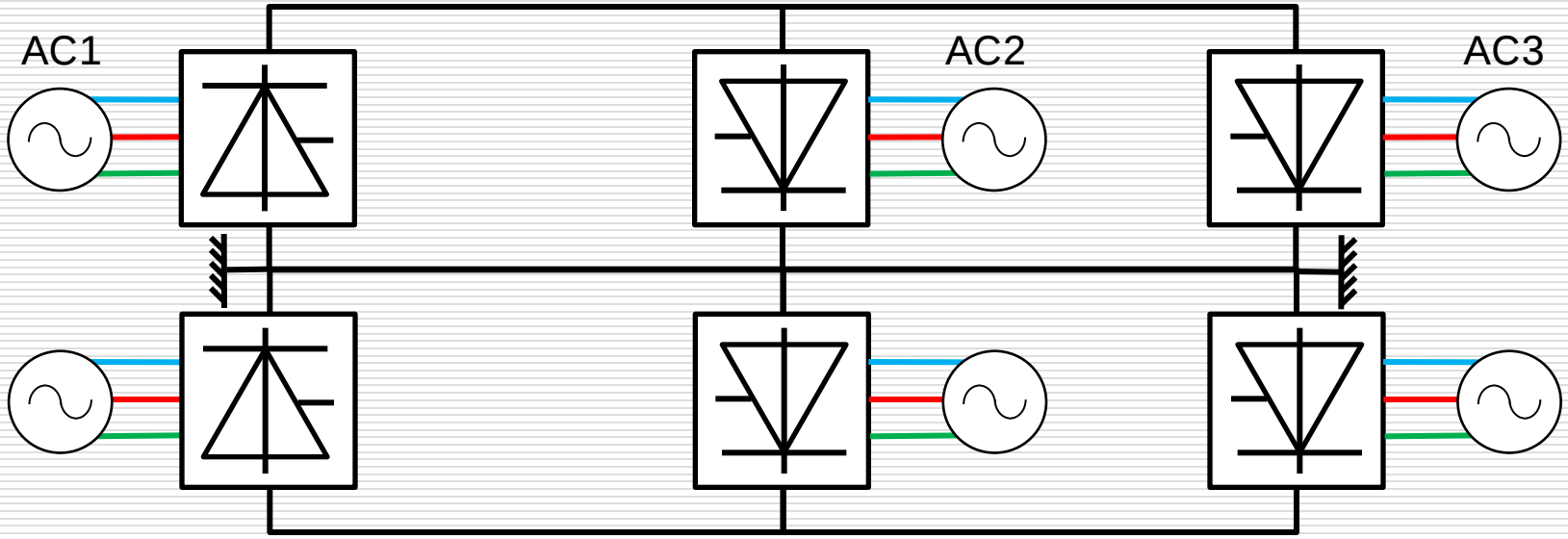
Types of HVDC Transmission system

- Back To Back:
  - Usually bipolar without earth return.
  - Converter & inverters are located at the same place.
  - No HVDC Transmission line.
  - Provides Asynchronous tie between two different AC network
  - Power transfer can be in either direction



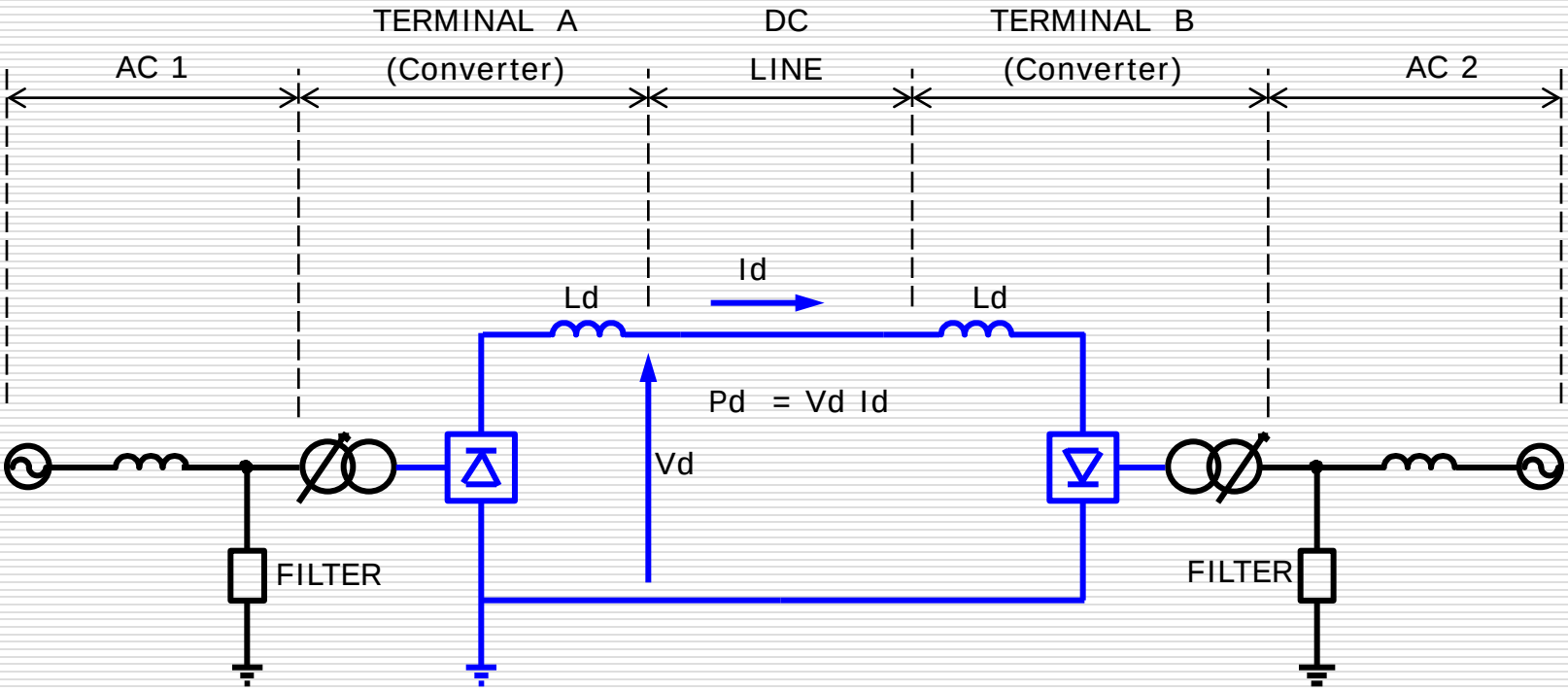
Types of HVDC Transmission system

- Multi Terminal System:
  - Three or more terminals connected in parallel, some feed power and some receive power from HVDC Bus.
  - Provides Inter connection among three or more AC network.

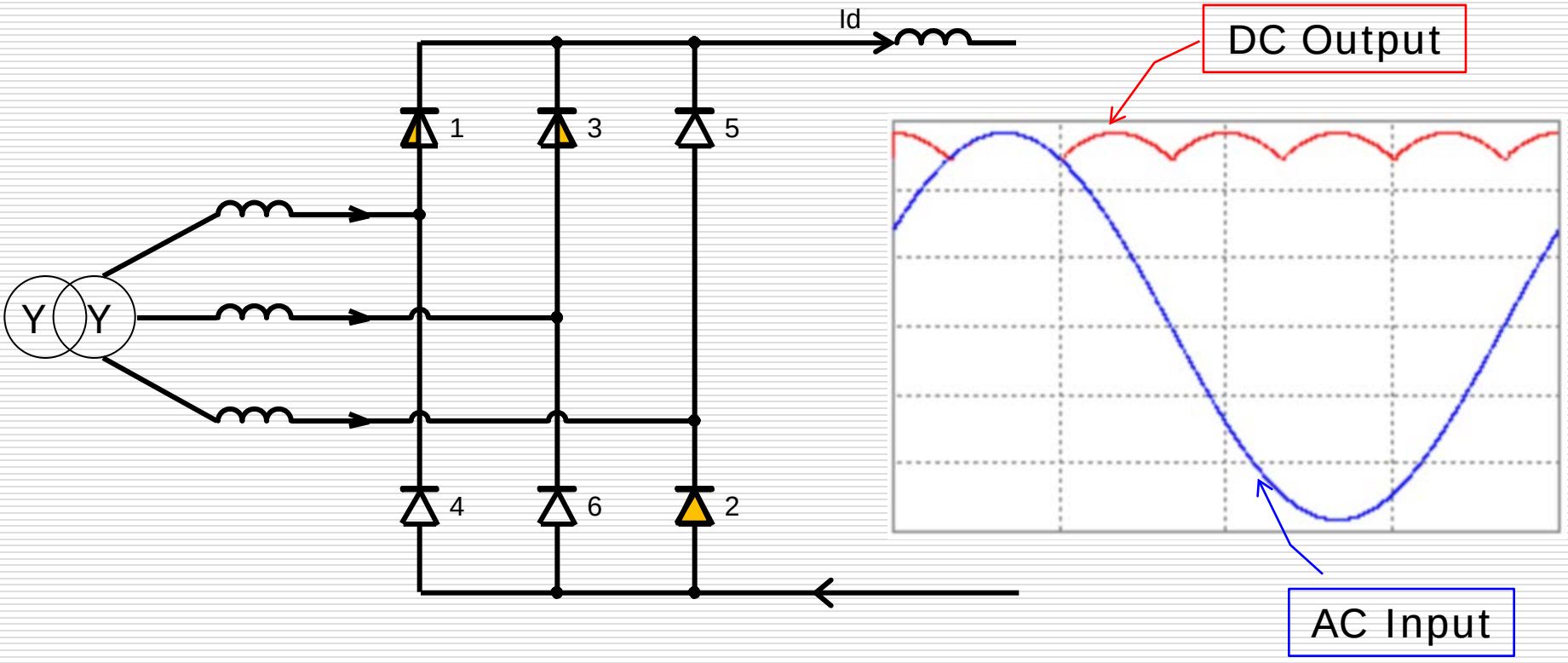


HOW HVDC WORKS

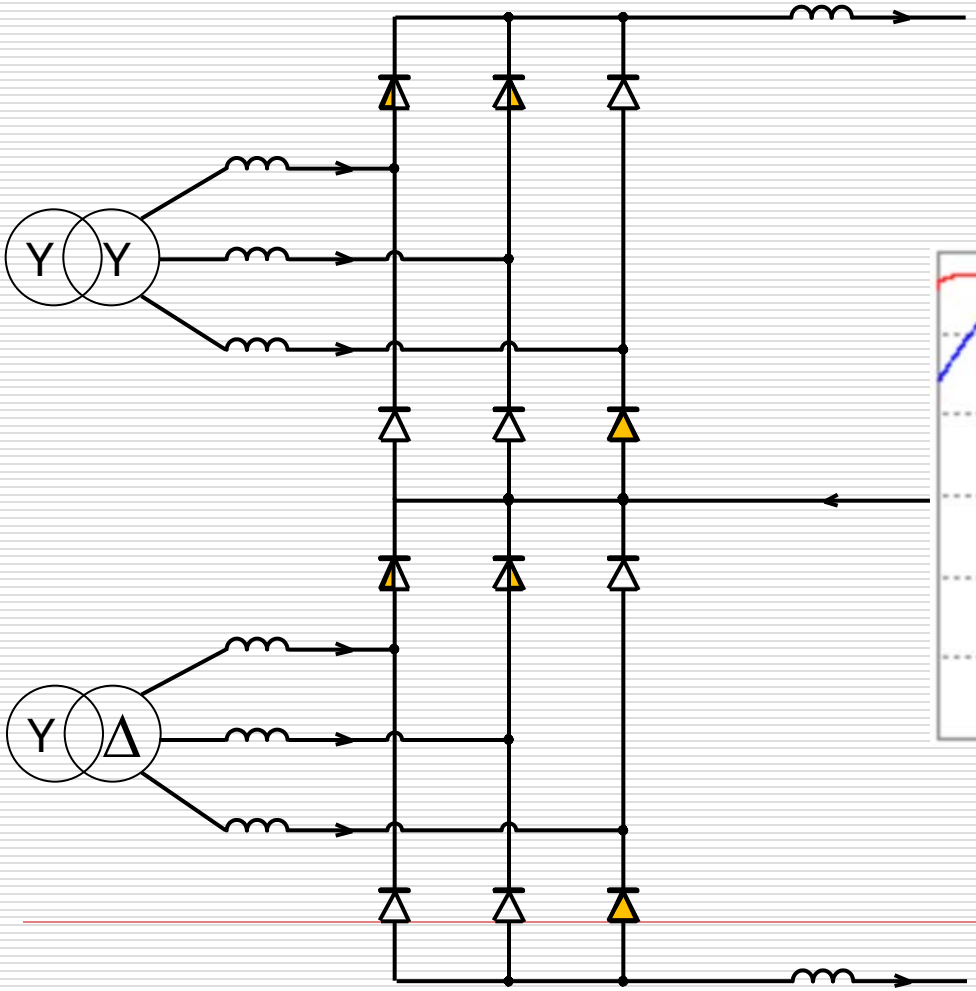
Basic Diagram of HVDC System

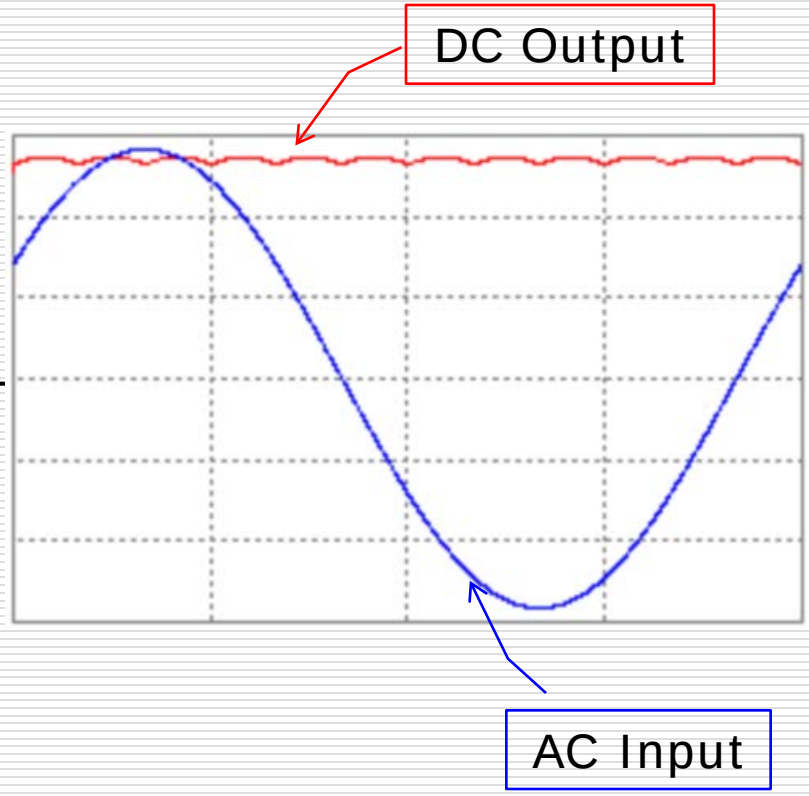


6-Pulse Convertor Bridge (Valve)

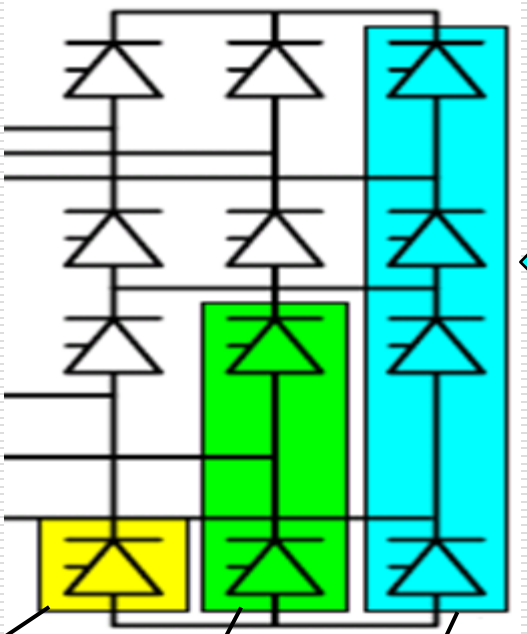


12-Pulse Convertor Bridge (Valve)





HVDC Thyristor Valve (1)

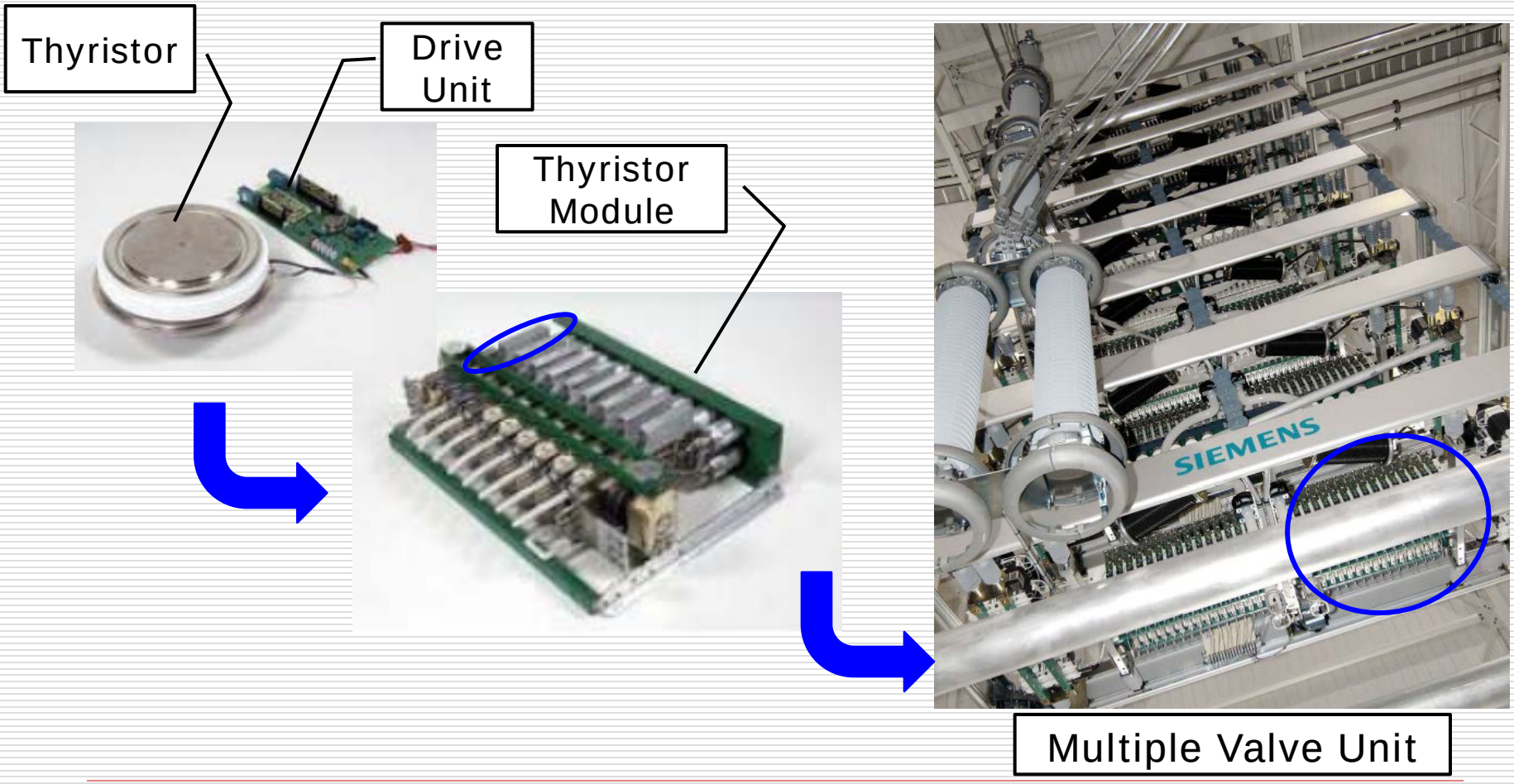


Single Valve

Double Valve

Quadruple Valve
(Multiple Valve Unit : MVU)

HVDC Thyristor Valve (2)



HVDC Converter Transformers & Filters

Converter Transformer

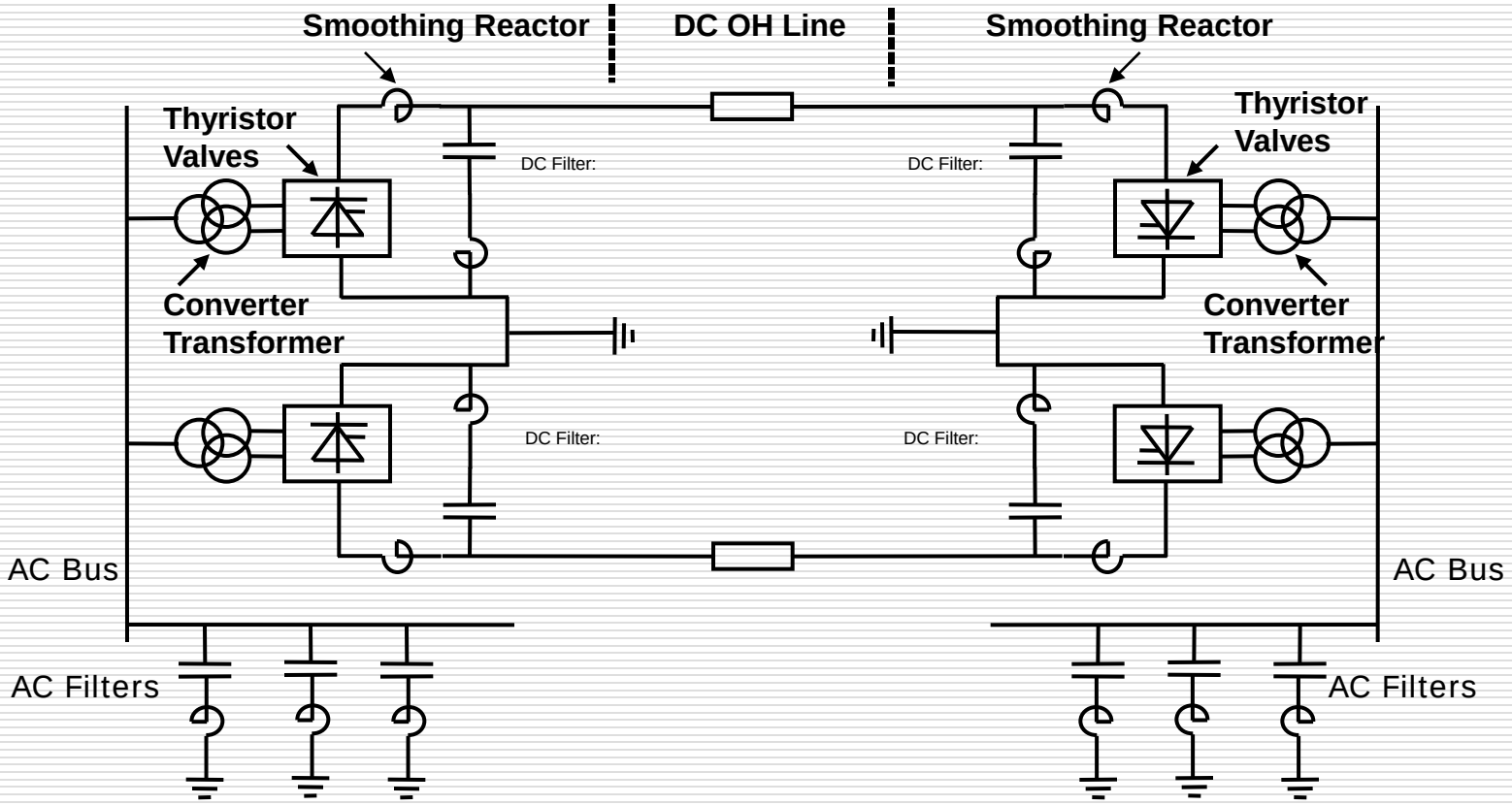
AC Filters

HVDC Station (3000MW)

BIPOLE HVDC

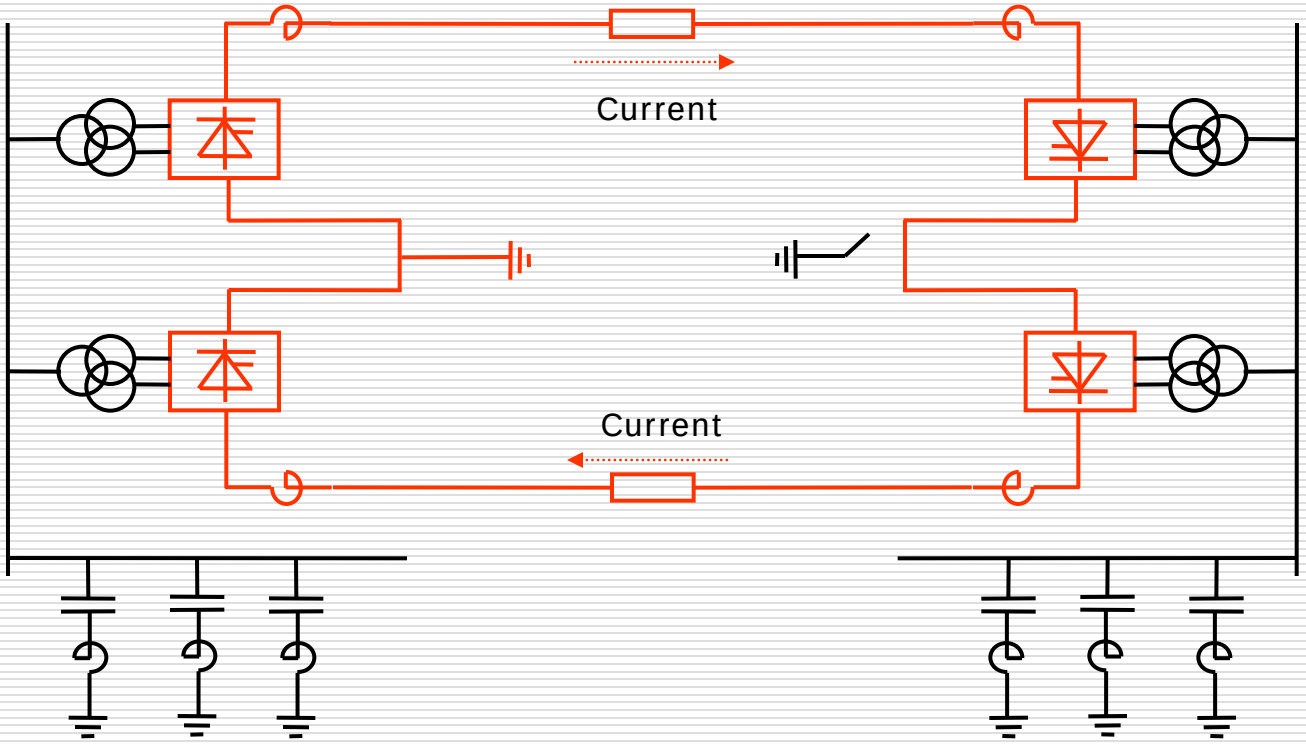
MODES OF OPERATION

BASIC HVDC Single Line Diagram



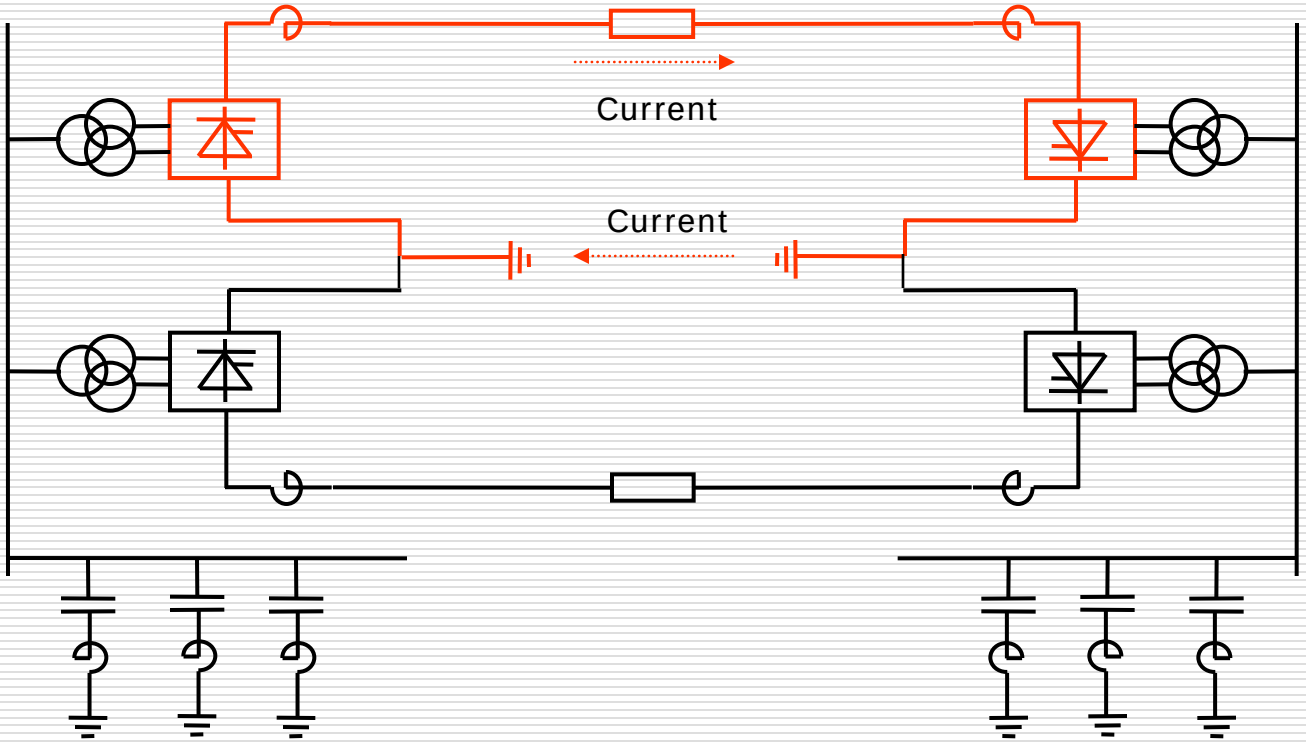
Modes of Operation (1)

Bipolar



Modes of Operation (2)

Monopole Ground Return



Modes of Operation (3)

Monopole Metallic Return