# RADHAKRISHNA INSTITUTE OF TECHNOLOGY AND ENGINEERING

## DEPARTMENT OF ELECTRICAL ENGINEERING

COURSE NAME : HIGH VOLTAGE SYSTEMS & DC TRANSMISSION
COURSE CODE : REL7D002
FACULTY INCHARGE : PROF. PRIYADARSHINEE DAS
DEPT./BATCH/SEMESTER : EE/2019-23/7TH

# Electrical Power Transmission

## High voltage Dc Transmission (HVDC)

# Hisrory:

- The development of direct current (DC) transmission dates back to the 1930's in Sweden and in Germany, and has been a proven technology since the first major installations in 1954.
- Over the last 40+ years, DC projects have shown to offer significant electrical, economic, and environmental advantages when transporting power across long distances.
- Early commercial installations included one in the Soviet Union in 1951 between Moscow and Kashira, and a 100 kV, 20 MW system between Gotland and mainland Sweden in 1954.
- The longest HVDC link in the world is currently the Xiangjiaba-Shanghai 2,071 km (1,287 mi), ±800 kV, 6400 MW link connecting theXiangjiaba Dam to Shanghai, in the People's Republic of China.
- Early in 2013, the longest HVDC link will be the Rio Madeira link in Brazil, which consists of two bipoles of ±600 kV, 3150 MW each, connecting Porto Velho in the state of Rondônia to the São Paulo area, where the length of the DC line is 2,375 km (1,476 mile).

Currently there are more than 20 DC transmission facilities in the United States and more than 35 across the North American grid as indicated in the map below.

# Review:

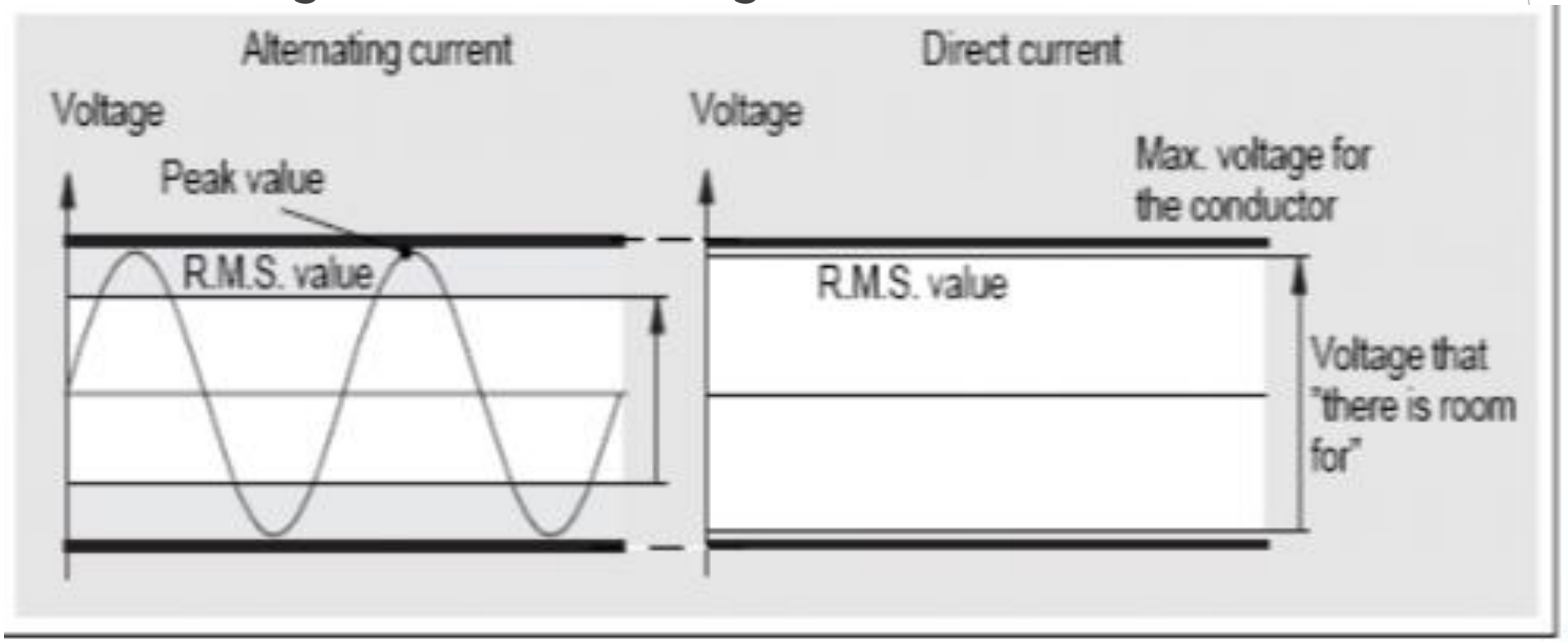
- First commercial HVDC transmission, Gotland in Sweden in 1954.
- First solid state semiconductor valves in 1970.
- First microcomputer based control equipment for HVDC in 1979.
- Highest DC transmission voltage (+/- 600 kV) in Itaipú, Brazil, 1984.
- First active DC filters for outstanding filtering performance in 1994.
- First Capacitor Commutated Converter (CCC) in Argentina-Brazil interconnection, 1998
- First Voltage Source Converter for transmission in Gotland, Sweden ,1999

# HVDC - Introduction

- HVDC (high-voltage direct current) is a highly efficient alternative for transmitting large amounts of electricity over long distances and for special purpose applications.
- Compared to alternating current, the direct current system is less expensive and loses less energy.
- HVDC can be transmitted through cables both underground and underwater.

# Cont…

- HVDC also allows transfer of power between grid systems running at different frequencies, such as 50 Hz and 60 Hz. This improves the stability and economy of each grid, by allowing exchange of power between incompatible networks.
- Better voltage utilization rating

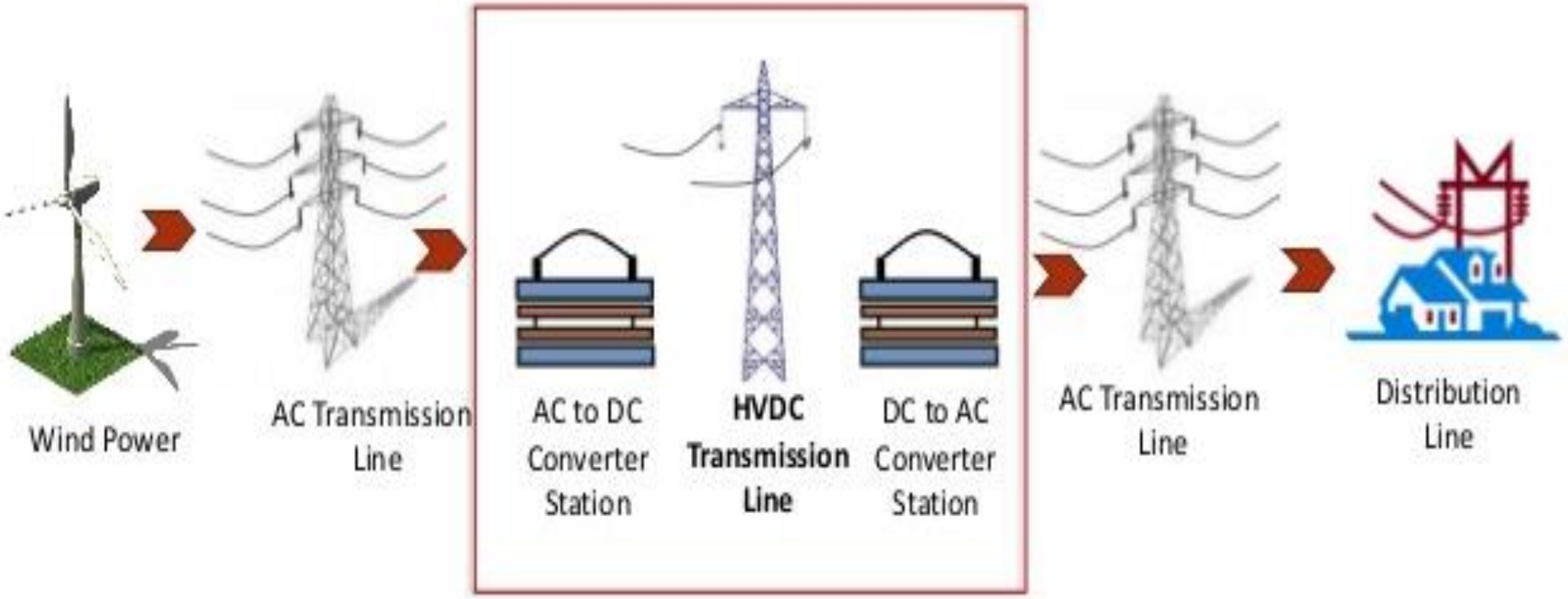


# Methods and working

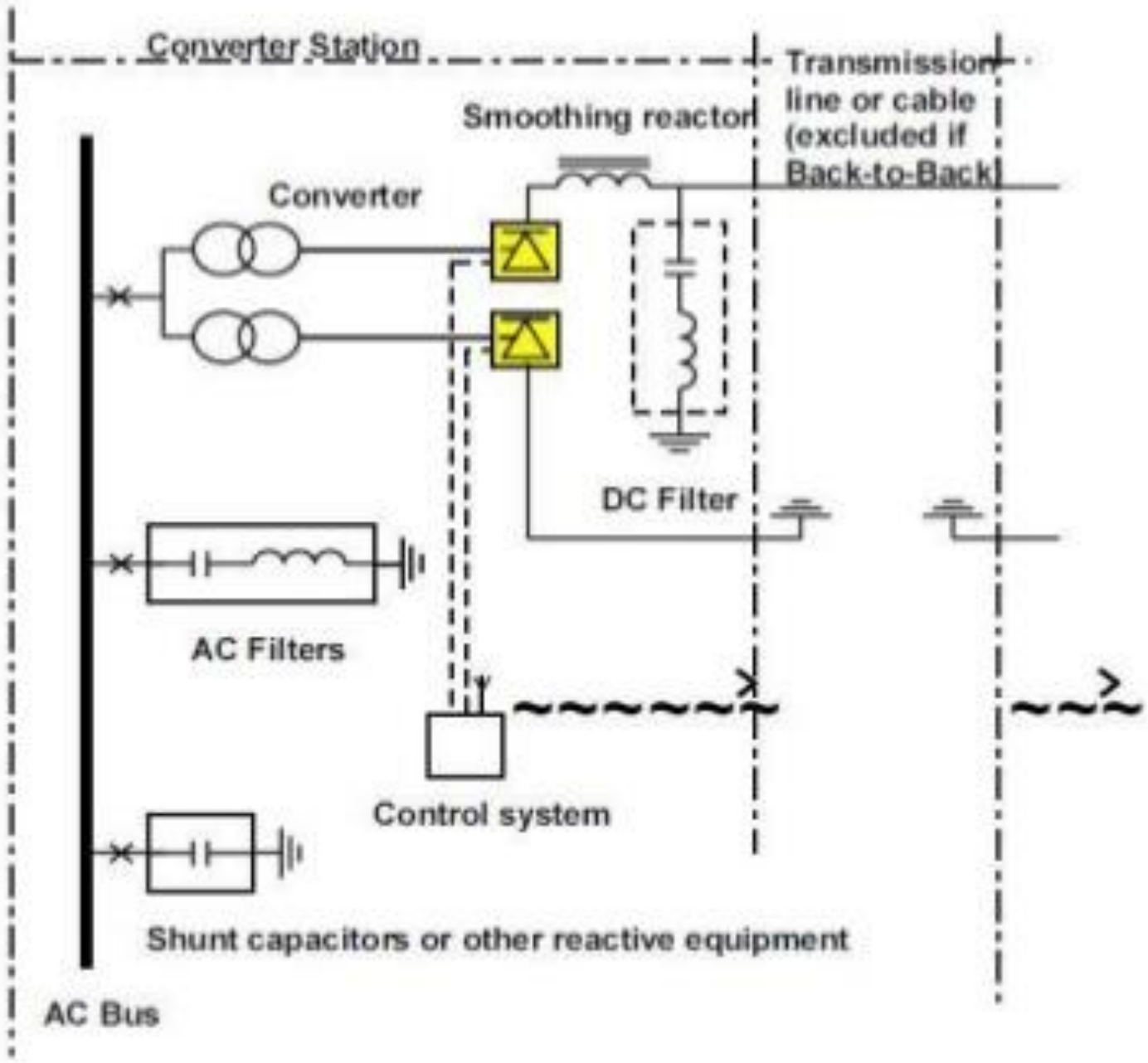
## How does it work ?

- HVDC transmission utilizes a converter station at either end of the system.
- A mercury arc valve or solid state valve (thyristor) is used for the conversion of AC and DC current.
- The valve at the beginning of the system converts alternating current to HVDC, the HVDC travels to the next location through a cable.
- The valve at the end of the system converts the HVDC back to alternating current.

# HVDC transmission system



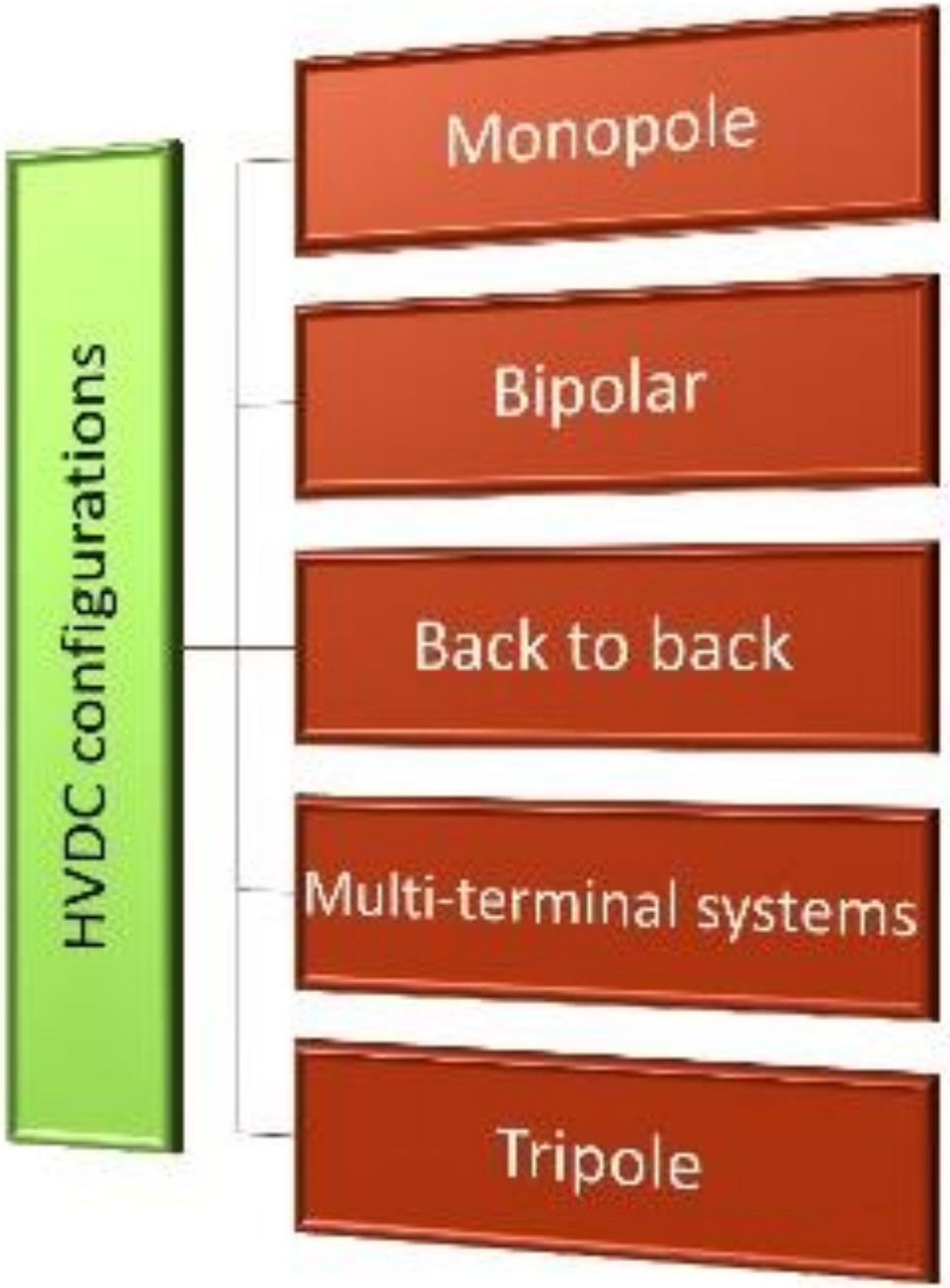
# Components of an HVDC transmission system



# Transmission Medium

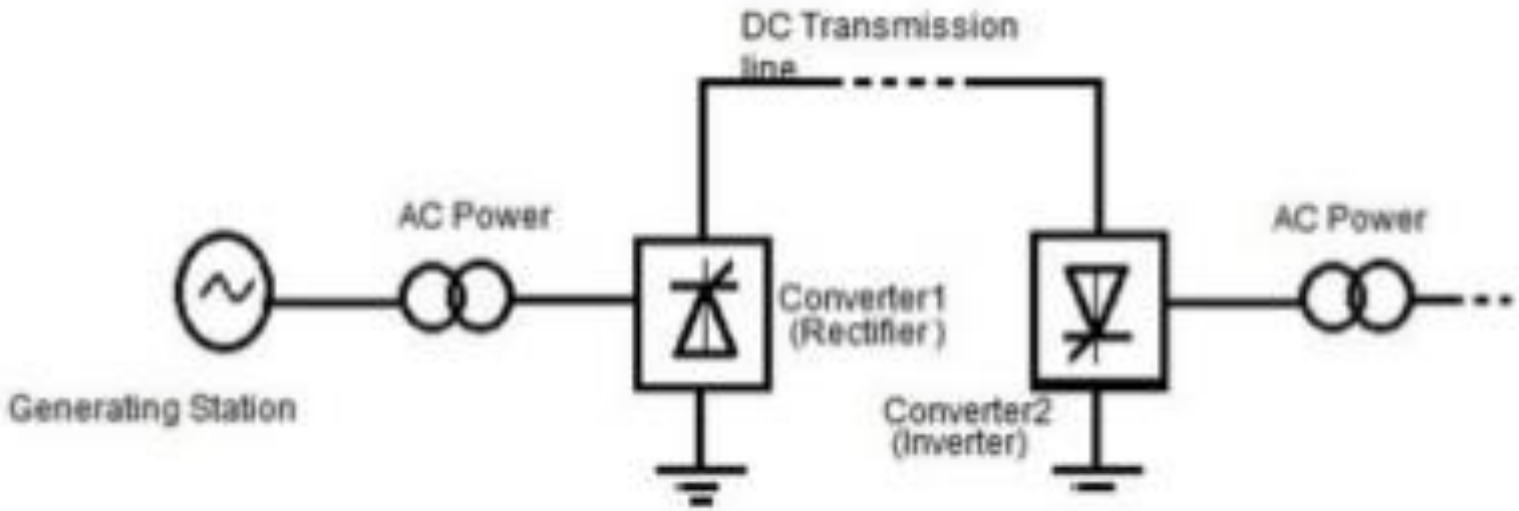
- For bulk power transmission over land, the most frequent transmission medium used is the overhead line.
- This overhead line is normally bipolar, i.e. two conductors with different polarity.
- HVDC cables are normally used for submarine transmission.
- The most common types of cables are the solid and the oil-filled ones.
- HVDC underground or submarine power transmissions:
  - This new HVDC cable is made of extruded polyethylene, and is used in VSC based HVDC systems.

# Types of HVDC configurations



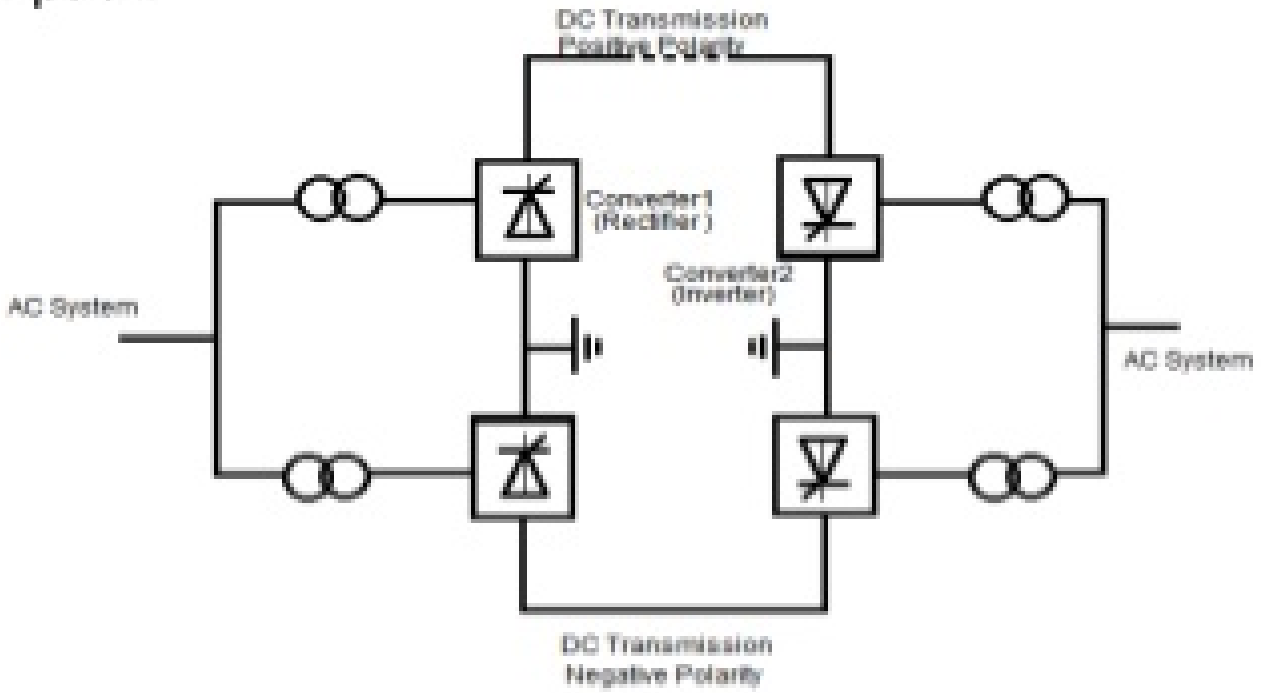
# Monopolar Link

- One of the terminal of the converter is connected to the transmission line, while the other terminal is connected to the ground.
- The ground is used as a return path here.
- Also Monopolar link can be used to transmit power over sea by using special electrode for the earth return.



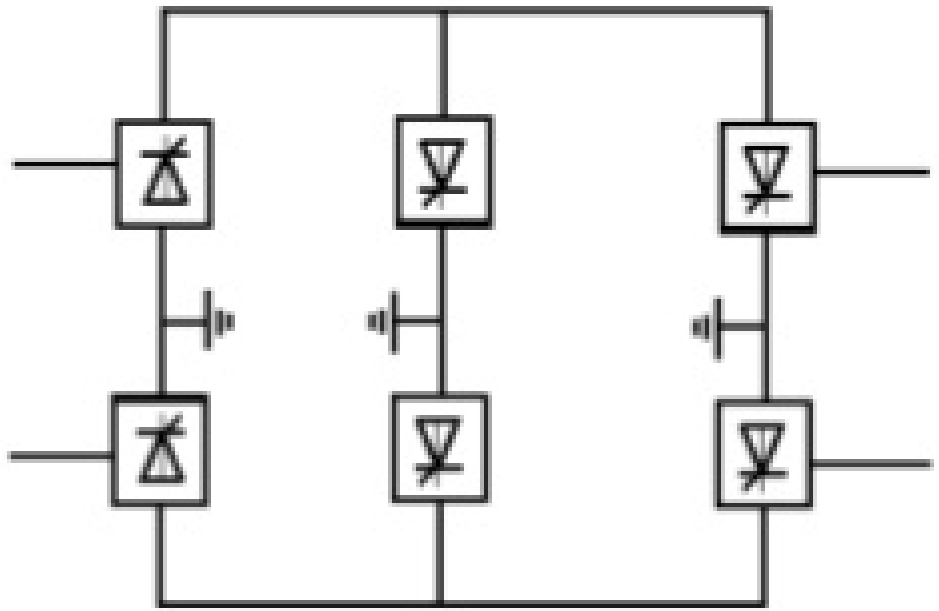
# Bipolar Link

- There are two pole/conductors. One operates at positive polarity and other is on negative polarity.
- The Bipolar link seems to be costlier than Monopolar, but it is more reliable than Monopolar.
- The advantage of bipolar is that whenever one of the poles fails; the system operates as Monopolar link with the ground as return path.



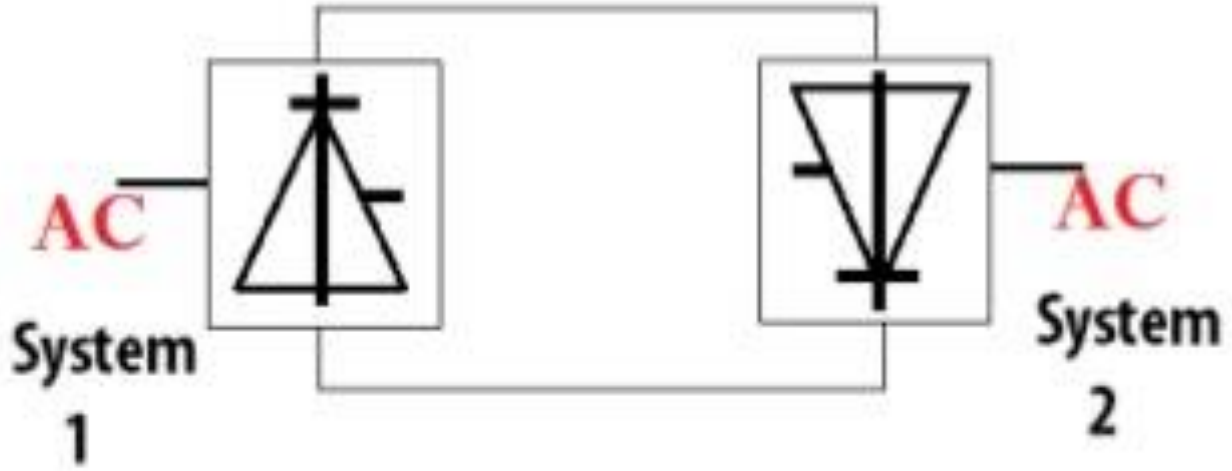
# Multi terminal Link

- A Multi terminal HVDC system is used to connect with more than two converter stations.
- complex network as compared to Monopole and Bipolar HVDC link.
- The reversal of power can be easily achieved using the Multi terminal HVDC link.



# Back to Back (B2B)

- Used to connect the asynchronous system with different frequencies.
- The length of the back to back connection is kept very small.
- Sometimes it may vary depending on the system requirement.
- Helps to achieve the connection between any asynchronous systems.



# Tripole

- Two of the three circuit conductors are operated as a bipole.
- The third conductor is used as a parallel monopole, equipped with reversing valves (or parallel valves connected in reverse polarity).
- The parallel monopole periodically relieves current from one pole or the other, switching polarity over a span of several minutes.
- As of 2012, no tri-pole conversions are in operation.

# Technical Advantages

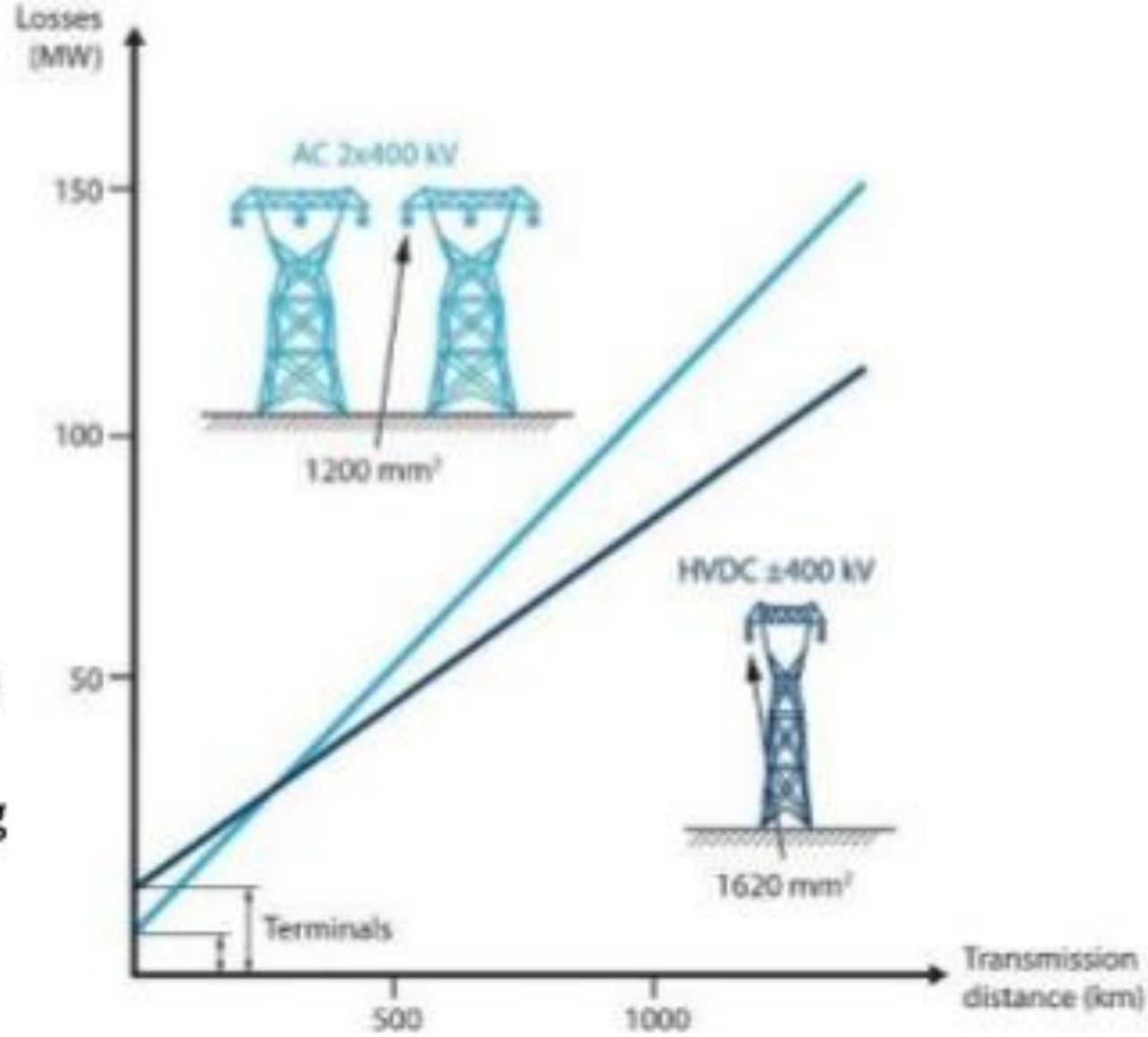
- System stability
- Short Circuit Current
- Independent Control of ac system
- Fast change of energy flow
- Lesser Corona Loss and Radio interference
- Greater Reliability.
- Direction of power flow can be changed very quickly
- Large HVDC schemes (5000 MW - 6400 MW) are used to access remote hydro power resources
- HVDC is more economical than HVAC for schemes with transmission distances more than 700 km.

# Economic Advantages

- DC lines and cables are cheaper than AC lines or cables.
- The towers of the DC lines are narrower, simpler and cheaper compared to the towers of the AC lines.
- Line losses in a DC line are lower than the losses in an AC lines.

# Lower Losses

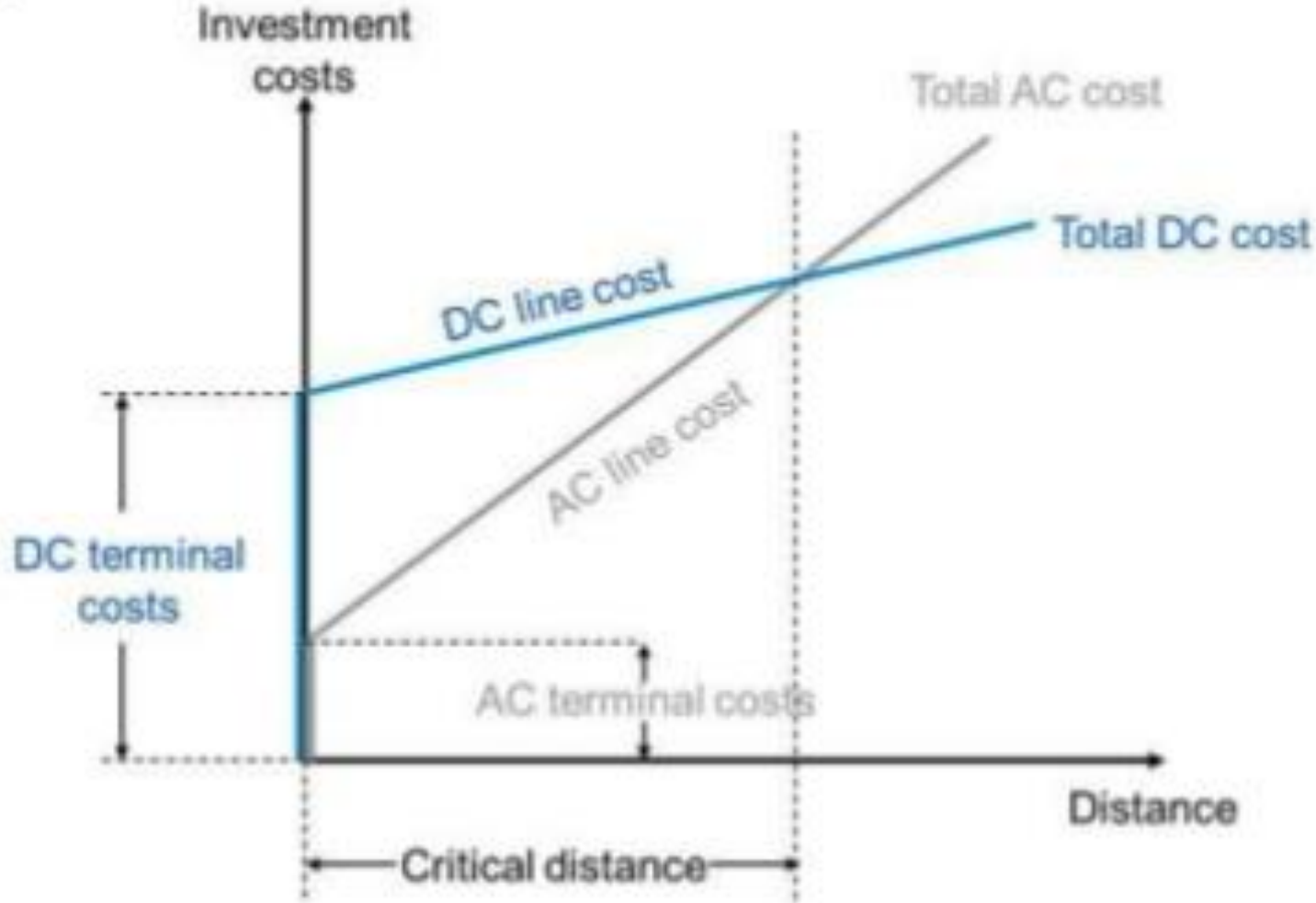
The diagram shows a comparison of the losses in 1,200 MW overhead line transmissions using AC and HVDC.



# Lower Investment Cost

- It is true that HVDC terminal stations are more expensive due to the fact that they must perform the conversion from AC to DC, and DC to AC.

- But over a certain distance, the so called "break-even distance" (approx. 600 – 800 km), the HVDC alternative will always provide the lowest cost



# Disadvantages

- The disadvantages of HVDC are in conversion, switching, control, availability and maintenance.
- HVDC is less reliable and has lower availability than alternating current (AC) systems, mainly due to the extra conversion equipment.
- The required converter stations are expensive and have limited overload capacity.
- At smaller transmission distances, the losses in the converter stations may be bigger than in an AC transmission line for the same distance.
- Operating a HVDC scheme requires many spare parts to be kept, often exclusively for one system, as HVDC systems are less standardized than AC systems and technology changes faster.

# Disadvantages:

- **(expensive)**

***Converter stations*** needed to connect to AC power grids are ***very expensive***.

Converter substations generate current and voltage harmonics, while the conversion process is accompanied by reactive power consumption. As a result, it is necessary to install ***expensive filter-compensation units*** and ***reactive power compensation units***.

- **(complex)**

In contrast to AC systems, designing and operating multi-terminal HVDC systems is complex.

- **(capacities)**

The number of substations within a modern multi-terminal HVDC transmission system can be no larger than ***six*** to ***eight***, and large differences in their capacities are not allowed.

it is practically impossible to construct an HVDC transmission system with ***more than five substations***.

- **(difficult grounding)**

Grounding HVDC transmission involves a complex and difficult installation, as it is necessary to construct a reliable and permanent contact to the Earth for proper operation and to eliminate the possible creation of a dangerous “step voltage.”

- **(power faults)**

During ***short-circuits*** in the AC power systems close to connected HVDC substations, power faults also occur in the HVDC transmission system for the duration of the short-circuit. ***Inverter substations are most affected.***

# Future recommendation:

- The need for a  faster, more efficient and more reliable deployment of offshore HVDC transmission systems for connection of wind farms, oil and gas platforms, multi terminal interconnectors as well as a future HVDC grid

# conclusion

- Increasing demand of electrical power and need for bulk efficient electrical power transmission system lead to the development of HVDC transmission system. HVDC transmission system today become one of the best alternative for transmitting bulk power over long distance with very less losses.

# Thank You !