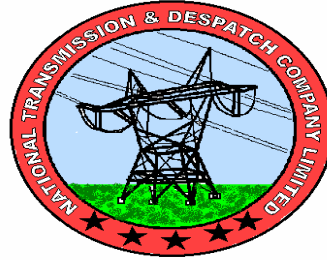


بِسْمِ اللَّهِ الرَّحْمَنِ الرَّحِيمِ

NATIONAL TRANSMISSION AND DESPATCH COMPANY LIMITED



Protection Perspective of HVDC Technology

By:

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- Converter transformer protection

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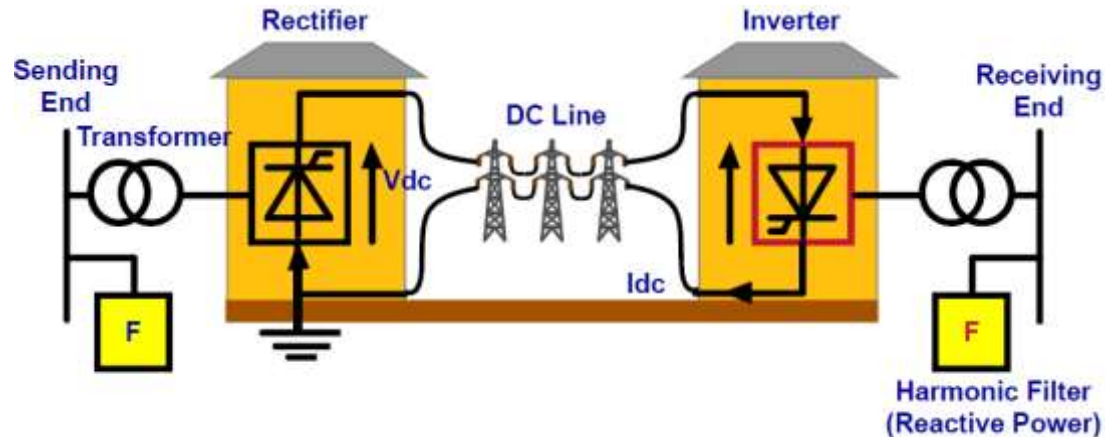
- Converter protection
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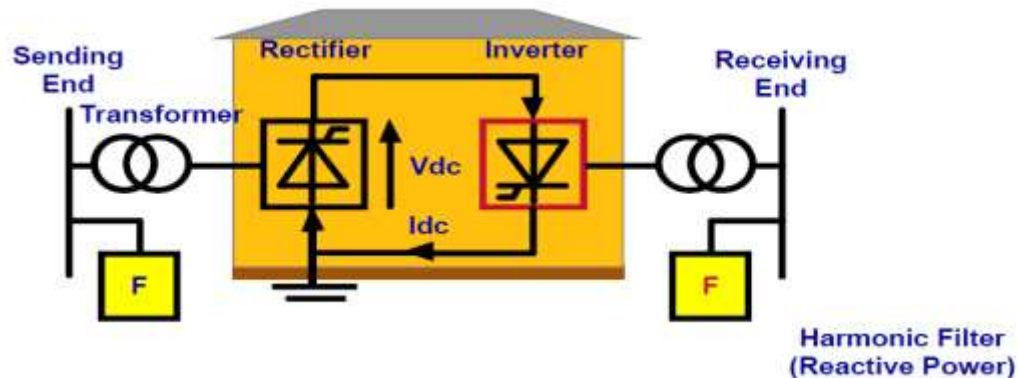
HVDC Transmission

Applications

- Bulk electricity transmission over long distance with few losses



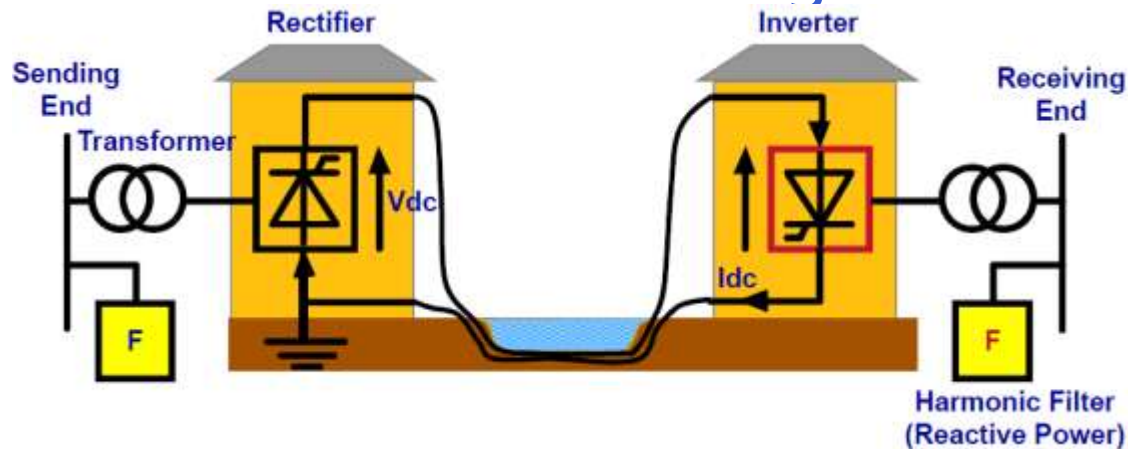
- Interconnection of AC grids (Back-to-Back)



HVDC Transmission

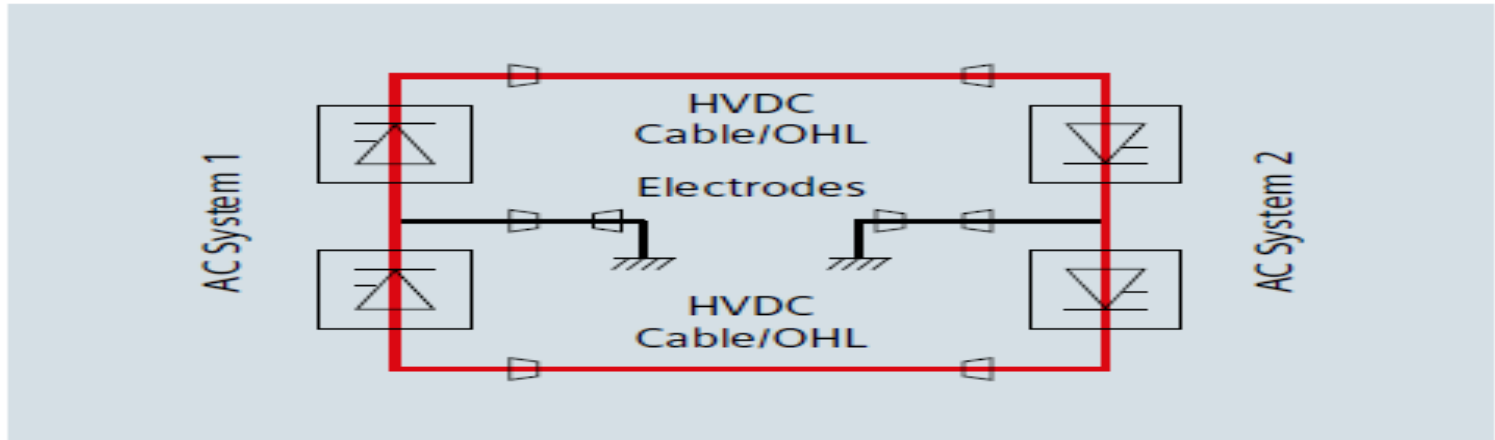
Applications

- Submarine or underground cable



- Offshore wind farm generation
- Multi-terminal connection

Bi-Polar HVDC Transmission system



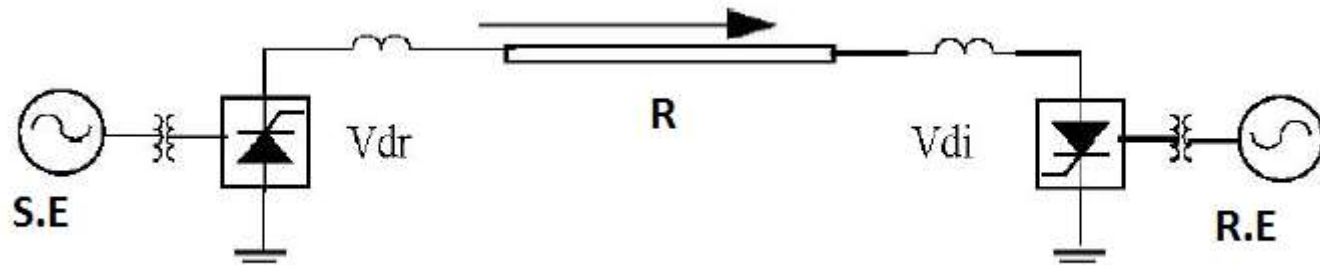
- Two poles - two conductors in transmission line, one positive with respect to earth & other negative
- The mid point of Bi-poles in each terminal is earthed via an electrode line and earth electrode.
- In normal condition power flows through lines & negligible current flows through earth electrode.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

Multi – terminal HVDC Transmission system

- Three or more terminal connected in parallel, some feed power and some receive power from HVDC Bus.
- Provides Inter connection between the three or more AC network.

HOW HVDC WORKS ?

POWER FLOW EQUATIONS



➤ FOR DC TRANSMISSION:

$$\text{POWER}(P) = \frac{V_{dr} (V_{dr} - V_{di})}{R}$$

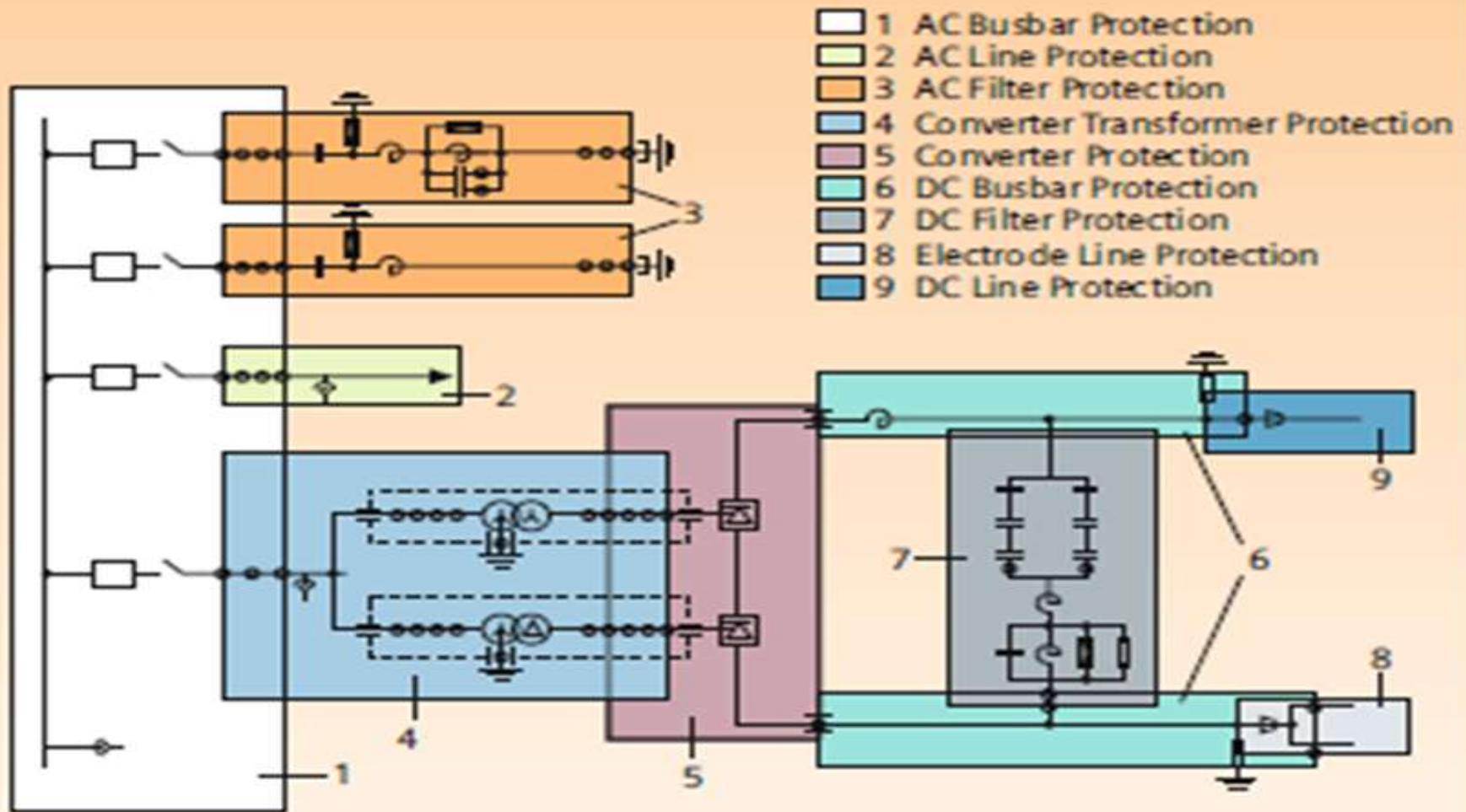
Where

V_{dr} is DC voltage at rectifier end

V_{di} is DC voltage at inverter end

R is the resistance of line

Protection Zones for HVDC Long-Distance Transmission Scheme



Protection of AC Portion

1. AC Bus-bar Protection

- The AC Busbar protection system consists of a Numerical Differential Protection scheme as per NTDC specifications
- In addition to Busbar Protection, independent Breaker Failure Protection with end zone fault protection shall also be provided as per NTDC Specifications.

Protection of AC Portion (Cont'd)

2. AC Line Protection

The AC Line Protection consists of two main protection systems with backup protection including auto reclosing, synchronizing etc. as per NTDC Specifications. The protection preferably incorporates the following functions:

- Main-I & Main-II Differential Protection or Main-I & Main-II Distance Protection depending upon short or long transmission line
- Back-up Over Current & Earth Fault Protection
- Over Voltage Protection on 500kV transmission line
- Auto Recloser with synchronizing Scheme

Protection of AC Portion (Cont'd)

3. AC Filter Protection

AC Filter protection selectively detects short circuits, over-currents, defective capacitor units and overload in the AC filter circuit. AC filter protection incorporates the following functions but not limited to:

- Differential Protection
- Overcurrent Protection
- Capacitor Unbalance Protection
- Capacitor Overload Protection
- Harmonic Overload Protection
- Zero Sequence Overcurrent Protection

Protection of AC Portion (Cont'd)

4. Converter Transformer Protection

The Converter Transformer Protection System consists of a main and a backup protection incorporating the following functions but not limited to:

- Main-1 & Main-2 Percentage Biased Differential Protection
- HV & LV Side Overcurrent Protection
- Thermal Overload Protection
- Neutral Directional Overcurrent Protection
- Restricted Earth Fault Protection
- Over Voltage Protection
- Over Excitation Protection
- Internal Transformer Protection i.e. Mechanical Protection e.g. Transformer Buchholz protection, OLTC Buchholz protection, HV/LV High Temperature Winding Protection, High Temperature oil Protection, Pressure Relief Valve Protection etc.

Protection of DC Portion

5. Converter Protection

The Converter Protection detects faults on the converter transformer secondary side, in the valve hall and failures which lead to overstress of the Thyristor Valves. It consists of a completely redundant scheme incorporating the following functions but not limited to:

- Overcurrent Protection
- Bridge Differential Protection for Wye and Delta Group
- Group Differential Protection
- Short-Circuit Protection for Wye and Delta Group
- DC Differential Protection
- DC Overvoltage Protection
- AC Overvoltage Protection

Protection of DC Portion (Cont'd)

6. DC Busbar Protection

The DC Busbar Protection detects ground faults on the high-voltage and on the low-voltage Busbar. It consists of a completely redundant scheme incorporating the following functions but not limited to:

- High-Voltage DC Busbar Differential Protection
- Low-Voltage DC Busbar Differential Protection
- DC Differential Backup Protection (includes the converter)

Protection of DC Portion (Cont'd)

7. DC Filter Protection

The DC Filter Protection detects short circuits, over-currents and faulty capacitor units in the DC filter circuit. It consists of a completely redundant scheme incorporating the following functions.

- Differential Protection
- Overcurrent Protection
- HV Capacitor Unbalance Protection
- HV Capacitor Differential Protection
- HV capacitor Overcurrent Protection

Protection of DC Portion (Cont'd)

8. Electrode Line Protection

The Electrode Line Protection equipment detects earth faults, short circuits, over-currents and open-circuit electrode lines. It consists of a completely redundant scheme incorporating the following functions but not limited to:

- Current Unbalance Protection
- Overcurrent Protection
- Overvoltage Protection
- Switch Protections

Electrode Line Protection (Cont'd)

- In addition to these protection functions, Pulse Echo Electrode Line Monitoring system monitors the electrode line continuously even when no power is transmitted. The Monitoring system shall be able to detect any faults in the electrode line (broken conductor and earth fault) and inform the operator about fault type and fault location.

Protection of DC Portion (Cont'd)

9. DC Line/Cable Protection

The DC Line/Cable protection detects any ground fault at the DC Line/Cable to limit any damage and to restore operation as soon as possible. It consists of a completely redundant scheme incorporating the following functions but not limited to:

- Travelling Wave Protection
- Under-voltage Detection
- DC Line/Cable Differential Protection

Protection of DC Portion (Cont'd)

10. Harmonic Protection

- A Fundamental Frequency Protection function detects 1st or 2nd harmonics in the DC current or in the DC voltage. These harmonics arise from converter misfiring or asymmetrical faults in the AC system. If the harmonic content exceeds a preset limit, then a binary signal initiates the 1st or 2nd harmonic protective action.
- The Sub-synchronous Resonance Protection detects resonances e.g. caused by oscillation of the power plant's generator. The resonances can be detected in the DC current. If the sub-synchronous resonances exceed a preset limit, then a binary signal initiates the sub-synchronous resonance protective action.

Hybrid Optical DC Measuring

- Precise and reliable measurement of both DC current and voltage is a key requirement for any HVDC system.
- DC currents and voltages are measured with a hybrid optical system.
- DC current is sensed by measuring the voltage drop across a shunt resistor.
- Local "sensor head" electronics at this high voltage potential convert the voltage drop across the shunt to a serial optical signal, which is transmitted to ground potential via fibre-optic cables.
- The electronics are powered by laser light, which is transmitted from ground potential to the HV level by fibre optics.
- HV isolation is achieved with the fibre-optic cable, which is embedded in a composite insulator.

Hybrid Optical DC Measuring (Cont'd)

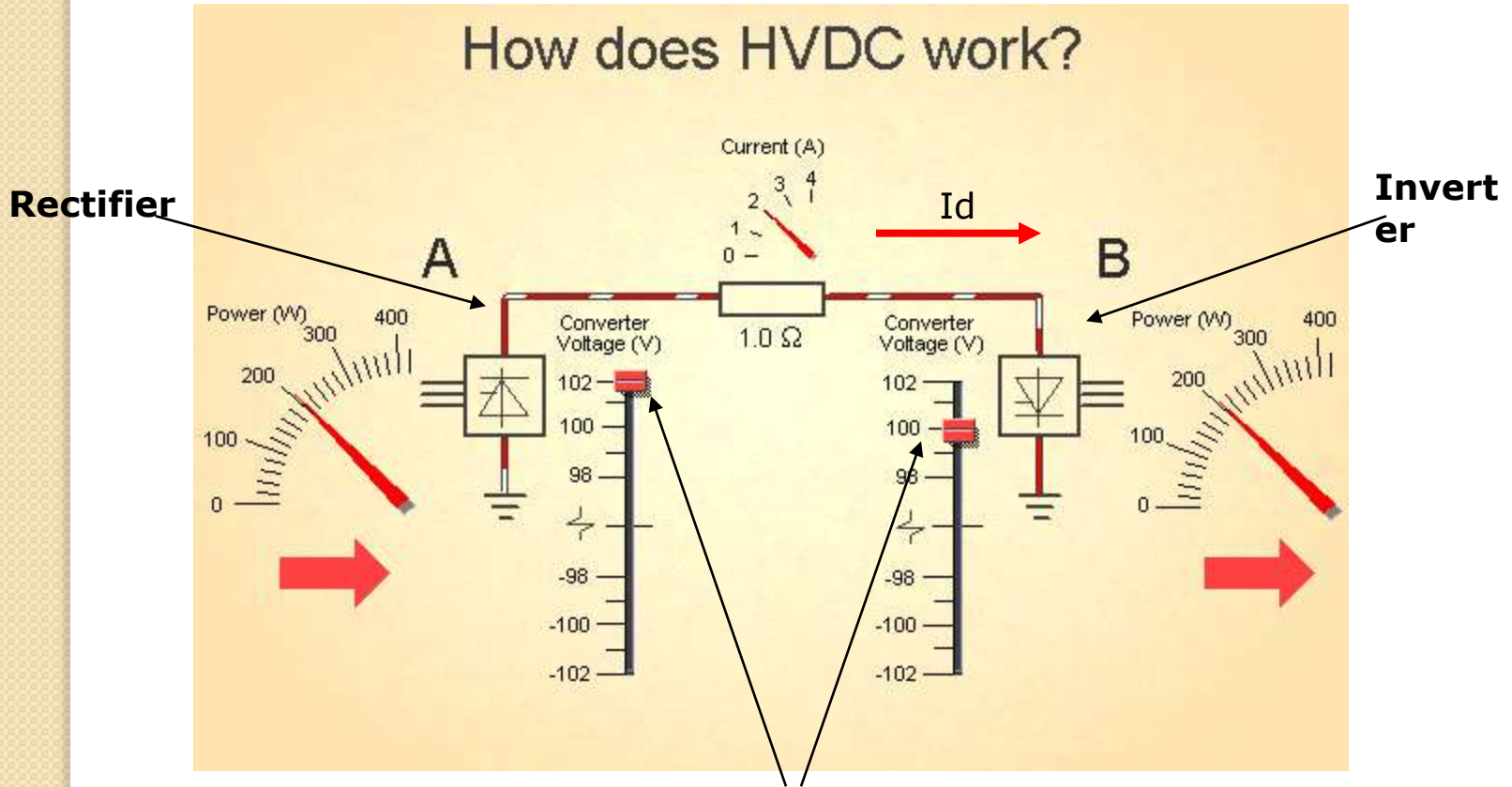
- DC voltage is measured with a resistive/capacitive voltage divider.
- The voltage signal at ground level is transmitted to the controls using the same laser-powered electronics as used for the current measurement.
- The scheme is completely redundant and each Control and Protection Measuring System is totally independent.

Thank You

Pakistan Zindabad

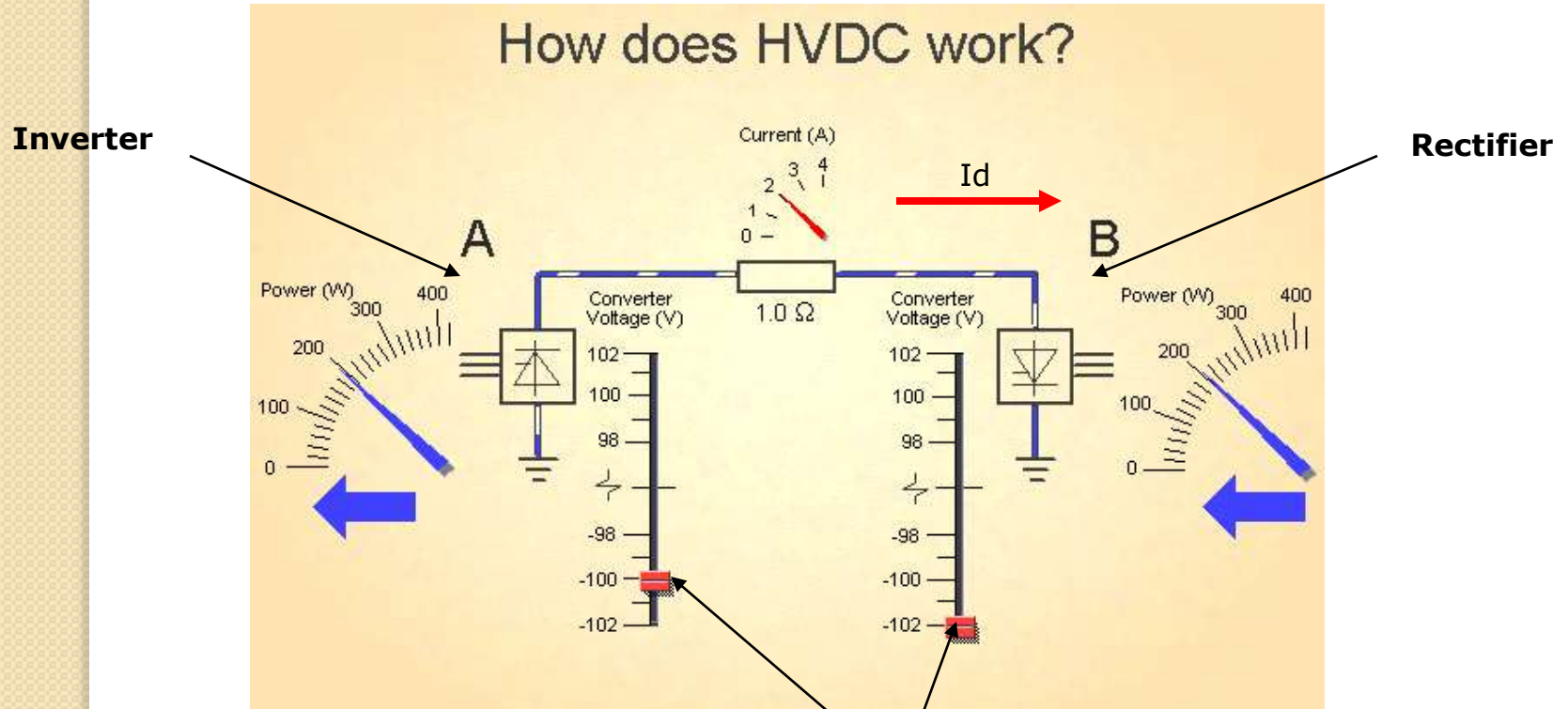


HVDC Transmission Normal Power Direction



Note! Only a small voltage difference

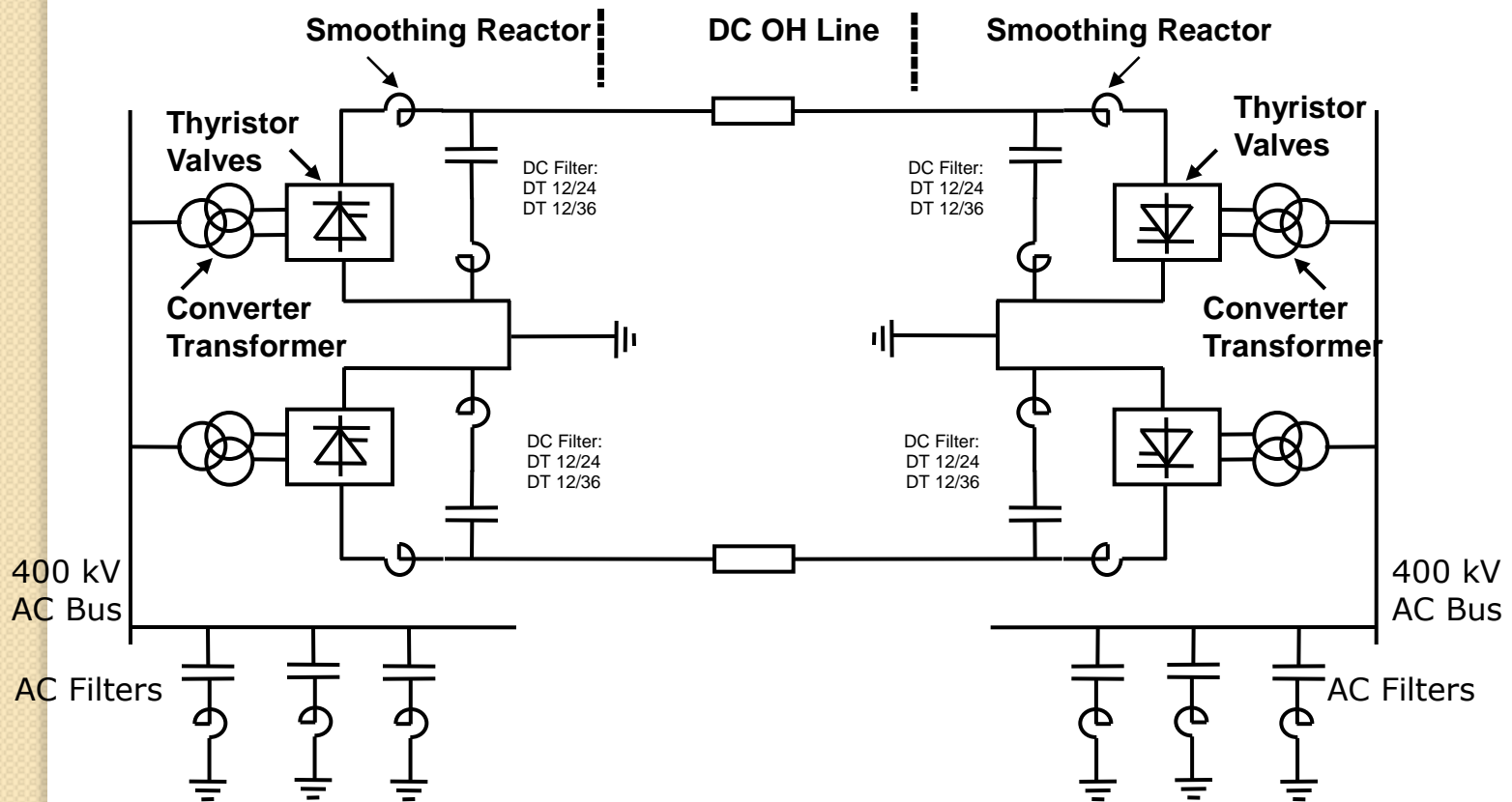
HVDC Transmission Reverse Power Direction



Note that the current flow is in the same direction. Only the polarity is reversed.

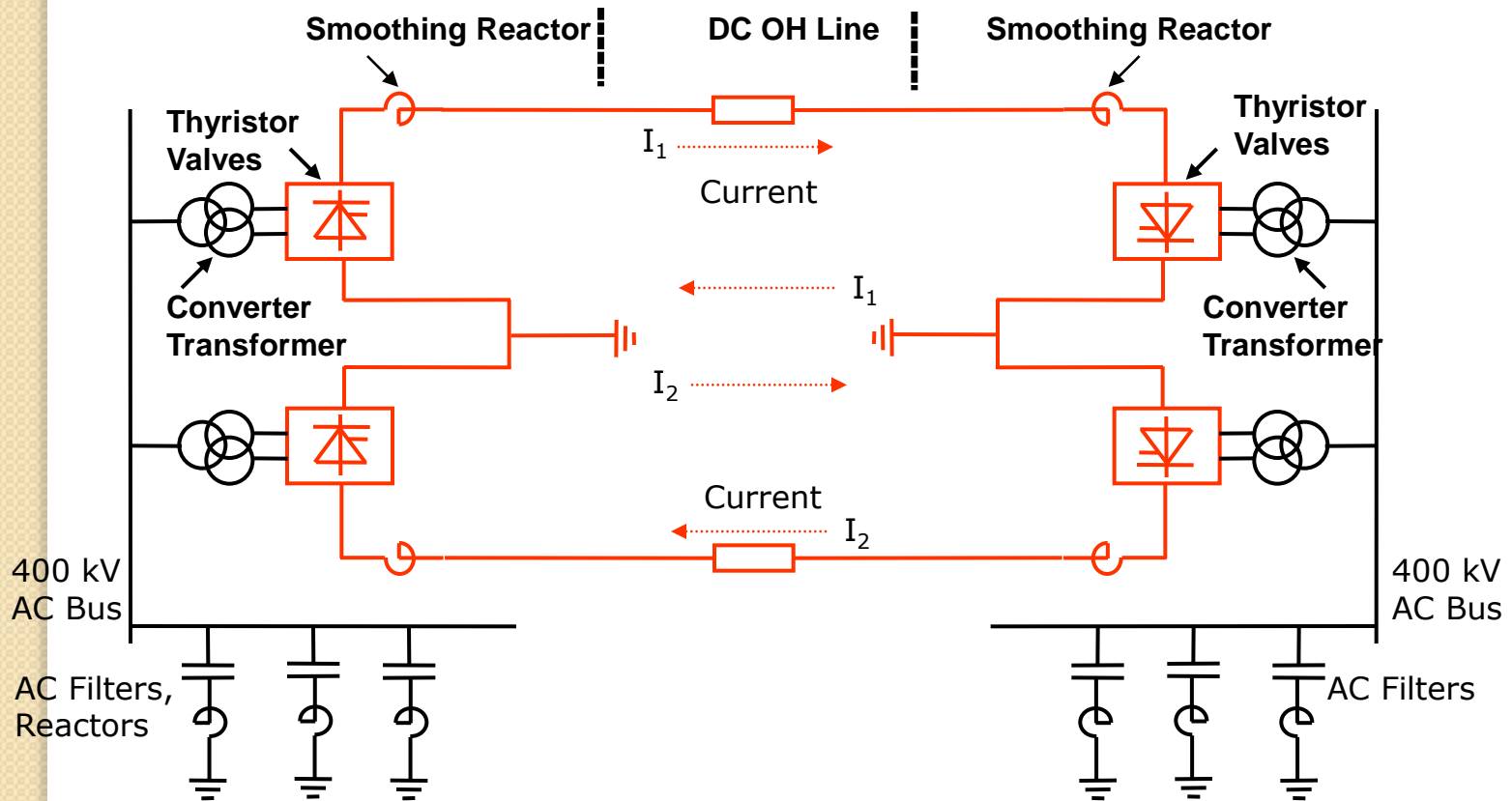
Note! Only a small voltage difference

BASIC HVDC Single Line Diagram



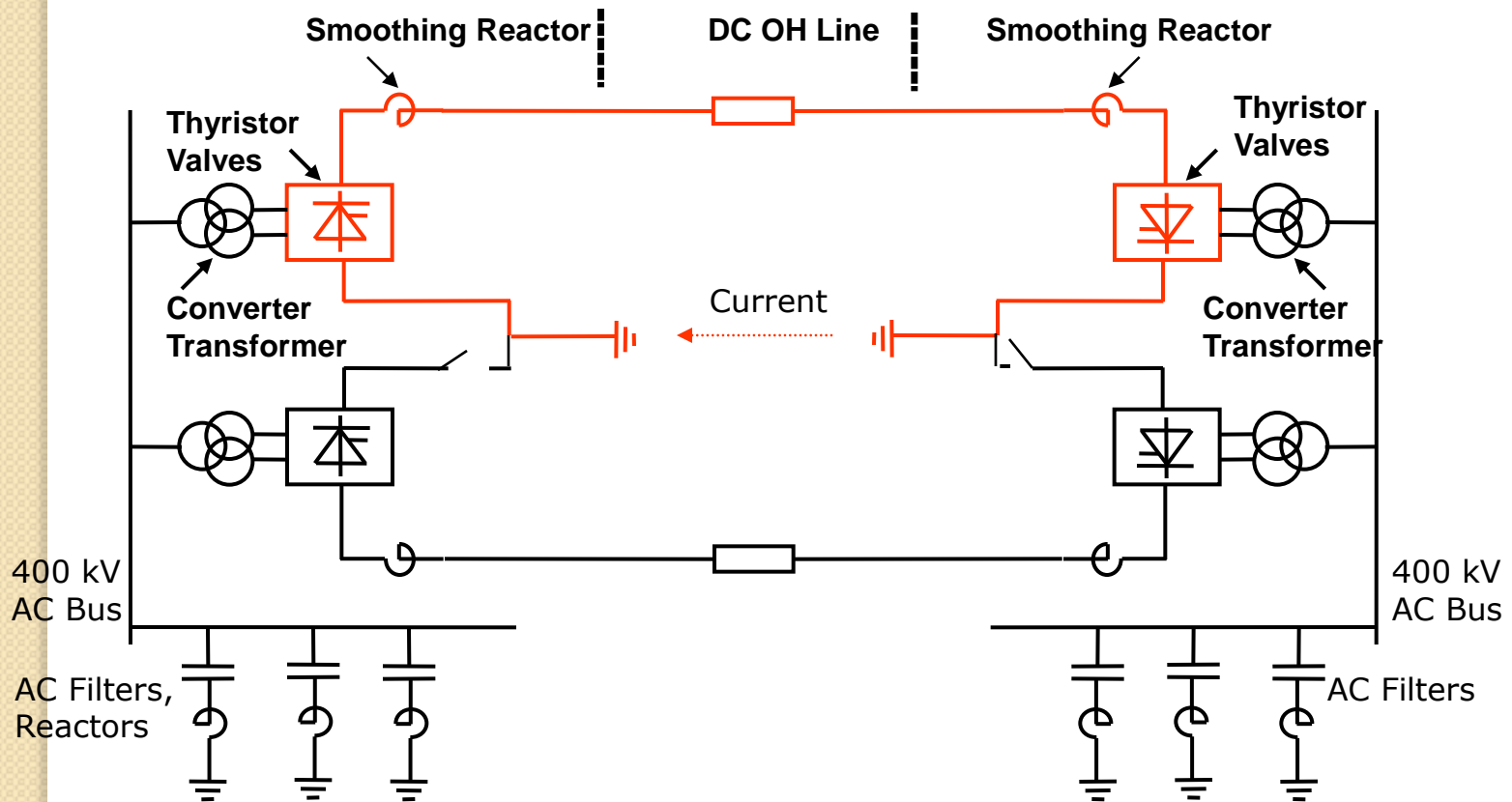
Modes of Operation

Bipolar



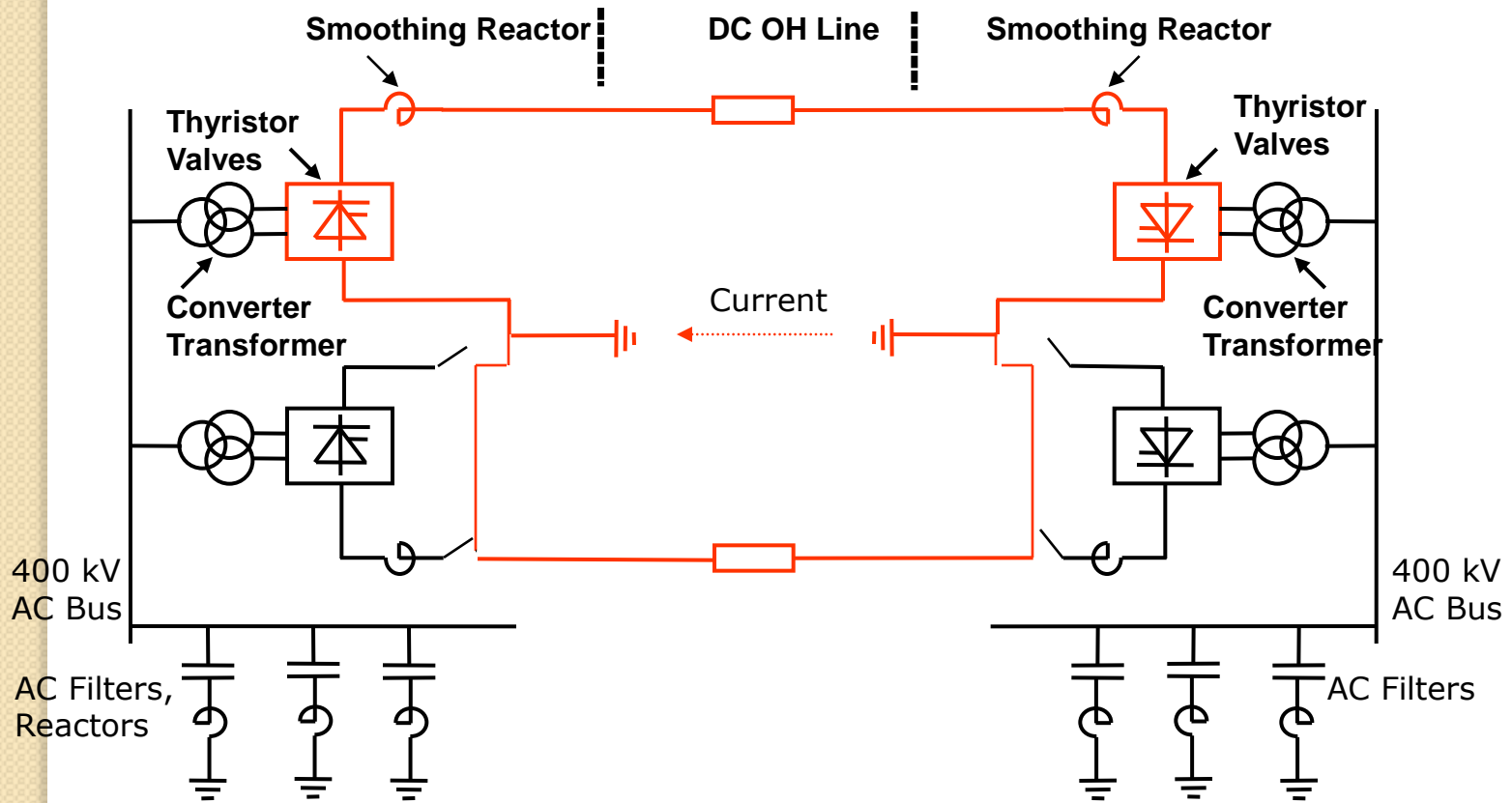
Modes of Operation

Monopolar Ground Return

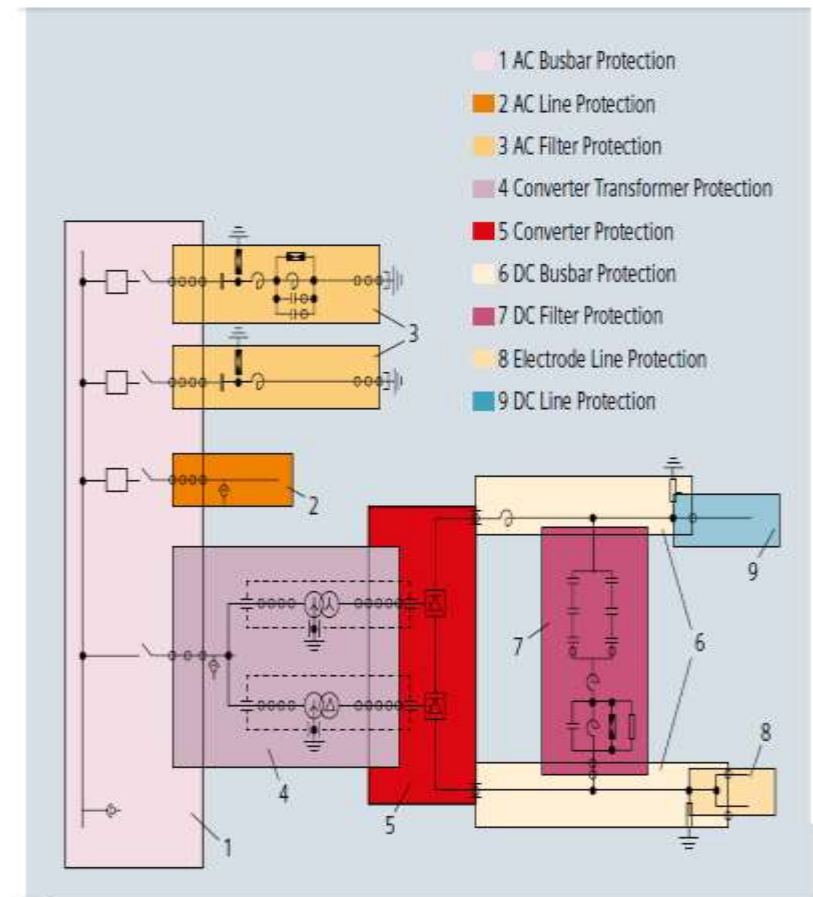


Modes of Operation

Monopolar Metallic Return



Protection Zones for an HVDC Long-Distance Transmission Scheme



Communication System

- Information exchange between the Operator Control Level and the Control and Protection Level is provided by a redundant Local Area Network (LAN).
- Information exchange between the control systems at the Control and Protection Level and the I/O units at the Field Level is achieved via a redundant optical field ring+star bus system.
- The exchange of data between both converter stations and between the converter station and the remote control centres can be executed through different transmission media.
- The data transmission media used is mainly dependent on the HVDC system application and on already existing communication installations.

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