HVDC
High Voltage Direct Current
Typical HVDC Station
Back to Back Converters indicates that the Rectifiers & Inverters are located in the Same Station.

Back-to-Back Converters are mainly used for Power transmission between adjacent AC grids which can not be synchronized.

Mono Polar With Ground Return Path:
For very long distance & in particular for very long sea cable transmission, return path with ground / sea electrodes will be feasible solution.

In many cases, existing infrastructure prevent use of electrodes. In such cases, metallic return path is used in spite of increased cost & losses.
This is a commonly used configuration for a bipolar transmission system. The solution provides a high degree of flexibility with respect to operation with reduced capacity during contingencies or maintenance.

Upon a single pole fault, the current of sound pole will be taken over by the ground return path & faulty pole will be isolated.
Simplified Single line diagram Bipolar converter station
12-pulse Rectifier or converter

A.C Filter

Converter transformer

A.C Side

Smoothing reactor

D.C Filter

D.C Side

Rihand-Delhi 1500 MW, Bipole HVDC Transmission System
Satellite Image (Rihand-Delhi HVDC)

A.C Side (A.C Filter, Converter Transformer)

Thyristor Valve Hall (12 Pulse Converter, Valve Cooling equipment)

D.C Side (Smoothing Reactor, D.C Filter, Surge arrestor, D.C Line)
The 12-pulse HVDC converter produces current harmonics (11th, 13th, 23rd, 25th, 35th, 37th etc.) on the AC side.

These harmonics are prevented from entering into the connected AC network by AC filters, i.e. resonant circuits comprising capacitors, inductances (reactors) and resistors.

The filters also produce a part of the reactive power consumed by the converter.
Conventional HVDC converters always have a demand for reactive power. At normal operation, a converter consumes reactive power in an amount that corresponds to approximately 50% of the transmitted active power. The simplest way to generate reactive power is in shunt connected capacitor banks.

Some of these capacitor banks can then be combined with reactors and resistors to form filters providing low impedance paths for the harmonics in order to limit them from entering into the connected AC network. A series resonance filter branch will give a very low impedance and thereby efficient filtering in a narrow frequency band around the tuning frequency. Such branches are therefore normally used for the largest harmonics, i.e. the 11th and 13th.
Each filter branch can have one to three tuning frequencies. Figure 5.4.1-1 shows different harmonic filter types with their impedance frequency characteristics.
Converter Transformer - 305 MVA (1 Phase, 3 Winding)
Rihand - Delhi HVDC uses “single-phase-three-winding Transformer”.

Converter transformers connect the AC network to the thyristor valve bridge, and adjust the voltage on the valve side to a suitable level based on the DC voltage used for the transmission.

**Converter Transformer Serves for following purpose:**

Supply of AC voltages in two separate circuits with a relative phase shift of 30 electrical degrees for reduction of low order harmonics, especially the 5th and 7th harmonics.

Act as a galvanic barrier between the AC and DC systems to prevent the DC potential to enter the AC system.

Voltage transformation between the AC supply and the HVDC system.
Thyristor Valve - 12 Pulse Converter
(6.5Kv, 1568 Amp, Water cooled, Suspended type)
The thyristor valve make the conversion from AC into DC & thus are the central component of any HVDC converter.

The basic circuit consists of two 6-Pulse bridge converter, but in order to eliminate the largest harmonics, two such bridges are connected in series forming a **12-pulse converter**.

The thyristor valves are normally located in a valve building and arranged as three structures (quadruple valves) suspended from the ceiling of the valve hall,
Thyristors are used as switches & thus the valve becomes controllable.

The Thyristor valve will have firing circuit in the same arrangement.

For Seismic requirement reasons, the entire thyristor valve are suspended from the ceiling of the valve hall.
The Thyristors are triggered by electrical gate pulses generated in a small electronic thyristor control unit (TCU) located near each thyristor.

These units receive triggering impulses 50 or 60 times per second from the HVDC control system.

In Rihand-Delhi HVDC, Light Triggered Thyristor (LTT) are used to trigger the thyristor, by injecting the photons into the gate of thyristor instead of electrons.

With LTT Technology, the gating light pulse is transmitted via fiber optic cable through the thyristor housing directly to thyristor.

Thus no elaborate electronic circuits are required for firing. The required power is just 40 mW.
The DC switchyard contains all the external equipment needed for an HVDC transmission:

- Voltage dividers
- Current measuring devices
- Smoothing Reactors
- DC Filters

Transmissions with cables (underground or underwater) do not require any DC filter. Transmissions with OH typically require DC filters to prevent the harmonics generated by the converter to be transported along the DC line. A harmonic filter for 12th and a high pass is usually enough.
Air insulated dry type reactor
- 180 mH

Oil insulated reactor in a tank
- 360 mH

The dc reactor contributes to the smoothing of the dc current and provides harmonic voltage reduction in the dc line. The dc reactor also contributes to the limitation of the crest current during a short-circuit fault on the dc line. It should be noted that the inductance of the converter transformer also contributes significantly to these functions.
Purpose of Smoothing Reactor (Air Insulated dry type reactor)

Advantage of the Dry-Type reactor is that maintaining spare parts is not very expensive because the usually consist of several partial coils. However for very large inductances it is possible to have more than one unit & it could be a problem if much space is not available.

For Air Insulated Dry-Type Smoothening Reactor, a wall brushing is needed to connect with the valves.

Purpose of Smoothing reactor

→ Prevention of Intermittent Currents
→ Limitation of DC Fault Currents
→ Prevention of resonance in the DC Circuit.
→ Reducing harmonic currents including limitation of telephone interference
Smoothing Reactor (Oil insulated reactor in a tank)

In High Seismic Regions, setting them on the post insulators or on an insulating platform is a possible solution. Oil insulated smoothing reactor are then the preferred solution.

One bushing of the Oil insulated smoothing reactor penetrates usually into valve hall, while other bushing is normally in a vertical position.
D.C Filter - 2 X (12, HP 24)
The HVDC converter also gives rise to voltage harmonics on the DC side (12th, 24th, 36th etc.). A large inductance (smoothing reactor) is always installed on the DC side to reduce the ripple in the direct current.

In addition, a DC filter is also normally needed to reduce the level of harmonic currents in the DC overhead line. The harmonics may otherwise cause interference to telephone circuits in the vicinity of the DC line.
For overhead line transmissions, it is normally necessary to install additional filter circuits between the pole bus (outside the smoothing reactor) and the neutral bus.

Capacitors or filter circuits may also have to be installed between the neutral bus and ground.

The filter types used on the d.c. side are essentially the same as those used on the a.c. side, i.e. series resonance filters and high pass filters.

The principle of the active DC filter is to inject a current generated by a power amplifier into the DC circuit cancelling the DC side harmonics coming from the HVDC converter.

The largest item of a DC filter, the capacitor, is often suspended, especially in seismic areas.
Why HVDC transmission?
Thank You
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