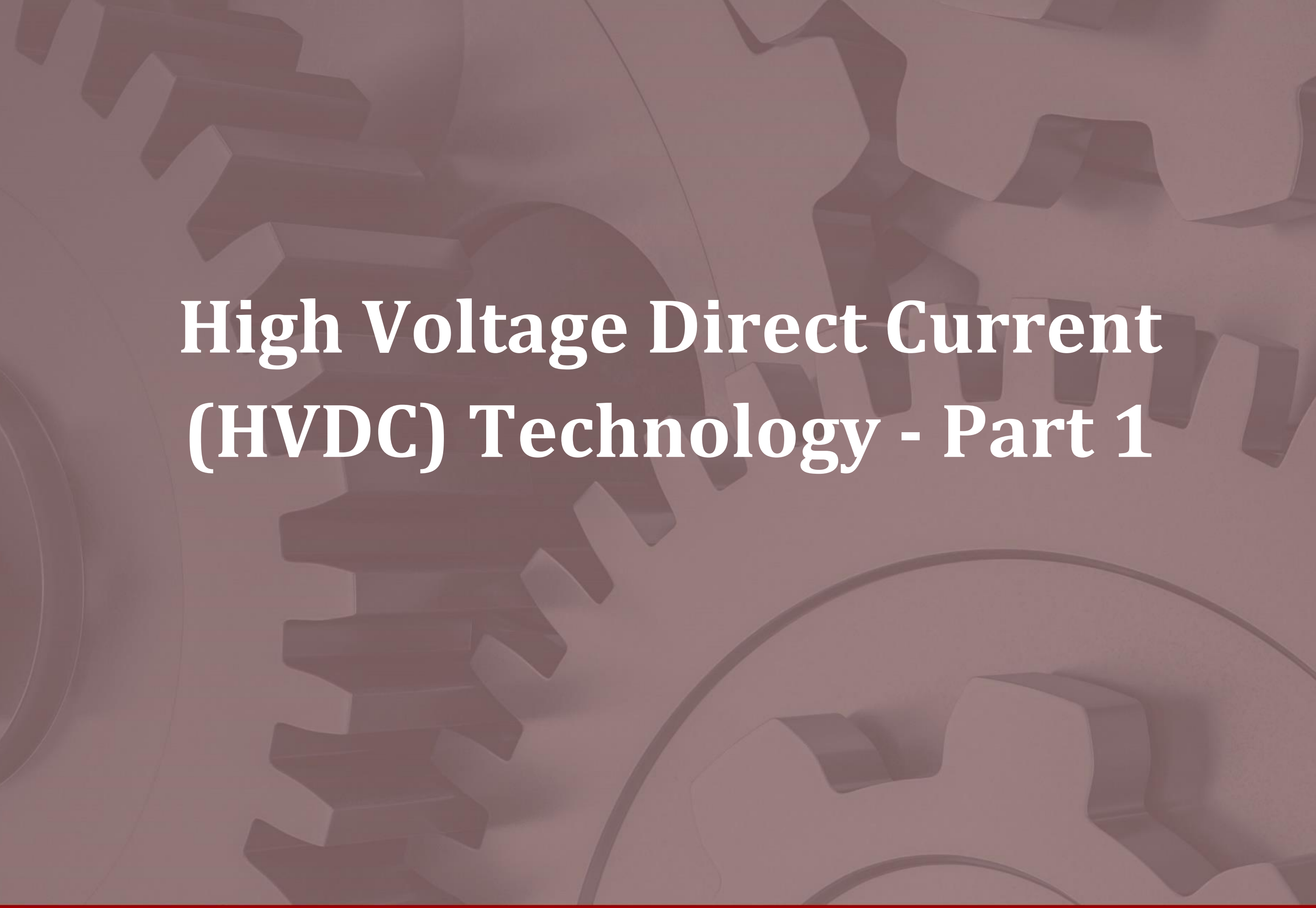

High Voltage Direct Current (HVDC) Technology - Part 1

An Online Continuing Education Course for Engineers

Course Number: E-2047

Credit: 2 Hours / 2 PDH / 2 CPD

High Voltage Direct Current (HVDC) Technology - Part 1

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Introduction To HVDC

Electricity is produced as an alternating current (AC). It is also transferred and distributed as AC and in the majority of applications, it is used as AC. Nevertheless, in many situations, it is financially and technically beneficial to use direct current (DC) links. In some situations, it may be the only possible power transmission method. In situations, when two different AC systems cannot be synchronized or when the interconnection cable length is too long for stable AC transmission, DC transmission can be applied. At sending “converter station” the AC is converted to DC current, which is then transferred to a second, receiving converter station and converted back to AC. In “back-to-back” HVDC arrangements the two converter stations are placed in the same building, reducing the DC transmission length to zero. HVDC transmission installations can be classified into four broad groups and any arrangement typically involves a combination of two or more of these. The groups are:

- Transfer of bulk power where AC would be uneconomical or infeasible

- Link between electrical systems which use different frequencies, or between non-synchronised or isolated power systems which, even though they have the same nominal frequency, cannot be run reliably in synchronism.

- Introduction of power infeed without greatly increasing the short circuit level of the client’s AC system.

- Improvement of AC system operation by the fast and precise control of HVDC power.

HVDC Arrangements

Monopolar HVDC Configurations

Monopolar HVDC configurations have either earth return or metallic return.

A Monopolar HVDC configuration with earth return contains one or more six-pulse converter units connected in series or parallel at each end, a single conductor and return through the ground or sea. This configuration is presented in Figure 1. It can be a practical arrangement for a HVDC cable transmission and/or the first stage of a bipolar scheme. At each line end, it demands an electrode line and an earth or sea electrode built for continuous service.

A Monopolar HVDC configuration with Metallic Return typically contains one high voltage and one medium voltage conductor as presented in Figure 2. A monopolar scheme is used either as the first stage of a bipolar arrangement, avoiding earth currents. It is also applied when installation of electrode lines and earth electrodes results in an uneconomical solution due to a short distance or high value of ground resistivity.

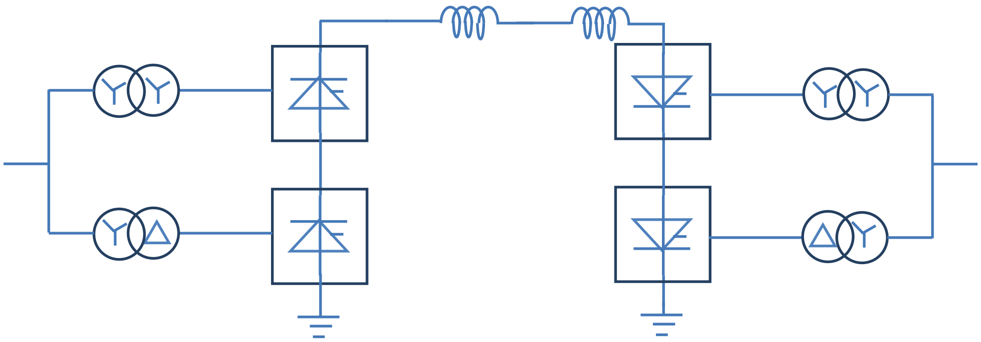


Figure 1: Monopolar HVDC arrangement with earth return

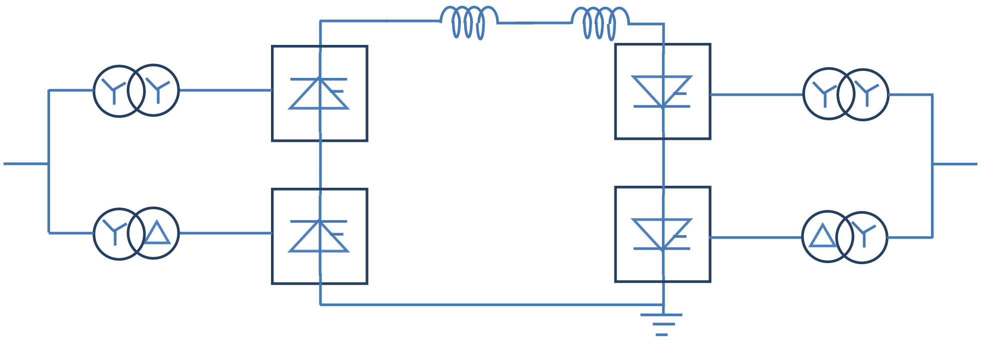


Figure 2: Monopolar HVDC arrangement with metallic return

Bipolar HVDC Configurations

A Bipolar HVDC configuration contains two poles, each of which includes one or more twelve-pulse converter units that are connected in series or parallel. Two conductors are used, one with positive and the other with negative polarity to ground for power transfer in one direction. For power transfer in the other direction, the two conductors change their polarities. A Bipole configuration is a combination of two monopolar configurations with earth path. It is presented in Figure 3. With both poles in service, the imbalanced current transfer in the earth path can be kept to a very low value.

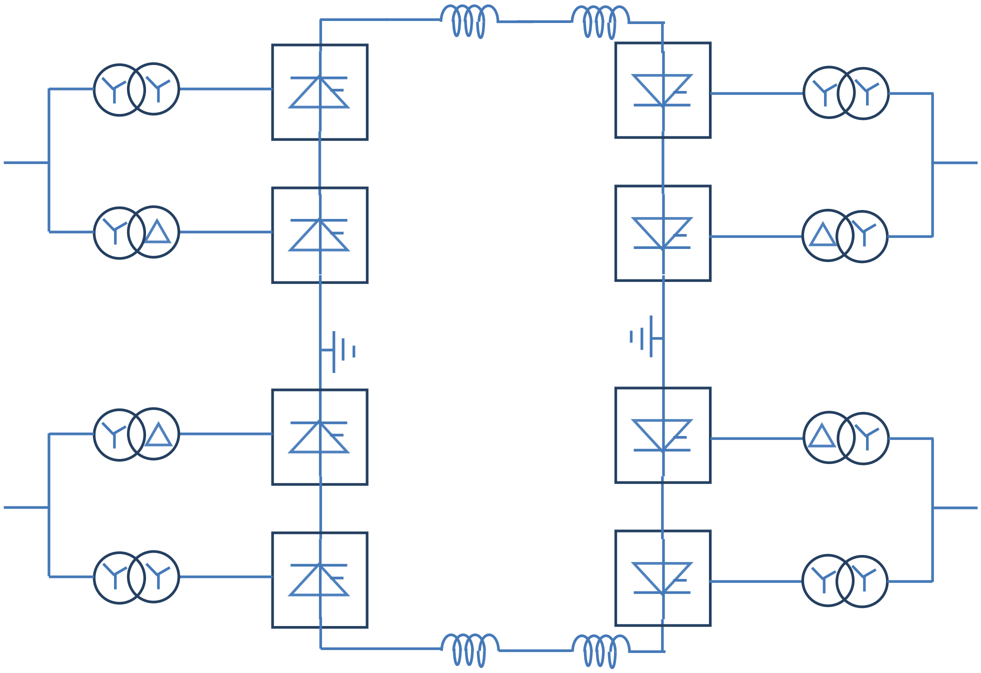


Figure 3: Bipolar HVDC configuration

This is a typical configuration with the following operational features:

- During an outage of one pole, the other could be continuously controlled with earth return.
- For a pole outage, in case long-term earth current flow is undesirable, the bipolar configuration could be run in monopolar metallic return mode. This is only possible if adequate DC arrangements are provided, as presented in Figure 4. Current transfer to the metallic path and back without interruption demands a Metallic Return Transfer Breaker (MRTB) and other special purpose switchgear in the terminal earth path. When a short interruption of power flow is allowed, such a circuit breaker is not necessary.

- During earth electrodes or electrode lines maintenance, service is possible with the connection of neutrals to the earthing grid of the terminals, with the imbalance current between the two poles kept to a very low value.
- When one pole cannot be ran with full load current, the two poles of the bipolar arrangement could be controlled with different currents, as long as both earth electrodes are connected.
- In case of partial damage to DC line insulation, one or both poles could be continuously operated at decreased voltage.

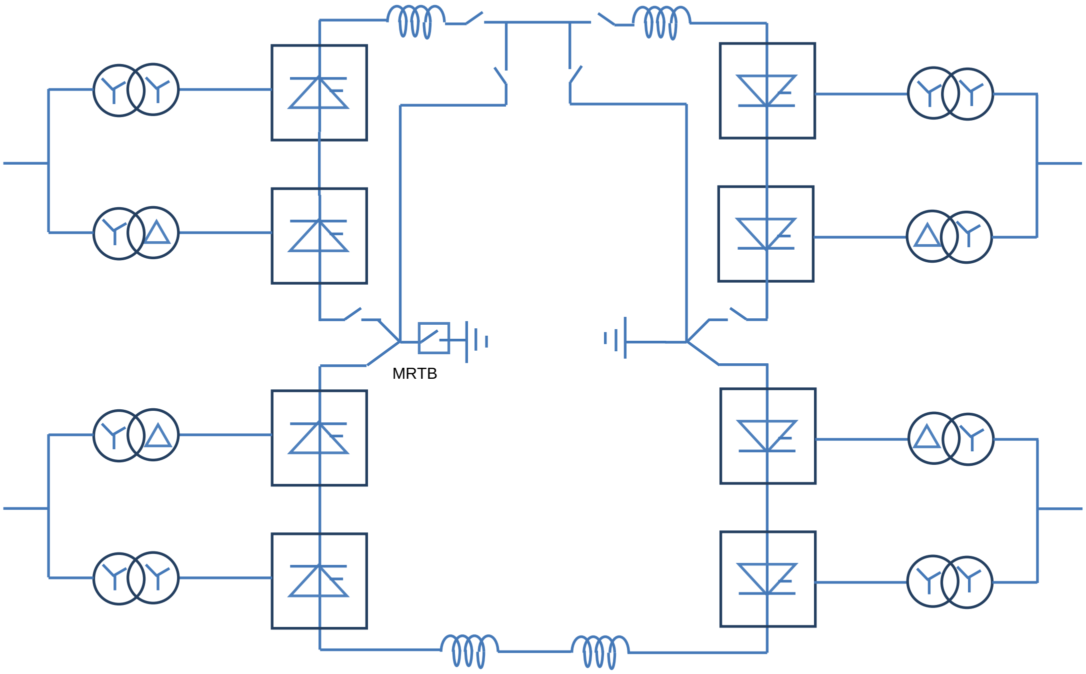


Figure 4: Bipolar configuration with a monopolar metallic return for pole outage

- In place of earth return, a third conductor can be added end-to-end. This conductor transfers unbalanced currents during bipolar service and functions as the return path when a pole is out of operation.

Back-To-Back HVDC Configurations

Back-to-back HVDC configurations are particular cases of monopolar HVDC interconnections. In these configurations, there is no DC transmission line and both converters are placed at the same site. For economic reasons, each converter is typically a twelve-pulse converter unit and the valves for both converters may be placed in one valve hall. The control mechanism, cooling devices, and auxiliary system may be incorporated into configurations common to the two converters. DC filters are not needed, nor are electrodes or electrode lines. The neutral connection is done within the valve hall. Back-to-back HVDC links which does not require a smoothing reactor are also developed. They do not require external DC insulation. Figure 5 presents two different back-to-back HVDC circuit configurations. Normally, for a back-to-back HVDC link, the DC voltage rating is low and the thyristor valve current rating is high in comparison with HVDC interconnections via overhead lines or underground cables. The reason is that valve costs are voltage-dependent, as the higher the voltage, the higher the number of thyristors. A low voltage tertiary winding can be installed into the converter transformer for the AC filters and compensation. Therefore, smaller reactive power switching steps can be accomplished. Large back-to-back HVDC configurations can contain two or more independent links so that the outage of one converter unit will not cause loss of overall power capability.

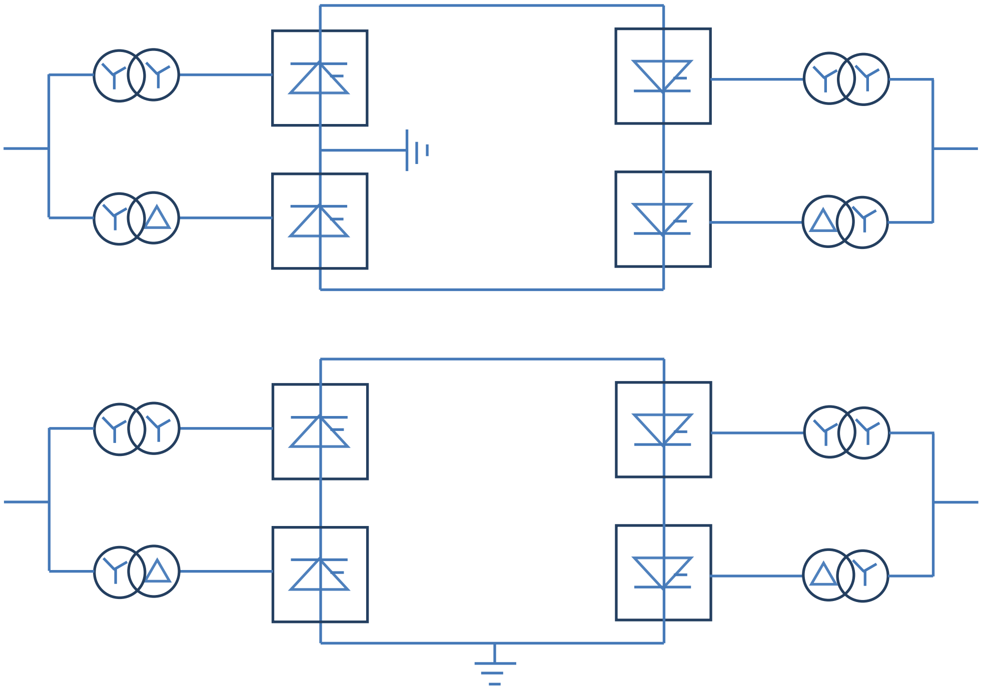
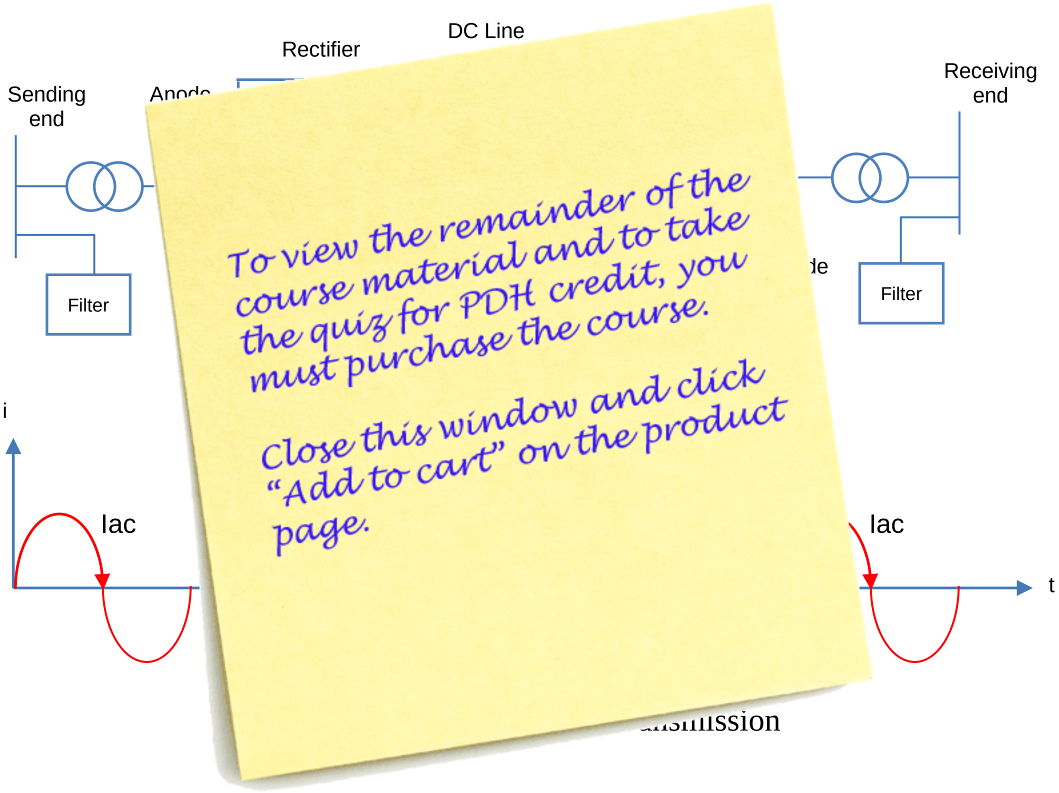


Figure 5: Back to back DC circuits

What Is HVDC?

A simple HVDC interconnection scheme is presented in Figure 6. AC power is fed to a converter which works as a rectifier. Rectifier output is DC power, which is independent of the AC supply frequency and phase. The DC power is transferred through a conduction medium. It can be an overhead line, an underground cable or a short length of the busbar and it is applied to the DC terminals of a second converter. The second converter is controlled as a line-commutated inverter and allows the DC power to run into the receiving AC network. Typical HVDC transmission uses line-commutated thyristor technology. Figure 7 presents a simple thyristor circuit. When a gate pulse (i_g) is applied while positive forward voltage is imposed between the anode and cathode (V_{thy}), the thyristor will transfer current (i_L). Conduction goes on without additional gate pulses as long as current runs in the forward direction. Thyristor "turn-off" happens only when the current tries to reverse. Therefore, a thyristor converter demands an existing alternating AC voltage (V_{ac}) in order to work as an inverter. This is why the thyristor-based converter topology applied in HVDC is known as a line-commutated converter (LCC).



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