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High Voltage Direct Current Transmission (HVDC)

Transmisión de Alta Tensión en Corriente Directa (HVDC)

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Abstract

High Voltage Direct Current (HVDC) transmission links are currently in operation throughout the world. Until a few years ago, what has limited the use of this way of transmitting power has generally been its cost, but with the advances in power electronics in reducing costs in thyristors: higher rated voltage and current, and simplification of the tripping and protection circuits, with more compact converter stations, with the use of GTO thyristors and with the cooling of the thyristors by liquid freon instead of water, a new panorama is beginning to be had to use this technique. The purpose of this article is to familiarize the reader with the fundamental concepts of High Voltage transmission in Direct Current, since this is an alternative for the transport of energy, it is analyzed and evaluated in many of the transmission expansion projects in the world.

HVDC, Direct current, Direct current transport

Resumen

En la actualidad existen en operación enlaces de transmisión de Alto Voltaje en Corriente Directa (HVDC, High Voltage Direct Current) en todo el mundo. Hasta hace algunos años, lo que ha limitado la utilización de esta forma de transmitir la potencia, ha sido generalmente su costo, pero con los adelantos de la electrónica de potencia en la reducción de costos en tiristores: mayor voltaje y corriente nominal, y simplificación de los circuitos de disparo y protección, con estaciones convertidoras más compactas, con el uso de tiristores GTO y con el enfriamiento de los tiristores por freón liquido en lugar de agua, se comienza a tener un nuevo panorama para utilizar esta técnica. El propósito de este artículo es familiarizar al lector con los conceptos fundamentales de la transmisión de Alto Voltaje en Corriente Directa, ya que esta es una alternativa para el transporte de energía se analiza y evalúa en muchos de los proyectos de expansión de transmisión en el mundo.

HVDC, Corriente directa, Transporte de corriente directa

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Introduction

The first commercial HVDC installation and the start of its expansion is considered to be in 1954 with the 90 km, 20 MW (200 A and 100 kV) submarine link between Sweden and the island of Gotland (Asplund & Carlsson, 2008). The use of an alternating current link was not feasible because of the large reactive compensation required.

Transmission voltages have been increased to 800 kV (Asplund G., 2007) and existing technology is available to reach 1000 kV (Elg *et al*., 2015).

High Voltage Direct Current transmission systems have had a very important breakthrough in the evolution of electrical power systems (EPS) in recent years, this type of systems introduce a high controllability in the EPS, but the limitation in its application has been mainly its cost and the specialised manpower required for its maintenance (Grainjer & Stevenson Jr., 1996; Sarmiento-Uruchurtu, 1997).

Basic definitions

The most popular terminology associated with High Voltage Direct Current (HVDC) transmission is defined below (Grainjer & Stevenson Jr., 1996).

Rectifier. A device or system for changing alternating current power to direct current power.

Converter. A converter for switching from alternating current (AC) to direct current (DC).

Inverter. A converter for switching from direct current to alternating current.

Loop. The AC component of the DC supply (modern converters have smoothing reactors resulting in a DC supply with almost no ripple).

Switching. The transfer of current from one valve to another.

Reactor. Inductance between the direct current output of the converter and the load. It is used to smooth ripple, reduce harmonics and limit fault current.

Valve. Unidirectional conduction device (mercury arc tubes, thyristors).

Harmonic filters. Harmonic filters are required because converters generate harmonic currents and voltages at both the AC and DC ends.

Reactive power sources. Converters inherently absorb reactive power. They are typically shunt capacitors or static VAR compensators.

Electrodes. Large surface area conductor, as DC lines use ground return for at least short periods of time.

AC circuit breakers. To clear transformer faults and take the DC link out of service. Not used to clear DC line faults; these are cleared by converter control.

Overlap angle (μ). The time, in degrees, during which current is switched between two rectifier elements. Also called switching time. In normal operation it is less than 60 degrees, typically between 20 and 25 at full load.

Delay angle (alpha). The time expressed in electrical degrees by which the switching is delayed. It may not exceed 180 degrees. Also known as firing angle.

Thyristor (SCR, Silicon Controlled Rectifier). A semiconductor device with an anode, cathode and a gate for trigger control.

DC transmission

When talking about the use of DC in transmission lines, it is not proposed to replace DC with AC, but to complement it. Specifically, it is proposed to assume a DC transmission link in an AC system or to interconnect two AC systems with a DC transmission line. Such a transmission system requires AC to convert to DC on the send side and DC to convert (or reverse) to AC on the receive side. The flexibility and advantages of these schemes depend heavily on the development of appropriate converters for the high voltages and power required (Escobar-Vargas, 2014).

Basic aspects of HVDC systems

The most common arguments in favour of HVDC technology are the following (Sarmiento-Uruchurtu, 1997):

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- Transmitting large blocks of power, particularly through submarines as the high capacitance in AC excessively limits the transmission distance, a situation that is not present in DC.

- Transmitting power over long distances through overhead lines (in the order of 800 km or more).

- Reducing active power losses. For the same transmission capacity, losses are generally lower in DC than in AC, even considering the losses in the converter stations.

- Connecting asynchronous systems either because of different operating frequencies or because of stability problems.

- Increase the level of controllability in the AC system where the HVDC system is connected.

- Increase the transmission capacity without increasing the short circuit capacity.

HVDC system configurations

The most common configurations in HVDC systems can be classified into three, namely (Sarmiento-Uruchurtu, 1997; Escobar-Vargas, 2014):

Point-to-point transmission. Most of the transmission lines that have been built are of this kind, by means of overhead lines or submarine cable or a combination of both. Many of the cable transmissions are monopolar, with only one monopolar conductor between converter stations and using the land or sea as the return path for the current.

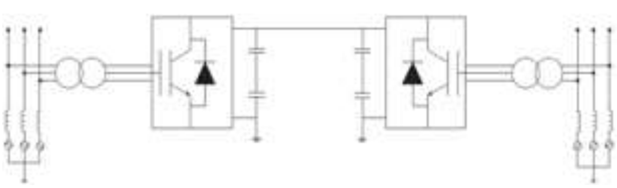

Figure 1 Monopolar transmission line
Source: Díaz-Martín (2013)

Overhead lines are generally bipolar, i.e. two conductors of opposite polarity (one positive and one negative) are used. A two-pole transmission is, de facto, a double transmission circuit since one pole can transmit power when the other pole is out of service.

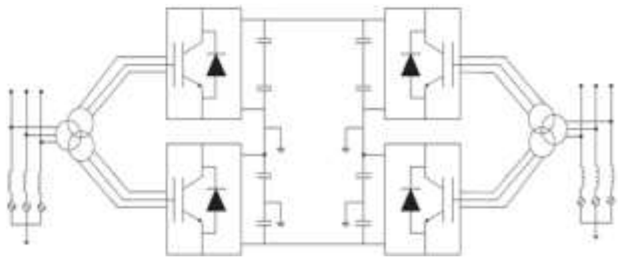

Figure 2 Bipolar transmission line
Source: Díaz-Martín (2013)

The voltage in such a link is selected to make the lowest investment and minimum losses. The highest voltage to date on an HVDC link is 600 kV on an overhead line and 450 kV on a submarine cable.

Back to Back configuration (zero distance line or asynchronous connection). There are several such stations in the world. In these, the rectifier and inverter are located together and are used to make an asynchronous interconnection between two AC stations. This is one of the advantages of HVDC, as two generation systems that have the same frequency, but their generation plants use different frequencies in their control systems, can be interconnected.

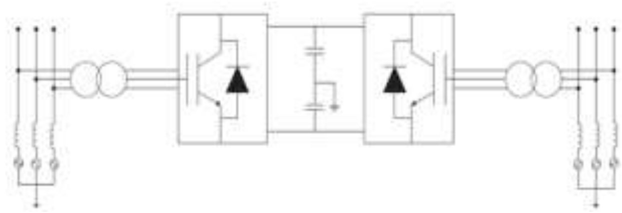

Figure 3 Asynchronous connection line
Source: Díaz-Martín (2013)

Multi-terminal systems. This system has more than two converter stations, so it is obviously more complicated than a point-to-point station. In particular, the control system is more elaborate and the telecommunication requirements between the stations will be higher.

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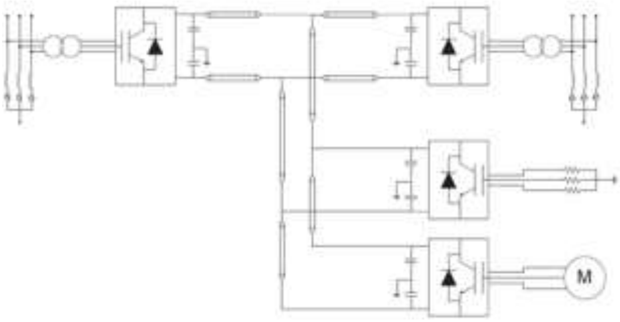

Figure 4 Multi-terminal connection line
Source: Díaz-Martín (2013)

There is only one such system in the world in operation and other such systems are under consideration.

HVDC applications

If the plants generate AC and the power consumed by the users is AC, the transmissions are usually AC. Why then, is it more suitable to use HVDC for transmissions? The reasons can be divided into two groups (Escobar-Vargas, 2014; Dodds *et al.,* 2010):

– HVDC results in lower investment and lower losses.

– HVDC is necessary or technically desirable.

In many cases projects are justified on a combination of benefits from both groups.

Environmental aspects are nowadays very important. HVDC in this respect is more favourable as the towers are smaller for the same transmission capacity.

The characteristics of HVDC systems differ greatly from AC systems. The active power can be controlled exactly in DC, but not in AC.

Another important thing is that the link is asynchronous.

The decision to install an HVDC transmission line can be due to several reasons, including (Grainjer & Stevenson Jr., 1996; Jiménez-Bahamón, 2016; Berizzo, 2022; Turrubiates-Guillén, 2017):

– Two different frequency systems.

– Underwater crossings with cable.

– Connection of two asynchronous systems.

– Overhead transmission over long distances when the cost savings of the direct current line outweigh the cost of the converter stations. For the same power to be transmitted, the cost in terms of length of a DC line is lower. The break-even point depends on power, voltage, equipment cost and other factors.There is only one such system in the world in operation and other such systems are under consideration.

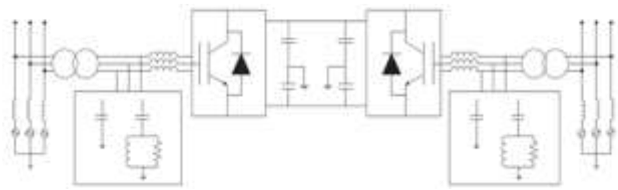

Figure 5 HVDC transmission line
Source: Díaz-Martín (2013)

– Direct current systems have an inherent overload capacity that can be used to dampen oscillations.

– Connection between two systems without raising the short-circuit level.

Limitations

On the other hand, it is also important to keep in mind their limitations (Berizzo, 2022; Turrubiates-Guillén, 2017):

– Lack of circuit breakers, limits the multi-terminal scheme, although it tends to disappear, as technological advances in recent years allow the installation of more than two terminals, as in the projects in Italy and the Quebec-New England interconnection.

– Reliability and maintenance of mercury arc converters. In the early installations, the conversion process was done by mercury arc valves and although thyristors are now used, several installations still remain with the old technology.

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– Production of harmonics due to the operation of the converters. Filters are required on both sides of the DC system.

– Generation of harmonics, which can be costly to eliminate.

Conclusions

DC links are classified according to the number of conductors: Monopolar. One conductor (negative polarity) and ground return, Bipolar. Two conductors, one positive and one negative (the neutral points).

They are grounded at both ends of the converters), Homopolar. Two or more conductors, all with the same polarity (negative) operating with earth return. Bipolar operation is possible in the event of a fault.

The main economy lies in the use of only two conductors per circuit, instead of the three required for alternating current; consequently, the towers carry less weight and losses are lower for the same transmitted power because HVDC can easily control the power flow, but it is also worth mentioning the disadvantages of this type of system among which are; There are no DC switches, the converters are very expensive and they also require filters, as they generate harmonics, although with the new developments in power electronics and the significant decrease in their cost on the one hand and the increase in the cost of rights of way for transmission lines, as well as raising the efficiency levels of transmission networks are factors that will motivate the use of High Voltage Direct Current systems in the coming years.

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