IJIREEICE ISSN (O) 2321-2004, ISSN (P) 2321-5526

International Journal of Innovative Research in Electrical, Electronics, Instrumentation and Control Engineering

ISO 3297:2007 Certified ⁒ Impact Factor 8.021 ⁒ Peer-reviewed / Refereed journal ⁒ Vol. 11, Issue 6, June 2023

DOI: 10.17148/IJIREEICE.2023.11615

A Review on Modern Trends in HVDC Transmission

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Abstract: The establishment of interconnections with the aim of achieving economic benefits is a global trend in the development of power networks. Where such solutions are technically possible and profitable (AC solution), synchronous links are typically used to realise the interconnections. An HVDC coupling station or HVDC long Distance transmission (DCsolution) can be utilised when synchronous connections is not technically possible. The use of AC transmission has increased. The primary technical issues that limit the development of modern DC transmission are gradually being resolved with the advancement of power electronics, material science, and other fundamental technologies. DC power grids have not been produced for engineering application on a global scale, however related research and research for important equipment parts are developing progressively. An interphase transformer-related interleaving approach AC-DC converter with high-frequency isolation. This arrangement is suggested for applications involving offshore wind energy conversion systems (WECSs) with high-voltage DC transmission (HVDC). It is based on a medium-voltage DC (MVDC) isolated port. The use of DC-DC converters to process the energy produced by offshore systems is an option to increasing the power density on those systems The use of wind turbines in this type of arrangement is a modern trend.

Keywords: HVDC Transmission, Power Electronics Devices, System Interconnections, Hybrid Transmission Technology.

I. INTRODUCTION

The high voltage direct current transmission lines (HVDC) serve a present and future the main character role in the transmission of electrical power given the current scenario of continuous and increasing production of energy from renewable sources and the progressive improving of international ties. The impact of transient overvoltages (TOV), which happen during fault situations on the DC side of an HVDC link, is one of the major problems with HVDC systems. In actuality, the true TOV phenomenon lack standard properties, even if electrical connections are tested to tolerate overvoltages with standardised characteristics[1].

AC transmission for long-distance bulk power transmission. The massive spread of HVDC technology is a result of the expanding electrification and rising demand for electrical power. As a result, several high capacity long distance HVDC projects are being considered. Multiple HVDC transmission lines connecting to the same AC network in close electrical proximity is becoming more typical. The term "Multi - infeed HVDC system" (MI-HVDC) refers to the integration of numerous HVDC links supplying power into various places in the same AC network area[2].

Whenever such solutions are technically possible and economical (AC solution), synchronous links are typically used to realise the interconnections. The usage of an HVDC coupling station or HVDC long Distance transmission (DC solution) is an option when synchronous connectivity is not technically possible. In addition, but not least, the DC solution can also be used along with synchronous interconnection to support the operation of the connected systems, increasing the reliability of the synchronous AC link[3].

As speed is essential in HVDC systems, its significance must be highlighted. As a result, local measurement-based algorithms are frequently utilised because of their quick operation. To increase its selectivity, they need limiting inductors, though. While communication-based algorithms are naturally selective, the communication time delay caused by the communication channel limits the speed at which they may operate[4].

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II. LITERATURE SURVEY

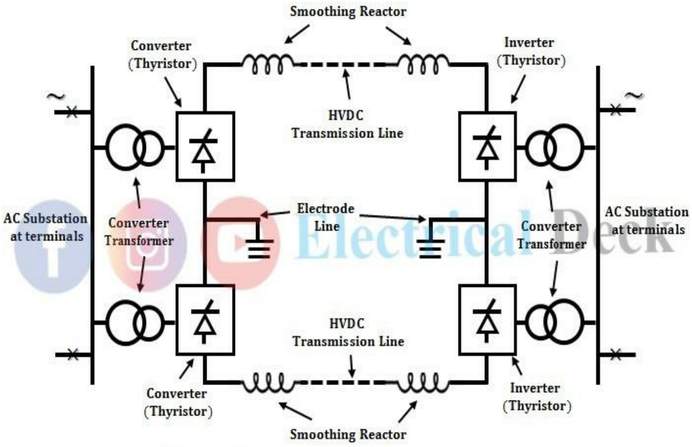
Mercury arc valves have been replaced by thyristor and IGBT valves, while oil-immersed reactors have been replaced with air-insulated ones. Series capacitors are assisting traditional commutation or completely replacing it thanks to PWM technology. Valves are leaving traditional valve halls and transforming into free-standing outdoor installations. Traditional filters have evolved into double tuned ones for more strict needs on the DC side, while the AC side has moved towards electronically tuned filters with a high Q factor[5].

With its designated "black start up" capabilities, Voltage Source Converter (VSC) is a promising technology in High Voltage Direct Current (HVDC) transmission. The ability of an HVDC system to restart an Alternating Current (AC) grid after a blackout without specific restrictions on the short-circuit power that should be ensured is known as black start capability[6].

A modern trend in this type of design is to process the energy generated by the wind turbines using DC-DC converters. The MVDC transmission bus and the wind turbines (WTs) can be connected using this topology in WECSs. The primary side's usage of full-bridge modules for each phase distributes the current among the semiconductors, resulting in lower losses at high power levels[7].

III. THEORY

HVDC Transmission System:



Schematic Diagram of HVDC Transmission System

Components of HVDC System:

Power semiconductors and valves:
The IGBTs or GTOs used needed a significant amount of current to switch on, which was a major issue. GTOs can be found in 2500V and 2100A versions. MCT, which can be switched OFF by a small current, is preferred as a valve since GTOs have the drawback that a big gate current is required to turn them OFF.Better cooling techniques also boost the power rating of thyristors. With ionised water cooling becoming typical, cooling losses are decreased.

Converter Control:
The development of micro-computer based converter control equipment has made possible to design systems with completely redundant converter control with automatic transfer between systems in the case of a problem. The micro-computer based control also has the flexibility to implement adaptive control algorithms or even the use of expert systems for fault diagnosis and protection.

DC Breakers: Parallel rather than series operation of converters is more frequent due to the flexibility it provides for planned system expansion. Since the control intervention is anticipated to minimise the fault, the DC breaker ratings are not likely to be higher than the full load values. Current
Conversion of existing AC lines: An experimental project to convert a single circuit into a double circuit is now underway, but there are certain operational issues brought on by electromagnetic induction from AC circuits.

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Six Pulse Converters:
The conversion from AC to DC and vice-versa is done in HVDC converter stations by using three phase bridge converters. The configuration of the bridge (also called Graetz circuit) is a six pulse converter and the 12 pulse converter is composed of two bridges in series supplied from two different (three-phase)transformers with voltages differing in phase by 30o.

Converter:
Converts AC to DC and DC to AC. It consists of rectifiers and inverters.

Electrodes:
Conductors that are used to connect the system to the earth.

Smoothing Reactors:
Smoothing reactors consist of inductors connected in series with the pole of each converterstation. It prevents Commutation failures experienced by inverters, reduces harmonics, and avoids breaking off the current.

DC Lines:
Cables or overhead lines that carry power.

Harmonic Filters:
Used to minimize the harmonics in voltage and currents of the converters used.

Reactive Power Supplies:
Converters at the terminals consume reactive power from the supply, thus shunt capacitors are used to provide this reactive power compensation.

AC Circuit Breaker:
Used for electrical safety like fault in transformers, disconnection of the DC link. Conductors used to link the system to the earth are called electrodes.

How does HVDC Transmission System Work?

A rectifier is used to convert the AC electricity that is produced in the producing substation into DC. As the DC travels down the overhead line, it is again converted to AC at the user end by means of inverters before being provided to the load. At the sending and receiving ends, converter stations have rectifiers and inverters. Input and output power are similar when DC is running across overhead lines, reducing losses and increasing efficiency. As two converter stations and one transmission line are shown in the diagram above, this kind of system is referred to as a “Point-to-point system” or “Two terminal DC system.” Similar to this, a substation is referred to as a “Multi terminal DC substation” if it has more than two converters and the connected DC terminal lines.

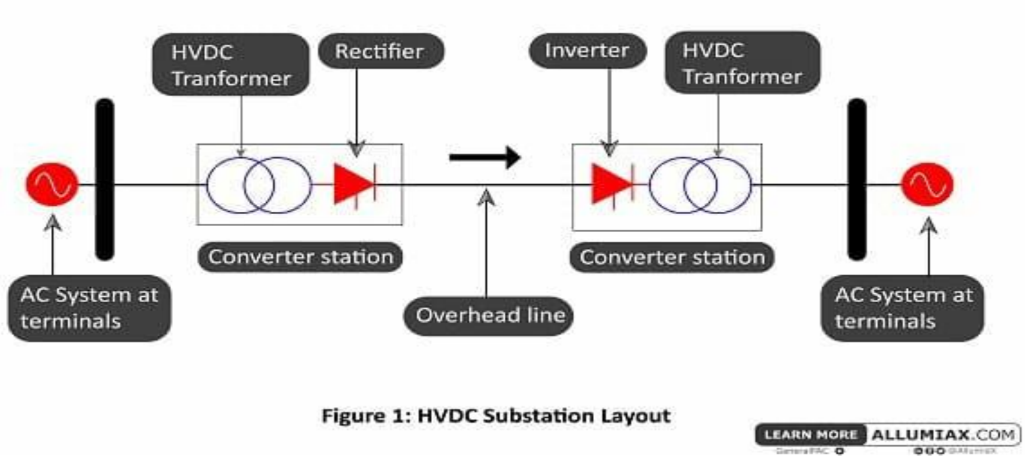

Figure 1: HVDC Substation Layout

HVDC Links Types:

Monopolar link:
Mono means "one," because it only has one conductor of negative polarity, and the earth and the sea serve as the return channel. Corona loss and radio interference in the line are decreased while operating with negative polarity in relation to the ground. Two converters are put at the end of each pole of a monopolar link, and they are each connected to an earth electrode. They are situated between 15 and 55 kilometres from the corresponding terminal stations. However, due to a number of drawbacks, monopolar HVDC links are no longer frequently employed. Previously, they were exclusively used for cable transmission and low power ratings.

Bipolar link:
Bi means "two," so a bipolar link has two conductors, one of which is positive and the other is negative with respect to the earth.In addition, it consists of converter stations at both ends and electrodes connected at the converter stations' midpoints for earthing, enabling independent operation of each pole. Also, because of the ground return mechanism, if any of the bipolar links stop functioning, the link automatically switches to monopolar mode, and keeps providing power for half of the system. HVDC transmission over long distances frequently uses bipolar links.

Homo-polar link:
The earth is always used as the return conductor in a homopolar link, which consists of two conductors with the same polarity, often negative. The cost of installation is decreased because the poles in this link are operated concurrently. This kind of relationship has few uses and is extremely difficult. It is therefore not in use currently.

IV. APPLICATIONS

- Long distance bulk power transmission
- Stabilization of power flows in integrated power system
- Asynchronous connection of AC system with different frequencies
- Underground or underwater cables

V. FUTURE SCOPE

The predicted period is likely to see the HVDC overhead transmission system maintain its higher revenue share, making it the dominant sector in the India HVDC market. HVDC transmission systems, which are more effective for offshore environments, are likely to benefit from many opportunities created by the country's plan to construct 30 GW of offshore wind energy projects by the 2030s.During the projection period, India's market for HVDC transmission systems is anticipated to be driven by the country's expanding transmission electric grid.

VI. CONCLUSION

An overview of current trends in HVDC systems is provided in this project paper. When HVDC was first introduced in the 1950s, it had a number of advantages, including the ability to connect asynchronous networks, financial gains, the ability to distribute power across great distances, and environmental gains. Over the course of its first 40+ years, HVDC technology has advanced impressively, considerably enhancing the capacities and operational features of converter stations. In HVDC, a power system's stability can be increased and power flow can be rapidly and accurately managed. Huge investments, like those made in China and India, indicate how crucial HVDC will be in the future, particularly in developed nations with huge populations.

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