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Analysis of HVDC and HVDC Light Technology

Swati Srivastava

Department of Electrical Engineering, Amity University, Noida, INDIA.

Abstract

Transmitting power at high voltage and in DC form instead of AC is a new technology proven to be economic and simple in operation which is HVDC transmission. The HVDC (High Voltage Direct Current) technology is used to transmit electricity over long distances by overhead transmission lines or submarine cables. It is also used to interconnect separate power systems. A further development in this technology is HVDC light where HVDC light converters are used for faster and efficient conversion of power. HVDC Light is a fundamentally new power transmission technology developed recently. It is particularly suitable for medium to small-scale power transmission applications. This new transmission and distribution technology, HVDC Light provides an important role to today's requirements on our network systems and opens up new opportunities for both investors and environmentalist alike. HVDC light technology for transmission of electric power is introduced in this paper. Its features, advantages and applications and comparison with simple HVDC system are pointed out. The paper gives a note on the advantages of HDVC light cables over AC underground cables.

Keywords: Hvdc; hvdc light; small scale power transmission; moder trend of transmission.

1. Introduction

HVDC Light is the successful and environmentally-friendly way to design a power transmission system for a submarine cable, an underground cable, using over head lines or as a back-to-back transmission. HVDC Light is HVDC technology based on voltage source converters (VSCs) [1]. Combined with extruded DC cables, overhead lines or back-to-back, power ratings from a few tenths of megawatts up to over 1,000 MW are available. HVDC Light converters are based on insulated gate bipolar transistors (IGBTs) and operate with high frequency pulse width modulation in order to achieve high speed and, as a consequence, small filters and independent control of both active and reactive power. HVDC Light cables have extruded polymer insulation. Their strength and flexibility make them well suited for severe installation conditions, both underground as a land cable and as a submarine cable. The converter station designs are based on voltage source converters employing state-of-the-art turn on/turn off IGBT power semiconductors[2]. HVDC Light has the capability to rapidly control both active and reactive power independently of each other, to keep the voltage and frequency stable. This gives total flexibility regarding the location of the converters in the AC system, since the requirements for the short-circuit capacity of the connected AC network are low (SCR down to zero). The HVDC Light design is based on a modular concept. For DC voltages up to ± 150 kV, most of the equipment is installed in enclosures at the factory. For the highest DC voltages, the equipment is installed in buildings. The required sizes of the site areas for the converter stations are also small. All equipment except the power transformers is indoors. Well-proven and equipment tested at the factory make installation and commissioning quick and efficient.

2. System Description

2.1 HVDC Light Technology

As its name implies, HVDC Light is a dc transmission technology. However, it is different from the classic HVDC technology used in a large number of transmission schemes. Classic HVDC technology is mostly used for large point-to-point transmissions, often over vast distances across land or under water. It requires fast communications channels between the two stations, and there must be large rotating units - generators or synchronous condensers - present in the AC networks at both ends of the transmission. HVDC Light consists of only two elements: a converter station and a pair of ground cables. The converters are voltage source converters, VSC's. The output from the VSC's is determined by the control system, which does not require any communications links between the different converter stations. Also, they don't need to rely on the AC network's ability to keep the voltage and frequency stable. These feature make it possible to connect the converters to the points bests suited for the AC system as a whole.

The converters are using a set of six valves, two for each phase, equipped with high power transistors, IGBT (Insulated Gate Bipolar Transistor) [2]. The valves are controlled by a computerised control system by pulse width modulation, PWM. Since the IGBTs can be switched on or off at will, the output voltages and currents on the AC side can be controlled precisely [2]. The control system automatically adjusts the voltage, frequency and flow of active and reactive power according to the needs of the AC system. The PWM technology has been tried and tested for two decades in switched power supplies for electronic equipment as computers. Due to the new, high power IGBTs, the PWM technology can now be used for high power applications as electric power transmission.

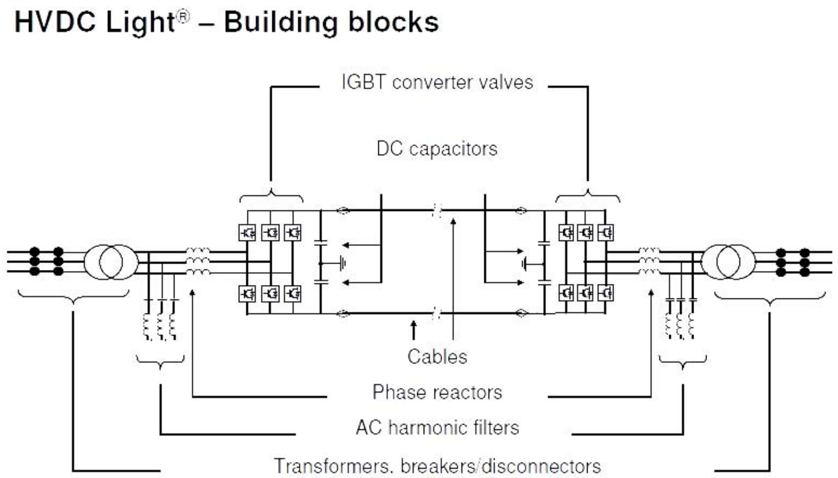

Figure 1: Building blocks of hvdc light system [1].

2.1.1 HVDC Light Cables

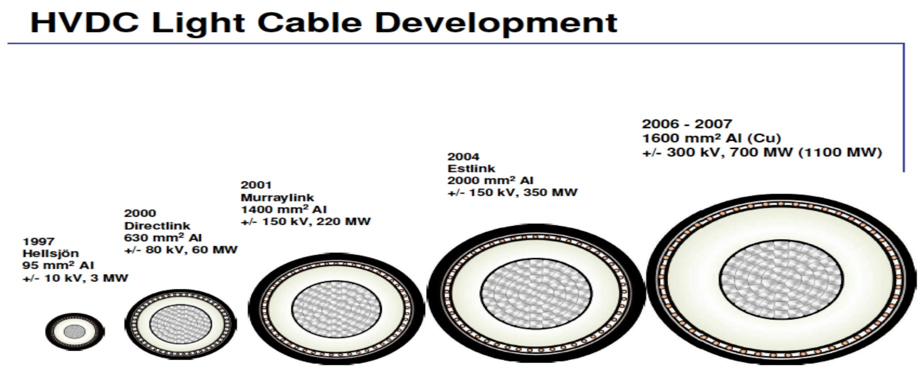

Figure 2: HVDC light cable system[2].

In Figure 2 there are different types of cables used for different puposes and locations. One of the most important of all the cables is Submarine cables, it supplies power to islands. The power supply to small islands is often provided by expensive local generation, e.g. diesel generation. By installing an HVDC Light transmission system, electricity from the mainland grid can be imported. Another issue is the environmental benefits to the island by reducing emission from local generation. Since HVDC Light is based on VSC technology, the converter can operate without any other voltage source on the island, i.e. no local generation on the island is needed for proper operation of the system. Submarine cables help remote small-scale generation to transmit power. Remote small-scale generating facilities are very often located on islands that will not need all the generated power in all situations [3]. This power can then be transmitted by HVDC Light to a consumer area on the mainland or an adjacent island. Interconnecting power systems through submarine cables is advantageous. The advantages of HVDC Light are of high value when connecting between individual power systems, especially when they are asynchronous. This refers to the possibilities for controlling the transmitted power to an undertaken value, as well as being able to provide and control reactive power and voltage in both the connected networks. Power to/from/between offshore platforms are possible through submarine cables. With its small footprint and its possibilities to operate at low short-circuit power levels or even to operate with a “black” network, HVDC Light has made it possible to bring electricity:

- From the shore to the platform
- From platform to shore
- Between platforms

The most important and desirable characteristics for offshore platform installations are the low weight and volume of the HVDC Light converter. Offshore, the converter is located inside a module with a controlled environment, which makes it possible to design the converter even smaller for an offshore installation than for a normal onshore converter station.

2.1.2 Underground cables

Interconnections: The environmental advantages of HVDC Light are of high value when connecting two power systems. This refers to the possibilities for controlling the transmitted power to the desired value, as well as improving AC network stability by providing and controlling reactive power and voltage support in the connected networks. Other important factors are: avoiding loop flows, sharing of spinning reserve, emergency power etc.

The rapid AC voltage control by HVDC Light converters can also be used to operate the connected AC networks close to their maximum permitted AC voltage and in this way to reduce the line losses in the connected AC networks.

2.2 Conventional HVDC

In the second half of the last century, high power HVDC transmission technology was introduced, offering new dimensions for long distance transmission. This development started with the transmission of power in a range of less than a hundred MW and was continuously increased. Transmission ratings of 3 GW over large distances with only one bipolar DC line are state-of-the-art in many grids today. In general, for transmission distances above 600 km, DC transmission is more economical than AC transmission ($\geq$1000 MW). Power transmission of up to 600 - 800 MW over distances of about 300 km has already been achieved with submarine cables, and cable transmission lengths of up to approx. 1,000 km are at the planning stage. Due to these developments, HVDC became a mature and reliable technology.

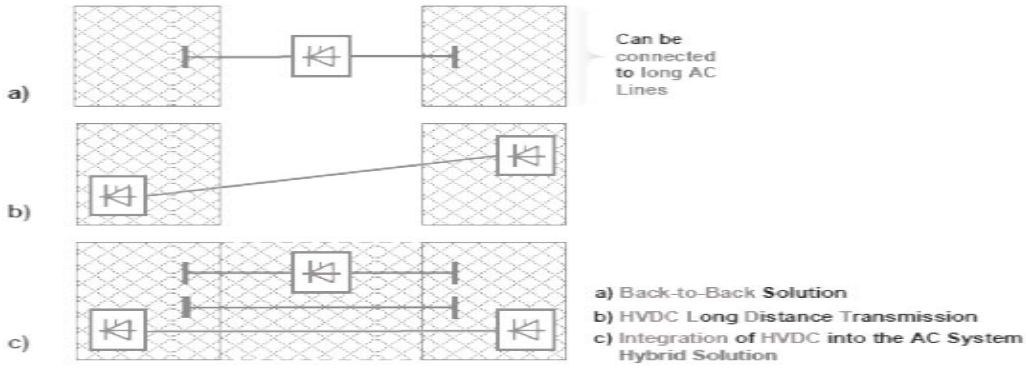

Figure 2: HVDC Interconnection[2].

3. Comparison Between Conventional hvdc and Hvdc Light

There are different basis on which conventional hvdc system and hvdc light can be compared. The area of application of both the systems varies and is one of the most demanded transmission system.

Table 1: Comparison of HVDC Light and conventional HVDC [4]

Comparison between HVDC Light and conventional HVDC		
	HVDC Light	Conventional HVDC
Power Range	50-110MW	upto 6400MW
Components used	IGBT is used in valves	Thyristor used in valves
Control methods	Pulse width controls active and reactive power	Phase angle control is done

By using HVDC light technology each terminal is an HVDC converter plus an SVC, suitable both for submarine and land cable connections, it needs short delivery time. By using IGBT, Multi-chip design is possible. It has forward blocking only, current limiting characteristics. Gate can be turned-off and it is fully controllable. It is forced commutated and high-speed device. The IGBT can be switched off with a control signal forced commutation up to 2000 Hz is possible[5].

In conventional HVDC system, it is most economical way to transmit power over long distances. Long submarine cables are used. It has around three times more power in a right-of-way than overhead AC. Thyristors used have single silicon wafer, both forward and reverse blocking capability and very high surge current capability. The thyristor cannot be switched off with a control signal, it automatically ceases to conduct when the voltage reverses, and it is line commutated, 50/60 Hz.

4. Conclusion

HVDC Light technology saves the environment by replacing remote fossil fuelled diesel generators with cost-efficient transmission of power from efficient and clean, large-scale generation production units. HVDC Light provides a convenient and cost-effective way for connecting renewable and non-polluting energy sources as wind power farms and photovoltaic power plants to a main grid. The HVDC Light technology is cheaper as compared to AC overhead line transmission for lower voltage levels and it is has large range to cover, it is faster and it makes transmission system reliable and is very efficient.

5. Acknowledgement

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