H.V.D.C.TECHNOLOGY OVERVIEW & APPLICATIONS

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ABSTRACT:-

High Voltage Direct Current (HVDC) technology has characteristics which make it especially attractive in certain transmission applications. The number of HVDC projects committed or under consideration globally has increased in recent years reflecting a renewed interest in this field proven technology. New HVDC converter designs and improvements in conventional HVDC design have contributed to this trend. This paper provides an overview of the rationale for selection of HVDC technology and describes some of the latest technical developments. Most commercial HVDC plants now operating are equipped with the same type of control system, the so-called individual phase control system. This system is simple and the operating experience is excellent. This may be the case when theHVDC transmission is connected to a very weak ac network or to a generator station with large variations in frequency.

INTRODUCTION:-

HVDC technology has developed rapidly over the last 20 years and so has the confidence in it, resulting in a shift from AC to DC for bulk power transmission [1]. These advancements in HVDC technology has also increased the boundaries of HVDC application, making it possible totransport bulk power to more remote and distant locations than ever before. This has, however, led to the requirement of much longer dc transmission lines. A typical example of importing power from a particularly distant location is the proposed Westcor Project where a 3000– 3500km HVDC line from the Democratic Republic of Congo (DRC) to Southern Africa will be built. The initial proposal is to use HVDC converter has normally a basic control system that controls the direct current in the rectifier and the extinction angle in the inverter. When it is desired to control any other quantity, e.g., transmitted power or frequency in the receiving ac network, a higher level control system generates the current order. The basic control system is, however, the heart of the system, and to a high degree it determines the operation properties of the whole HVDC plant.a 750- 800kV HVDC link to transport around 3GW.

The proposed protection system is a distance based system and for added reliability no communication systems are required to make any protection decisions. The system does, however, make provision for the use of telecommunications to optimize the overall response of the protection but is in no way reliant on it.

FUNCTIONAL REQUIREMENTS:-

Opinions may differ about the requirements for an optimal control system for HVDC transmission. Some of the most important requirements, in the authors' opinion, are stated below:

1) Sufficient stability margins and control speed of response when the ratio between ac network short-circuit capacity and transmitted power is low;
2) Correct rectifier and inverter operation at frequency variations- very large frequency deviations may be obtained when the HVDC transmission is the only load to a power station;
3) Low amount of abnormal harmonics generated by the converters (in order to reduce telecommunication disturbances)-this leads to equidistant firing, i.e., equal distances between all consecutive firing instants in steady state;
4) Safe inverter operation with fewest possible commutation failures also at distorted alternating voltages, e.g., due to earth faults;
5) Lowest possible consumption of reactive power, i.e., operation with smallest possible delay angle a and extinction angle 'y, without increased risk for commutation failures;
6) Smooth transition from current control to extinction angle control.

SHORTCOMINGS OF EXISTING SYSTEMS:-

The most commonly used main protection for HVDC transmission lines is voltage derivative protection. Newer schemes may, however, adopt traveling wave protection as the main protection, as opposed to voltage derivative. Both methods are very similar in nature utilizing the same traveling wave concept with the only differences being in the detection algorithms. The advantage of these methods is that the first incident/reflected wave from the fault is used in the detection and, therefore, the response time is very fast, providing fault detection within 2-3ms [3]. However, the settings to be applied involves detailed network studies in order to ensure that the protection only operates for dc line faults and is stable for all other disturbances. The major shortcoming is that both these main protection systems suffer from the fact that $\partial V/\partial t$ and $\partial I/\partial t$ are dependent on the fault loop impedance. This implies that the greater the fault loop impedance, the more the waves are damped. Therefore, difficulties in detecting these waves will arise as the fault distance and/or fault impedance increases beyond a certain threshold. This limitation in the protection coverage of the existing systems is what renders them unsuitable for the protection of HVDC schemes with extremely long transmission lines.

PROTECTION SYSTEM DEVELOPMENT:-

The proposed protection has been established using successive traveling wave reflections as opposed to first wavereflections.A DC line fault with fault resistance R, locatedDfkilometres from terminal A is shown. The Bewley Latticediagram in Fig 1 is used to illustrate the successive reflection and refraction that takes place as a result of this fault condition. considers a monopole system, however, majority of the HVDC systems are bipolar with the poles located within close vicinity between one another. This results in mutual coupling between the poles, with surges onone pole inducing surges on the other. As a result errors mayarise in the correlation process if the actual pole quantities are used.A bipole system is, ground mode network as shown in [4]. These modal voltages and currents as opposed to the actual quantities are used by protection system.

HVDC APPLICATIONS:-

HVDC transmission applications can be broken down into different basic categories. Although the rationale for selection of HVDC is often economic, there may be other reasons for its selection. HVDC may be the only feasible way to interconnect two asynchronous networks, reduce fault currents, utilize long cable circuits, bypass network congestion, share utility rights-of-way without degradation of reliability and to mitigate environmental concerns. In all of these applications, HVDC nicely complements the ac transmission system.

Fig. 1. HVDC converter station with AC filters in the foreground and valve hall in the background

Fig.2. ± 500 kV HVDC transmission line

CORE HVDC TECHNOLOGIES:-

Two basic converter technologies are used in modern HVDC transmission systems. These are conventional linecommutated, current source converters (CSC) and selfcommutated, voltage-sourced converters (VSC). a conventional HVDC converter station with current source converters while Fig. 1.shows a

HVDC converter station with voltage source converters.

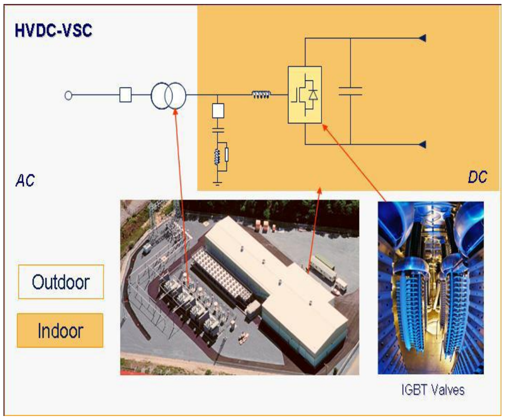

Fig. 3. HVDC with voltage source converters

A:-Line-Commutated, Current-Sourced Converter

Conventional HVDC transmission employs line commutated, current-source converters (CSC) with thyristorvalves. Such converters require a synchronous voltage source in order to operate. The basic building block used for HVDC conversion is the three-phase, full-wave bridge referred to as a 6-pulse or Graetz bridge. The term 6-pulse is due to six commutations or switching operations per period resulting in a characteristic harmonic ripple of 6 times the fundamental frequency in the dc output voltage. Each 6-pulse bridge is comprised of 6 controlled switching elements or thyristor valves. Each valve is comprised of a suitable number of series-connected thyristors to achieve the desired dc voltage rating. Most modern HVDC transmission schemes utilize 12-pulse converters to reduce the harmonic filtering requirements required for 6-pulse operation, e.g., 5^{th} and 7th on the ac side and 6th on the dc side. This is because, although these harmonic currents still flow through the valves and the transformer windings, they are 180 degrees out of phase and cancel out on the primary side of the converter transformer. Fig. 2 shows the thyristor valve arrangement for a 12 pulse converter with three quadruple valves, one for each phase.Line-commutated converters require a relatively strong synchronous voltage source in order to commutate. Commutation is the transfer of current from one phase to another in a synchronized firing sequence of the thyristor valves. The three phase symmetrical short circuit capacity available from the network at the converter connection point should be at least twice the converter rating for converter operation.

B. Self-Commutated Voltage-Sourced Converter

HVDC transmission with VSC converters can be beneficial to overall system performance. VSC converter technology can rapidly control both active and reactive power independently of one another. Reactive power can also be controlled at each terminal independent of the dc transmission voltage level.

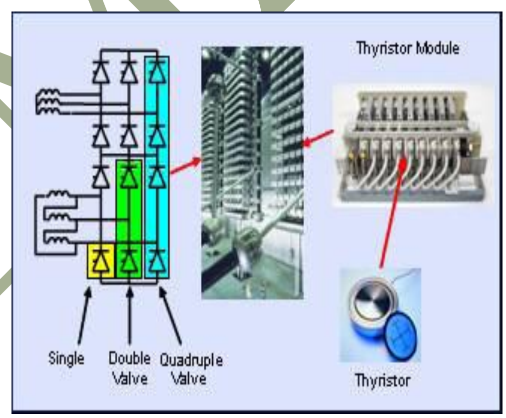

Fig. 4. HVDC thyristor valve arrangement

This control capability gives total flexibility to place converters anywhere in the AC network since there is no restriction on minimum network short circuit capacity. Self commutation with VSC even permits black start, i.e., the converter can be used to synthesize a balanced set of three phase voltages like a virtual synchronous generator. The dynamic supportof the ac voltage at each converter terminal improves the voltage stability and can increase the transfer capability of the sending and receiving end AC systems thereby leveraging the transfer capability of the DC link. Fig. 7 shows the IGBT converter valve arrangement for a voltage source converter station.

HVDC CONTROL & OPERATING PRINCIPLES:-

A. Conventional HVDC

For conventional HVDC transmission one terminal sets the dc voltage level while the other terminal(s) regulates the (its) dc current by controlling its output voltage relative to that maintained by the voltage setting terminal. Since the dc line resistance is low, large changes in current and hence power can be made with relatively small changes in firing angle, alpha. Two independent methods exist for controlling the converter dc output voltage. These are 1) by changing the ratio between the direct voltage and the ac voltage by varying the delay angle or 2) by changing the converter ac voltage via load tap changers (LTC) on the converter transformer. Whereas the former method is rapid the latter method is slow due to the limited speed of response of the LTC. Use of high delay angles to achieve a larger dynamic range, however, increases the converter reactive power consumption. To minimize the reactive power demand while still providing adequate dynamic control range and commutation margin, the LTC is used at the rectifier terminal to keep the delay angle within its desired steady state range, e.g., 13-18 degrees, and at the inverter to keep the extinction angle within its desired range, e.g. 17-20 degrees, if the angle is used for dc voltage control or to maintain rated dc voltage if operating in minimum commutation margin control mode. Fig. 10 shows the characteristic transformer current and dc bridge voltage waveforms along with the controlled items Ud, Id and tap changer position, TCP.

B. VSC-Based HVDC

Power can be controlled by changing the phase angle of the converter ac voltage with respect to the filter bus voltage, whereas the reactive power can be controlled by changing the voltage with respect to the filter bus voltage. By controlling these two aspects of the converter voltage, operation in all four quadrants is possible. This means that the converter can be operated in the middle of its reactive power range near unity power factor to maintain dynamic reactive power reserve for contingency voltage support similar to a static var compensator. It also means that the real power transfer can be changed rapidly without altering the reactive power exchange with the ac network or waiting for switching of shunt compensation. Fig. 3 shows the characteristic ac voltage waveforms before and after the ac filters along with the controlled items Ud, Id, Q and Uac.

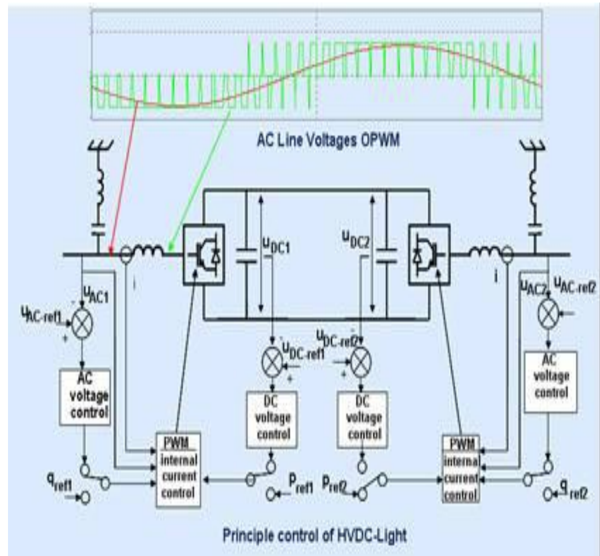

Fig. 5. Control of conventional HVDC transmission

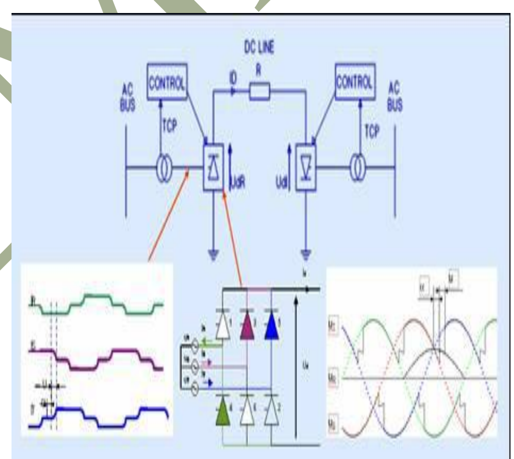

Fig. 6. Control of VSC-based HVDC transmission

OPTIMIZATION :-

Most HVDC systems should have communications between converter stations for relaying control signals. Irrespective of the reliability of the telecommunications, if it is available and capable, it should be used to enhance the protection system. One simple method of enhancing the protection system is to have the local detection system described above installed at both line ends with fault detection information relayed between the line ends using the telecommunicationinfrastructure. Now let us say a line fault develops on the line, 90% from the rectifier terminal, under normal circumstance this would be cleared only after a time delay. However, if telecommunications is used, the inverter will register a fault of 10% from its terminals indicating that the fault is definitely on the line. This information can be sent through to the rectifier to initiate non delayed tripping.

CONCLUSION:-

A new main dc line protection system has been developed and presented in this paper. The protection system is distance based with none of the shortcomings of the existing main protection systems, thereby, making it suitable for the protection of HVDC schemes with extremely long transmission lines. For added reliability the protection system requires no communication system to detect and clear line faults. However, the system does allow the communication system to be used, when available, to optimize the overall response of the protection system. The authors have identified the definite advantages of the voltage derivative method over the proposed local detection method when it comes to detecting close up faults. Theauthors have, therefore, decided to include a rapid detectionoption, based on the voltage derivative method, in thealgorithm of the new proposed system. This allows the response times to be optimized for both close up and distant faults.

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