

A Review on the Need of HVDC Transmission System

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Abstract—With the growing demand of electricity on a daily basis, we cannot rely on conventional electric authority systems like long-haul distributed power stations as well as complicated and heavy load / distribution networks. High voltage direct current (HVDC) transmission systems include an extremely imperative role in authority systems. Without the appropriate study of the HVDC system, it is unfeasible to obtain an accurate mathematical model of the system and in the absence of proper modeling the influence transmitted in the HVDC system cannot be considered. The power transmitted through the HVDC system depends upon the competence of the controller and the converter station.Conservatively, the PID controller was used for the polar current control of the rectifier and the excitation control on the inverter side. This paper is an indication of the HVDC system and covers the essential part of the foundation of the HVDC system. Due to enlarged demand for power at the load center and concentration to distributed power generation, a lot of high capacity long distance HVDC systems are requisite and are intended to achieve various advantages. As growth in the power electronics field advances, HVDC systems are more consistent.

Keywords—*HVDC, Transmission, Thyristor Valves, Monopolar, Biopolar, Multi Thermal*

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I. INTRODUCTION

High Voltage Direct Current (HVDC) transmission that is based upon Line-Commutated Converter (LCC) machinery has been extensively utilized about the world for the vigor transmission [1]. While the current Voltage-Sourced-Converter (VSC)based on HVDC proficiency may be the favored option for multi-terminal DC grid or breeze farm incorporation, the LCC HVDC immobile out-performs the VSC in very longaloofness unpackaged energy transmission due to its advancedcompetencies. On the other hand,convinced well-known glitchesallied by using LCC HVDC willimmobilize exist today, which limits the additional application of this technology. The greatest notable one is commutation disappointment which can happen under 10%–14% of voltage desolation at inverter AC bus [2].

A. NEED FOR HVDC TRANSMISSION

The conveyance of bulk energyoverhead 500 km gives growth to the following problems:
1. Disparity of voltage outline
2. Reduction in vigor transfer.
3. Group of reactive energy.

B. HIGH VOLTAGE DC TRANSMISSION:

In the history of electricity, the first saleable electricity produced (through Thomas Alva Edison) in which direct current (DC) was used for electrical vigor and also the very first electrical energy transmission methods were also direct current schemes. The majordownsidemostlycombined the datum that DC vigor at squat voltage was problematic to be transmitted over extended distances, henceforth giving growth to extra high voltage (EHV lines) carrying irregular current. Bypresenting of high voltage rating valves, it makesconceivable to transmit DC power at very high voltages over extensive distances, recognized as the HVDC transmission techniques
Succeeding are the reasons that HVDC transmission techniques have become necessary:

- Conservationwelfares
- It is additionalinexpensive (cheapest solution)
- Asynchronous draws are achievable
- Governor on the power movement
- Sublime benefits to the transmission, includingstability, power quality etc.

II. THE COMPONENTS OF AN HVDC TRANSMISSION SYSTEM

To contribute the designers of transmission techniques, the mechanisms that encompass the HVDC method, and the options accessible in these machineries, are existing and conversed.
The three foremostrudiments of an HVDC technique are: the converter position in the transmission and getting ends, the transmission intermediary, and the conductors.

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The converter station:. The foremostmachineries of a converter station are underneath:

- **Thyristor valves:** it can be build-up in diverse ways that is depending upon the solicitation and thedesigner. Conversely, the greatestcommunaltechnique of positioning the thyristor valves is in a twelve-pulse collection by using three quadruple valves. Every single thyristor valve consists of a convinced amount of sequenceassociatedThyristorsthrough their auxiliary circuits. All communication among the control apparatus at earth potential and each thyristor at high potentialarecompleted through fiber optics.
- **VSC valves:** The VSC converter made of two levels or multiple level converter, phase-reactors and AC strainers. Every single valve in the converter bridge is constructed through a convinced number of seriesassociated IGBTs together by using their supplementary electronics. VSC valves, control apparatus and cooling apparatus would be in inclusions (such thatordinary shipping containers) which make transport and connection very informal. Every modern HVDC valve is water-cooled and air sequestered.
- **Transformers:** The converter modernizersacclimatize the AC voltage level to the DC voltage level and they donate to the commutation reluctance. Frequently they are of the solitary phase three zigzagging types, but depending upon the transportation necessities and the rated vigor, they can be decided in other conducts
- **AC Filters and Capacitor Banks:**Arranged the AC side of a 12-pulse HVDC converter, recent harmonics of the instruction of 11, 13, 23, 25 and advanced iscreated. Filters are installed in order to limit the quantity of harmonics to the level obligatory through the network.. In the adaptation process the converter consumes reactive energy which is remunerated in part through the filter sets and the rest via capacitor banks. In the circumstance of the CCC the reactive energy is remunerated through the series capacitors installed in the series between the converter valves and the converter modernizer. The abolition of switched reactive energy compensation apparatusabridge the AC switched and minimize the number of circuit-breakers desirable, which will decrease the area compulsory for an HVDC station constructed through CCC. By VSC converters, there is no necessary to compensate several reactive powers consumed through the converter themselves and the recent harmonics on the AC side are associatedstraight to the PWM frequency. Consequently the amount of filters in this category of converters is condensedmelodramatically compared by natural commutated converters.
- **DC filters:** HVDC converters generate harmonics in all effective modes. Such harmonics can produceturbulences in telecommunication systems. Consequently, specially designed DC strainers are used in order to decrease the disturbances. Frequently no filters are desirable for pure cable transmissions as well as for the Consecutive HVDC stations. Conversely, it is essential to install DC filters if an OH line is used in all the transmission organization The filters desirable to take care of the harmonics produced on the DC end, are frequently considerably smaller and lessluxurious than the filters on the AC side. The contemporary DC filters are the Lively DC filters. In these filters the passive part is abridged to a minimum and modern energy, electronics is used to measure, capsize and re-inject the harmonics, consequently rendering the filtering very operative.

III. PROBLEMS ASSOCIATED WITH HVDC

Converter stations desired to attach to AC power grids are very luxurious. At the level of Converter Stations the cost of installation is quite high, compulsory at every end of a D.C. transmission link, while in an A.C. Link only transformer stations are mandatory.

Imprudent power prerequisite: Together in rectification and in inversion reactive energy is compulsory.

Exertion of circuit breaking: In the circumstance of D.C,commonplace zero crossing is not contemporary, hence DC circuit contravention ischallenging. High vigor generation problematic,Owing to the problems related with commutation in D.C. machineries, voltage and rapidity are limited. Moderately, lower energy can be produced through D.C.

In dissimilarity to AC methods, conniving and operating multi-terminal HVDC schemes aremultifaceted. Converter substations produce current and voltage harmonics.Throughout short-circuits in the AC energy systems close toassociated HVDC substations. Thenumeral of substations within a modern multiterminal, the HVDC transmission scheme can be no superiority. The high-frequency residentsoriginateon direct current, transmission systems can cause radio noise Grounding HVDC transmission contains a complex and problematic installation The flow of current by the Earth in manual systems can cause the electro-corrosion onsubversive metal connections, mostly pipelines.

IV. TYPES OF HVDC SYSTEMS:

Three foremost types of HVDC scheme were:

- Monopolar link
- Bipolar linking
- Back-to-back HVDC
- Multi Terminal HVDC

a. Monopolar HVDC System

In this conformation showing fig. 1, two converters detached through a solitary pole line are rummage-sale.

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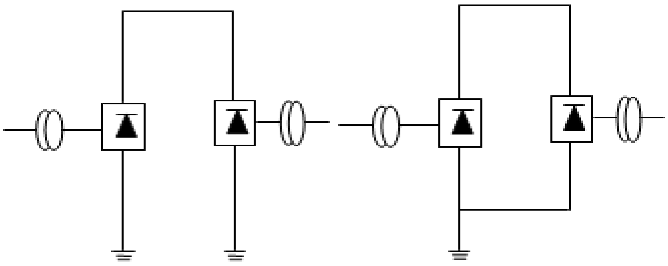

(a)With Crushed Return (b) With Metallic Return

Figure 1 Monopolar HVDC Controller

Optimistic or negative DC voltage can be used (one via the conductor and ground as the return path), but in the circumstance of using undesirable polarity the corona belongings in the DC line are less [5]. Depending upon the application, in the circumstance of the monopoly line, pulverized or a metallic conductor can be used as recurringpart, as exemplified in Figure1

b. Bipolar HVDC System

In this situation, the conformationusages two conductors, one optimistic and the other negative (both are the metallic conductor, ground is used as reappearance path). The connection between the two groups of the converter is stranded at one ortogether ends [5]. The Foremostbenefit of this configuration is given through the fact that solitary of the poles can endure to transmit power in asituation the other one is out of service [3, 5]. Consequently, the two poles may be used self-sufficiently, if both impartial points are stranded [10]. The bipolar HVDC system configuration is demonstrated in Fig. 2.

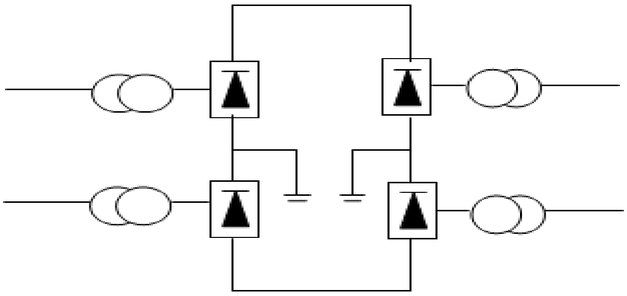

Figure 2 Bipolar HVDC System

c. Back-to-back HVDC System

In back to back formation, the two converters positions are placed at the similar site and there is no transmission of energy through a DC link over a long distance [3]. The block illustration of a back-to-back system is presented in Figure 3

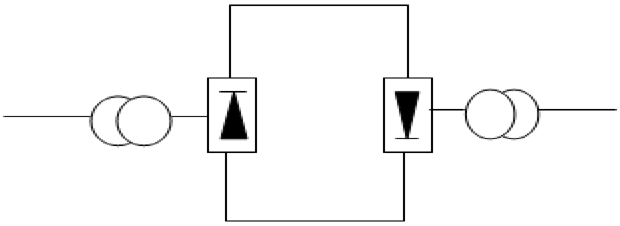

Figure3 Back to back HVDC System

d. Multi-terminal HVDC System

A multi-terminal HVDC transmission system that has consisted of three or supplementary converter substations, some of them working as inverters although the other ones as rectifiers [7]. Depending upon the locating of the converter substations, two basic arrangements of the multi-terminal HVDC scheme can be obtained that are series multi-terminal HVDC scheme and parallel multi-terminal HVDC scheme. These two preparations are obtainable under the figure4.

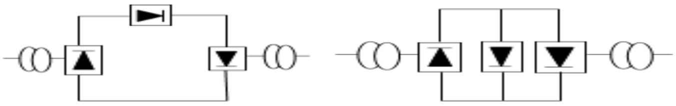

Figure 4 Multi-terminal HVDC System

V. THYRISTORS

The thyristor is an internal part of the HVDC converter station. Thyristor is a 3-terminal semiconductor device. The two terminals, the anode and the cathode behave like a diode, except that no current flows from the anode to the cathode until the appropriate signal is applied to the third terminal "gate". Thyristors are also known as silicon controlled rectifiers (SCRs). A thyristor firing angle thyristor behaves like a diode in that it conducts current in one direction and current flows in the other direction. Unlike a diode, a thyristor must be titled with its "gate" by a sufficiently large current pulse to start conduction when its anode and cathode are biased in the forward direction. When an AC signal is applied to the thyristor's anode, the entrance of the thyristor can receive its turn-on throb at a specific phase angle of the applied AC signal. This phase angle is called α (α) and is also called firing angle.

a) THYRISTOR FIRING IN HVDC

The gate of the thyristor of the HVDC converter station must be turned through a precisely controlled cyclic sequence and if the signal used to control the gate current is not electrically isolated from the high voltage of the thyristor itself it will not. A thyristor of a modern HVDC valve is fired from an optical signal sent from the circuit at ground potential. These signals are generated from the converter controller. A source of firing energy is provided by a power supply unit which is charged from the forward voltage of the device when not conducting in each module.

VI. COMMUNICATION FAILURES

A commutation fault is a disadvantageous dynamic event that occurs when the converter valve, which should be turned off, continues to operate. Thus, the current is not transmitted to the next valve in the firing sequence. The occurrence causes temporary interruption of transmission power, stressing the converter device [3]. In addition, the direct current may increase drastically and lead to additional heating of the conversion valve. As a result, the lifetime is shortened [4], most of the commutation faults are caused through voltage disturbance due to AC system failure and cannot be completely avoided [16]. In order to successfully switch the thyristor valve, it is necessary to eliminate the internal accumulated charge generated during the forward conduction period in order to establish the forward voltage blocking function [2]. Otherwise, the valve may start re-conducting even if it is not ignited, causing an undesirable short circuit and a commutation failure may be initiated [4].Essentially the incidence of three events previous to or during the commutation procedure could culminate into commutation disappointments. These events are:

- A reduce in the commutating voltage.
- Anunexpectedaugment in the direct current.
- A hardware malfunctioning in the dismissal control.

VII. RELATED WORK

Ying Xue et al [1], presented a novel hybrid converter configuration of the conventional line commutated converter (LCC), HVDC technology aimed at eliminating commutation obstacles in case of serious failure. Increase the effective rectified voltage by utilizing the dynamic series insertion of the capacitor during commutation. Detailed mathematical analysis of both single-phase and three-phase failures of zero impedance was done to select the required capacitor size and its voltage level. The performance of the proposed method was verified by simulation results of RTDS (Real Time Digital Simulator), and as a result, the proposed converter configuration showed that the failure of commutation can be eliminated in both fault cases. As a result, it was possible to achieve partial power transfer capability at the time of single-phase failure and fast failure recovery from three-phase failure. Further simulation results shown that the inverter AC voltage and current harmonic contents did not increase significantly, indicating that the voltage stress on the thyristor valve was comparable to that of the original benchmark system.

Jong-Geon Lee et al [2], In order to prevent voltage collapse of PCC and to limit fault current, applied researches of resistive super-conducting fault current limiter (SFCL) of LCC-HVDC grid system was conducted using mathematical and simulation analysis. The simulation model was designed with Matlab / Simulink taking into consideration the Hainan - Jeju HVDC power grid in Korea, including traditional AC system and onshore wind power plant and resistant SFCL model. As a result, it was observed that application of SFCL to LFC-HVDC system was an effective solution to alleviate commutation problem. The procedure of determining the optimum sintering resistance of SFCL, which made it probable to reinstate commutation fracture, was deeply researched.

Jong-Geon Lee et al [3], The Impedance of applied power system of resistive superconducting fault current limiter known as the optimal solution to alleviate HVDC guilt in both HVDC (LCC-HVDC) method and VSC-HVDC (Voltage Source Converter HVDC) method Was considered. First, developed a simulation model of two types of LCC-HVDC and VSC-HVDC systems with point-to-point connection model. From the designed model, the fault current characteristics of the fault condition were analyzed. Second, SFCL was applied to each type of HVDC system and a comparative study of the modified fault current characteristics were analyzed. As a result, applying AC-SFCL to a point-to-point LCC-HVDC system was a desirable solution to mitigate fault current stress and prevent rectification faults in HVDC power systems interconnected with AC grid that was inferred.

Tao Gao et al [4]discussed about the CIGRE HVDC benchmark model of PSCAD software and the test system was often used as a standard system for HVDC control studies, but similar programs and emulators to the main circuit model for different DC control equipment and control strategy [1] In this paper, the author investigated the bus voltage and current level in weak electric field system. As a result, CCC was more stable than LCC, but the weak AC system was a signal phase fault or 3 phase fault, CCC was less prone to commutation malfunction.

D. Van Hertem et al [5], HVDC was a specialized technology used for long distance bulk power transfer and connecting different synchronization zones or submarine connections. Recently, HVDC experienced resurgence. In Europe, this reconstruction was being promoted by a large increase in electricity generation from renewable energy sources, liberalization of energy system, and difficulty in investing in new overhead power transmission. In many countries such as China, India, Brazil, energy consumption from remote areas increases rapidly, and it was caused by the necessity of a large amount of energy. HVDC transmission uses a power electron transducer to interface between an alternating current (AC) grid and a direct current (DC) grid. There were two types of HVDC , a conventional line rectifier converter (LCC) using a thyristor and a voltage source converter (VSC) using an insulated gate bipolar transistor (IGBT). Although LCC HVDC had the highest available rating, VSC was highly controllable and easy to integrate crosslinked polyethylene (XLPE) cable for bi-directional power flow.HVDC can be seen as a future transmission technology, especially as a connection technology for renewable energy sources, and as a new backbone system. This new backbone system was expected to take the form ofDC connection, most of which was built using cable connection.

VIII. CONCLUSION

This study covers the basic review to the HVDC systems and also provides a brief information corresponding to the past work that had been don in this field. This paper can be proved as a guide paper for those scholars who are working or will be work in this field. Since it provides a deep knowledge to the types of HVDC systems and the role of the thyristor in HVDC. It can be concluded that the innovations can be introduced in this field to improve the performance of the HVDC transmission system.

REFERENCES

[1] Ying Xue et al, "Elimination of Commutation Failures of LCC HVDC System with Controllable Capacitors", IEEE Transactions On Power Systems, Vol. 31, No. 4, Pp. 3289-3299, July 2016

[2] Jong-Geon Lee et al, "Mitigation of commutation failures in LCC–HVDC systems based on superconducting fault current limiters", Physica C: Superconductivity and its Applications, Vol. 530, Pp. 160–163, November 2016

[3] Jong-Geon Lee et al, "Comparative study of superconducting fault current limiter both for LCC-HVDC and VSC-HVDC systems", Physica C: Superconductivity and its Applications, Vol. 518, Pp. 149–153, November 2015

[4] Tao Gao et al, "Comparison of CCC and LCC in HVDC System", Energy Procedia, Vol. 16, Part B, Pp. 842-848, 2012

[5] D. Van Hertem et al, "6 – High Voltage Direct Current (HVDC) electric power transmission systems", Electricity Transmission, Distribution and Storage Systems, Pp. 143-173, 2013

[6] Ying Xue et al, "Reactive Power and AC Voltage Control of LCC HVDC System With Controllable Capacitors", IEEE Transactions on Power Systems, Vol. 32, No. 1, Pp. 753-764, Jan. 2017

[7] Yaping Hu et al, "Commutation failure analysis considering direct current dynamics in LCC-HVDC systems", AC and DC Power Transmission (ACDC 2016), 12th IET International Conference on, December 2016

[8] J. Burr et al, "Comparison of Different Technologies for Improving Commutation Failure Immunity Index for LCC HVDC in Weak AC Systems", AC and DC Power Transmission, 11th IET International Conference on, July 2015

[9] Chunyi Guo et al, "An Evolutional Line-Commutated Converter Integrated With Thyristor-Based Full-Bridge Module to Mitigate the Commutation Failure", IEEE Transactions on Power Electronics, Vol. 32, No. 2, Pp. 967-976, Feb. 2017

[10] Rong Zeng et al, "Hybrid HVDC for Integrating Wind Farms With Special Consideration on Commutation Failure", IEEE Transactions on Power Delivery, Vol. 31, No. 2, Pp. 789-797, April 2016

[11] Hao Xiao et al, "Efficient approach to quantify commutation failure immunity levels in multi-infeed HVDC system", IEEE, vol 10, Issue 4, PP 1032-1038, March 2016,

[12] Patrick Panciatici et al, "Dynamic Security assessment: Challenges (An European TSO perspective)", IEEE, July 2014.

[13] Sara Lumbreras et al, "Optimal Design of the Electrical Layout of an Offshore Wind Farm Applying Decomposition Strategies", IEEE, Vol 28, Issue 2, PP 1434-1441, Aug 2012 .

[14] Chandupatla Chakradhar Reddy et al, "Theoretical Maximum Limits on Power-Handling Capacity of HVDC Cables", IEEE, Vol 24, Issue 3, PP 980-987, June 2009

[15] John Reeve et al, "Dynamic Fault Analysis for HVDC Systems with ac System Representation", IEEE, Vol PAS 91, Issue 2, PP 668-696, March 1972

[16] Antônio P. C. Magalhães et al, "Identification of incipient faults in subsea HVDC systems", IEEE, june 2016

[17] Yuxin Zhong et al, "Cascading failure model of AC-DC system and blackout mechanism analysis", IEEE, Oct 2014

[18] M Ramesh et al, "Fault identification in HVDC using artificial intelligence — Recent trends and perspective", IEEE, April 2012.

[19] Ch. Chakradhar Reddy et al, "On the computation of electric field and temperature distribution in HVDC cable insulation", IEEE,Vol 13, Issue 6, Dec 2006,

[20] Rahimi E, et al, "communication failure in single and multifeed HVDC system", IEEE,PP 182-186, 2006

[21] Bauman J et al, "Commutation failure reduction in HVDC systems using adaptive fuzzy", IEEE, Vol 22, Issue 4, PP 1995-2002, 2007

[22] Thio, C.V et al, "Commutation failures in HVDC transmission systems", IEEE Trans. Power Deliv., Vol 11, Issue 2,PP. 946 – 957, 1996

[23] Huang et al, "Improving performance of multi-infeed HVDC systems using grid dynamic segmentation technique based on fault current limiters", IEEE, Vol 27, Issue 3, PP 1664-1672, 2012

[24] Huang D,et al , "Ultra high voltage transmission in china: developments, current status and future prospects ", IEEE Vol 97, Issue 3, PP 555-583, 2009,

[25] Zhou, C et al, "Study on commutation failure of multi-infeed HVDC system ", IEEE Power System Technology Conf., PP. 2462 – 2466, 2002