A Review of High Voltage Direct Current Transmission System

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Abstract : ***As the advancements in long distance and large capacity power transmission, lower losses, asynchronous interconnections and Fast and Flexible Control the count of high-voltage direct current (HVDC) is expanding speedily in the human race. The High voltage direct current (HVDC) transmission mechanisms comprise the great indispensable role in the authority networks. On the basis of the capability of the controller and the converter station by the HVDC method the power is broadcasted. In this paper so many papers are reviewed by the author and the critical section of the establishment of HVDC method is also covered in this paper. While the improvements are prepared in the power electronics area about HVDC method will be much desirable and consistent.***

IndexTerms - Gateway nodes.

- **Introduction**

The utilization of the HVDC high-voltage direct current mechanism is raising quickly in the world as it offers advancements such as Few losses, asynchronous interconnections [1], large distance and high capacity power transmission, Quick and reliable control etc. These merits formulate that the HVDC method is more desirable rather than the HVAC method [2]. The unsteadiness of the power system is occurred by the presence of errors or faults in the HVDC transmission Lines that also directs to the huge economic loss [3]. The devastation of power system stability is avoided by rapidly indentifying the faults or errors in the system. For the security of the HVDC transmission line the Distance Relaying Principle is broadly utilized because of its high speed error clearance comparative to the over current relays [4]. The electrical distance is evaluated to the fault by the distance relay that compares the outcome among the given threshold that establishes the protection zone [5]. The HVDC transmission methods have become attractive because of the reasons discussed below [6]:

- Control on the power flow
- Environmental benefits
- Asynchronous connections are sufficient
- It is more efficient (less expensive resolution)
- Magnificent profits to the broadcast containing steadiness, power eminence etc.

The basic procedure of alteration from AC to DC (rectifier) of electrical current is presented at the transmitter section and also the procedure [7] of alteration from DC to AC (inverter) is performed at the receiver section in the HVDC mechanism.
There are three conducts to obtain the alteration:

- **Natural Commutated Converters**.

Nowadays the natural commutated converters are very helpful in the HVDC method. The thyristor element is used to enable the alteration procedure. Due to the thyristor is a controllable semiconductor so it handles very high currents such as 4000A and also capable to obstruct much high voltages that is up to 10 kV [8]. The thyristor valve is probable to be made to connect the thyristor in series. The valve is capable to perform at much high voltages as many hundred of kV. The thyristor valve is run on 50 hz and 60 hz net frequency The DC voltage is altered to manage the angle of the bridge. The transferred power is handled or controlled quickly and effectively in this way [9].

- **Capacitor Commutated Converters (CCC).**

In the thyristor-based commutation an enhancement is, with the help of commutation capacitors that are placed in series the idea of CCC is illustrated within the transmitters of the converter and the regulators of the thyristor. The commutation breakdown presentation of the converters is advanced by the commutation capacitors when associated to the poor networks [10].

- **Forced Commutated Converters.**

A variety of advancements such as feed of passive networks (without generation), independent control of active and reactive power, power quality is proposed by this kind of converters. With the help of semiconductors the valves of these converters are constructed with the capability of turning-on as well as turning-off so that converter is known as the Voltage Source Converters (VSC) [11]. Basically, a couple of semiconductors that are the Gate Turn-Off Thyristor (GTO) and the Insulated Gate Bipolar Transistor (IGBT) utilized in the voltage source converters. Since early eighties in the industrial applications both the semiconductors are utilized frequently. Among the high frequency and with no net frequency the Voltage Source Converter commutates [12]. The presentation of the converter is obtained with the help of the Pulse Width Modulation. With the help of PWM the 3 phase angle is generated and by altering the PWM pattern generates the amplitude up to a specific limit that is happened about immediately. Therefore, both the active and reactive power is probable to handle independently that is proposed by the PWM [13]. In the transmission system the PWM Voltage Source Converter a near to perfect element is made by this. From the point of view of the transmission network it performs as a motor or generator with no mass which can handle active and reactive power about instantly.

1.1 PROBLEMS ASSOCIATED WITH HVDC

- To link the AC power grids by the converters is much costly. Also at the converter stations the expense of installation is very high that installation is needed at every end of the DC transmission link where only transformer stations are needed in the AC link [14].
- **Reactive power requirement:** Reactive power is necessitated in both the rectification and in the inversion.
- **Difficulty of circuit breaking:** The natural zero crossing is absent in the DC therefore the breaking of DC circuit is complex.
- **High power generation difficult:** In the DC machines because the issues related to the commutation so the voltage and speed are restricted. Relatively with the DC less power can be produced.
- The designing and functioning multi-terminal HVDC method is complicated than the AC method.
- The current and voltage harmonics are created by the converter substations.
- In the AC power method throughout short-circuits near to associated HVDC substations.
- The count of substations is not huge in the modern multi-terminal HVDC transmission mechanism.
- The high-frequency parts in the direct current transmission mechanism create radio noise.
- The complicated and hard installation is included in the grounding HVDC transmission.
- In the monopole methods the flow of current by the earth generate the electro-corrosion of undergroung metal installations mostly pipeline [15].

- **RELATED WORK**

Antônio P. C. Magalhães et al [2016], [1] proposed the growing interest in offshore applications that employed enhanced use of subsea oil plants with connection of renewable. In both situations, there was the possibility of applying a HVDC transmission system. In order to reduce the initial investment amount a DC submarine cable could be employed as it was considered to be relatively less expensive. For proper application of processes prior knowledge regarding all the potential and related faults such as current stress or voltage stress was essentially required. The presented work discussed the efficiency offered by distinct fault location techniques that operated on the basis of travelling waves in case of complex submarine cables. The first objective was to estimate the dielectric stress related with possible faults and it also analyzed the effect of the correctness associated with the cable parameters may have in a fault location structure.

J. Burr et al [2015], [10] represented how well VSC HVDC, Static synchronous Compensation (STATCOM) and Static Var Compensators (SVC) were capable to support LCC HVDC based on their enhancements of the LCC HVDC Commutation Failure Immunity Index (CFII) and showed a comparison of their comparative abilities.

Jong-Geon Lee et al [2015],[13] proposed the application of resistive superconducting fault current regulator which had been referred as optimal solution to manage with the power system fault for the purpose of improving HDVC fault involved in Line Commutated Converter HVDC (LCC-HVDC) and Voltage Source Converter HVDC (VSC-HVDC) system. Firstly, simulation models for two types of LCC-HVDC and VSC-HVDC system which had point to point linking model were established. Fault current characteristics associated with certain faulty conditions were critically analyzed for the proposed model. Secondly, application of SFCL on each types of HVDC system and comparative analysis of altered fault current characteristics were examined. The mitigation of fault current pressures was resolved by exposing LCC-HVDC system to the application of AC-SFCL having dedicated point connection. This helped in reducing the commutation failure involved in HVDC electric power system. This system was essentially interconnected with AC grid.

Ying Xue et al [2016], [22] offered a novel hybrid converter configuration for conventional Line-Commutated Converter (LCC) HVDC technique pointing to eradicate commutation disappointments under serious liabilities. During commutation, dynamic sequence insertion of capacitors was exploited to upsurge the effective commutation voltage. Pursued among the complete numerical study for the zero impedance single-phase and three faults to select the obligatory capacitor size and its level of voltage the functioning principles were signified. The performance of the recommended technique was authenticated by the results of simulation in Real Time Digital Simulator (RTDS) which determined the ability of converter configuration approach in removal of commutation breakdowns in either case of faults. Therefore partial power transferring ability during single-phase fault and fast fault retrieval from three-phase fault can be accomplished. No significant amount of enhancement was reflected by simulation results in terms of harmonic content of inverter AC voltage and current. It was noticed that voltage stress offered by thyristors valve and that involved in original benchmark system were considered to be similar.

Yaping Hu et al [2016], [21] had characterized the scheme commutation issues expanding from the ac errors of the LCC-HVDC mechanism. In order to observe the effects of commutation failure on the system's performance uninterrupted current dynamics were brought into consideration. Based on theoretical analysis, the effects of ac fault level and fault happening time on commutation failure was computed. In addition, this paper offered a more detailed commutation failure criterion. As compared with the conventional, the offered criterion in this paper disclosed the relationship between commutation failure and fault occurring time which revealed the non-probabilistic nature of commutation failure. On the basis of CIGRE BENCHMARK model employed in PSCAD/EMDTC analytical results were derived through time-domain simulation. Ultimately, the experimental outputs on the basis of the CIGRE BENCHMARK model in PSCAD/EMTDC were obtained.

RongZeng et al [2016], [17] discussed the configuration of hybrid HVDC system. The utilization of the farm-side voltage-source converter rectifier was implemented by the projected hybrid HVDC mechanism. In order to perform the assimilation of wind power a grid-side LCC inverter was used. A critical analysis was performed for observing the effects imposed by commutation failure in LCC inverter that occurred in the case of AC network disturbance on efficiency of entire system. The use of modules built up by employing mixed half-bridge and full-bridge was suggested for enhancing the LCC inverter at grid side. For the rectifier the topology among the modular multilevel converter (MMC) was basically implemented at the wind farm section. The capability of hybrid HVDDC system to perform under LCC inverter commutation failure was verified by the simulation results obtained through MATLAB. This proved MMC configuration in hybrid system relatively more significant than other techniques.

Ying Xue et al [2017], [23] addressed the AC voltage control and reactive power associated with inverter in LCC HVDC. The system was considered to be capable of performing in cases having negative extinction angle which provided significant amount of reactive power control. This also facilitated the distribution of reactive power. The active power was considered as most significant control prospect at rectifier associated with inverter AC terminal voltage due to the reason that large variations in it were neglected. The reactive power control and capacitor voltage levels obtained on the basis of desired control range were theoretically explored. For the negative destruction angle calculations in addition a novel destruction angle calculation mechanism was projected. The simulation results obtained through Real-Time Digital Simulator (RTDS) verified the efficiency of system in terms of reactive power and ability to control the voltage. The CCC HVDC

along with SVC was used in RTDS for analyzing the effectiveness of voltage control and reactive power for the evaluation of simulation results that indicated their significance. The use of the proposed technology in achieving efficient control over AC voltage for power systems suggested its use for two-area four-machine AC power system.

Tao Gao et al [2012], [19] This research was based on the CIGRE HVDC Benchmark Model in PSCAD software, the test system served as standard system as it was frequently applied for HVDC control study. As the system involved different DC equipment for controlling along with control schemes the analogous program and emulator were added to circuit model. This paper investigated the bus voltage and recent level in feeble AC system. By observing simulation results it was concluded that LCC was less constant than CCC. Both three-phase fault and signal-phase fault occurred in weak AC systems.CCC was considered to be less susceptible to commutation failure.

- **CONCLUSION**

In this paper the general review of HVDC method is covered and also the concise knowledge of the previous work that had been completed is offered. The researchers who put efforts or going to put efforts in this area this review paper will be demonstrated as a lead paper. As the adequate data is offered to the HVDC method and the function of the thyristor in HVDC. In this area it is accomlished that the modernization can be commenced to enhance the functioning of the HVDC transmission method.

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