A REVIEW STUDY ON HVDC CIRCUIT BREAKERS

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ABSTRACT

The need for electric control and financial access to distant sustainable power source sources, such as seaward wind control or sunlight-based warm age in deserts, has reignited interest in multi-terminal high voltage direct current (HVDC) frameworks (systems). There was a lot of study done around there, especially in the 1980s, but just two three-terminal frameworks were discovered. Since then, HVDC technology has advanced significantly, and despite a number of technical challenges, the acceptance of large-scale HVDC systems is now widely discussed and debated. The accessibility of HVDC circuit breakers (CBs) will be critical for the recognition and dependability of these systems, making them one of the main enabling advancements. Various ideas for HVDC breaker designs have been disseminated and licensed, but no acceptable solution to intrude on HVDC cutoff has been discovered. This article aims to condense the literature on innovation areas relevant to HVDC breakers, especially in the last two decades. Existing discrepancies are shown by comparing the mainly 20+ year old, cutting edge HVDC CBs with the new HVDC innovation.

KEYWORDS: *Circuit Breaker, Distribution, Electric Power, HVDC, Technology.*

1. INTRODUCTION

The excitement for HVDC multi terminal frameworks has been reignited in recent years. The ever-increasing need for electric power and the financial accessibility to distant sustainable vitality sources, such as seaward wind control or sun-based warm age in deserts, necessitate an electric vitality transmission framework that can span extremely vast distances with little loss. Traditional HVDC point-to-point structures may assist meet this need and are already available.

Connecting more than two HVDC terminals to form a coordinated multi-terminal HVDC framework (organization) has a number of advantages, including a reduction in the number of terminals (lower costs and losses), the blackout of one dc line does not interrupt the power stream at any terminal, each terminal can work at different power and current, and the power trade with all air conditions. Investigating the acceptance of HVDC systems is thus appealing **[1–3].**

The HVDC circuit breaker's primary function is to halt high voltage direct current flows in the network. The arc at natural current zero in the AC wave is readily interrupted by an AC circuit breaker. The energy to be interrupted is likewise zero at zero current. To resist natural transient recovery voltage, the contact gap must regain its dielectric strength. The issue is more complicated with DC circuit breakers because the DC waveform lacks natural current zeros. Forced arc interruption would result in a high transient recovery voltage, restrike without arc interruption, and eventual breaker contact destruction **[4–7].** Three major issues must be addressed while constructing HVDC circuit breakers. These are the issues:

- Creating a fictitious current zero.
- Preventing arc restrikes
- Energy stored in the body is dissipated.

During the 1980s, there was a lot of interest in multi-terminal HVDC systems, but only two three-terminal systems were recognized. Advances in HVDC technology have reignited interest in HVDC systems. The main impediment to the implementation of an HVDC control network is the framework's significant vulnerability to DC line interference. The intrusion of a DC blame current into a framework blame condition is more complicated than the intrusion of an AC blame current. Despite the absence of a current zero intersection point, the rate of ascent of DC blame current is astonishingly large due to the low inductance of the DC side of the framework, necessitating extremely fast interference innovation. More attention should be drawn to the improvement of HVDC circuit breakers as a crucial innovation to make HVDC multi-terminal frameworks safely operational and to prepare for the combining of mass measure of seaward wind vitality to AC matrix.

DC circuit breakers, specifically for high voltage applications, are currently neither economically or widely available. The origin of the need for an HVDC circuit breaker is explained in this article, and the basic requirements of an HVDC electrical switch are given. Following that, HVDC circuit breaker advances such as mechanical circuit breakers with snubber, half breed circuit breakers, and unadulterated strong state circuit breakers are audited, and each topology is thoroughly investigated. Furthermore, a comparison of various topologies based on findings from literary works is presented. Finally, suggestions for circuit breaker development are presented **[7–9].**

VSC-HVDC-based multi-terminal grid clearly, many of the planned seaward wind ranch operations will have a large power limit and will be built far from the coast. As a result, for conveying capacity to a receiving inland network, a long connection length will be required. Transmission of control via normal AC connections isn't feasible due to separations and plant limitations **[6].**

HVDC transmission technology was first demonstrated in 1954 for enabling the interchange of mass measures of electrical control at high voltage across great distances. HVDC transmission lines are appealing not just from a technical standpoint, but also from a financial one. There are two notable HVDC improvements that are used for point to point control exchange as well as connectivity of different electrical systems these days: current source converter (CSC) based and voltage source converter (VSC) based advancements.

In CSC frameworks, it's necessary to add channels and additional capacitors on the air conditioners side, and the power stream is unidirectional, so inverting the power-stream heading necessitates a hazardous modification in the framework's extremities. VSC frameworks, on the other hand, are built on Isolated Gate Bipolar Transistors (IGBT). In VSC frameworks, dynamic and responsive control streams are freely adjustable, and it is also possible to increase the voltage and power rating of the system by using staggered VSCs. The proximity of sounds in VSC frameworks is limited to high repetition, which causes the channels to be activated. Furthermore, VSC-HVDC technology transfers dynamic power and can provide the necessary level of receptive control at both the power transmitting and receiving ends. This enables clothes designers to reduce the size of the channel once again.

Many of the proposed offshore wind farm projects will have a high power capacity and will be built far from shore, according to a VSC-HVDC based multi-terminal grid. As a result, significant cable length will be required to transmit electricity to a receiving onshore grid. Transmission of electricity via traditional AC wires is not possible due to distances and plant capacity. In 1954, HVDC transmission technology was proven in practice for transferring large amounts of electrical power across great distances at high voltage. HVDC transmission lines are not only appealing from a technological standpoint, but they are also cost-effective. There are two main HVDC technologies in use today for point-to-point power transmission and asynchronous electrical network interconnection: current source converter (CSC) based and voltage source converter (VSC) based technologies. In CSC systems, filters and extra capacitors must be installed on the ac sides, and the power flow is unidirectional, thus reversing the power-flow direction necessitates a change in the system's polarity, which may be troublesome.

1.1. Circuit breakers for high-voltage direct current (HVDC):

Different types of HVDC circuit breakers are categorized in this section, along with a functional analysis of each topology.

1.2. HVDC circuit breaker (mechanical):

A. Passive mechanical resonance CB are mechanical HVDC electrical switch with separate reverberation circuit is a long-standing innovation that was first developed for CSC-HVDC frameworks. CB is a standard air impact electrical switch with a couple of interrupter components. Current flows via the CB during normal activity, and it is commutated into a substitute route during incursion. It is necessary to examine the current situation during the intrusion operation in order to comprehend the method.

1.3. Hybrid Technologies :

Technologies that combine the best of both worlds. The hybrid switching method involves combining controlled strong state devices with a mechanical breaker or disconnector in a connected arrangement. Solidstate switches are used to provide the compensation method in most half-and-half electrical switches, and it only functions during the interference phase. All of the switches are integrated circuits. Recent advancements in semiconductor switches, as well as improvements in their qualities such as separate voltage, conduction misfortunes, exchanging time, and dependability, have increased the possibility of using these devices as the primary interrupters in circuit topologies for half and by and large, two main structures.

A fast mechanical breaker is equipped with a set of parallel strong state switches in this topology. This architecture combines the minimal losses of a pure mechanical breaker with the fast exchange response of a pure strong state device. This architecture is faster than conventional circuit breakers since the curve chamber should only produce sufficient voltage for replacement, not a false current zero crossing point. This architecture has been used to create medium voltage frameworks **[10].**

Another design that has been proposed makes use of a fast strong state device as the main current source and a quick mechanical disconnector. The parallel path is activated by arranging strong state switches in a certain order. In the most basic sense, an IGBT is a fast strong state device. This IGBT just has to provide a sufficiently high voltage to compensate for the current flowing to the parallel full IGBT breakers, thus it has a lower rating than a parallel way breaker. Normally, it may be recognized by arranging a pair of IGBTs in such a way that the conduction mishaps and voltage drop are kept to a minimum.

The current will simply flow via the detour during normal operation, and the current in the principle breaker will be zero. When a DC fault occurs, the assistive DC Breaker quickly commutates the current to the basic DC Breaker, and the fast disconnector opens. The main DC breaker cuts the current when the mechanical switch is in the off position. With no current and low voltage stress, the mechanical switch opens. In the aftermath of being in the empty position when the main DC breaker opens, the quick disconnector will be exposed to the recuperation voltage defined by the defensive dimension of the arrester banks.

1.4. Circuit breaker made entirely of solid-state components:

They are a strong pop interference because of their fast and ultra-quick swapping devices. A pure strop may be faster than any other pure semiconductor base made possible by different combinations of sty subordinate circuits. There are two types of circuit breakers in literary works, and various structures may be constructed within one of these topologies.

In most pure strong state circuit breakers, a huge number of IGBTs, IGCTs, or other semiconductor-based switches are connected in series and parallel to assist the voltage and current of the framework during normal and fault circumstances. Investigations on how to develop and enhance the procedures of strong state circuit breakers are ongoing, and new promises have been made.

1.5. surge arrestor paralleled by CB:

A flood arrestor Rv is connected in parallel with the semiconductor switch T, which serves as the main breaker. T is on during a normal job and directs current from the source to the heap. T will be killed if a short out is found to be the cause. The heap current commutates to the flood arrestor Rv at that point. The surge arrestor Rv's cinching voltage constrains the flood voltage crosswise across T.

1.6.*Losses in power:*

Among all configurations, mechanical circuit breakers and half-and-half ones with no semiconductor devices in principle path of current have the lowest power misfortunes. An very tiny voltage drop on the metal contacts of the basic electrical switch explains this. These topologies have power misfortunes that are less than 0.001% of the VSC station control misfortunes. Furthermore, in the primary current path, half and half topologies with low evaluating semiconductor switches speak to significant power losses.

The power misfortunes in this kind of electrical switch are less than 0.1 percent of the intensity mishaps in a VSC framework. Unadulterated strong state designs, on the other hand, suffer from high control disasters. Because there are so many IGBTs or other semiconductor devices in the main current path in these topologies, the total voltage drop of the electrical switch is usually very large. The power losses associated with this invention in examination with a VSC station may be as high as 30%.

1.7.Voltage rating of:

Mechanical HVDC ostensible voltage up to 550kV ar circuit breakers have also been verified by testing up to 120kV voltage rating, and it is required to reach up to 320kV dimension. Pure semiconductor circuit breakers are not available in high voltage tests and have only been designed and built for use in medium voltage applications. However, with advances in semiconductor devices, it is expected that an 800kV voltage rating will be possible.

1.8. Currently rated:

With an aloof reverberation framework, mechanical HVDC circuit breakers can stop flows up to 4kA, and with a dynamic reverberation framework, they can stop flows up to 8kA. The flow incursion dimension of 9kA has been provisionally demonstrated for half breed electrical switch topologies, and a step up to 16kA is theoretically possible. When considering the typical high voltage rating for pure semiconductor circuit breakers, a current interference value of 5kA makes sense.

2. DISCUSSION

With the growing interest in developing, operating, and integrating huge amounts of renewable energy resources such as offshore wind farms and solar production in deserts, a need for multi-terminal high voltage direct current (MTDC) systems has emerged. According to preliminary research, a voltage source converter-based HVDC (VSC-HVDC) system is the greatest choice for implementing future multi-terminal HVDC systems that integrate large amounts of energy across long distances to the AC grid.

The requirement for quick HVDC circuit breakers is the most significant disadvantage of VSC-HVDC systems. The goal of this article is to summarize HVDC circuit breaker technology, as well as recent major efforts to create contemporary HVDC circuit breakers. Each technology is given a short functional examination. Different technologies are also compared based on information collected from literatures. Finally, suggestions for improving circuit breakers are offered.

3. CONCLUSION

The main impediment to HVDC lattices being recognized is the lack of develop HVDC fault current breaking advances. The current state of HVDC circuit breakers has been summarized and discussed in this article. All of the shown breaking strategies have limited capabilities in terms of interfering with the ongoing problem and could be enhanced. When it comes to mechanical circuit breakers, which are the most important devices for preventing fault current interference, efforts should be focused on increasing the size of the components of the reverberation circuit. Furthermore, in order to get a greater current rating, the conductivity of the circular segment chamber should be increased. Because half-and-half circuit breakers have a higher efficacy and acceptable infiltration speed, the development of faster mechanical switches with a higher flood voltage withstand and lower creation disasters may result in further advancements in this area.

New wideband-hole semiconductors such as SiC or GaN based switches should be investigated for application in strong state circuit breakers. Furthermore, dynamic entrance driving innovations may help enhance semiconductor switch execution in pure strong state electrical switches. Furthermore, accurate, strong models for semiconductor switches with validity in high voltage and high flows must be developed for use in constructions and reenactments. The use of DC blame current limiters in HVDC systems may be interesting to think about if you want to increase your chances of detecting permanent problems from transient network events.

REFERENCES:

2. Cai L, Chang Z, Zhang K, Xu T. Hybrid HVDC circuit breaker operation test for VSC-HVDC. Dianli Jianshe/Electric Power Constr., 2017, doi: 10.3969/j.issn.1000-7229.2017.08.002.

3. Wei X, Yang B, Tang G. Technical Development and Engineering Applications of HVDC Circuit Breaker. Dianwang Jishu/Power Syst. Technol., 2017, doi: 10.13335/j.1000-3673.pst.2017.1915.

4. Shao M. et al. Research of the control unit of forced zero HVDC circuit breaker. Gaoya Dianqi/High Volt. Appar., 2015, doi: 10.13296/j.1001-1609.hva.2015.11.008.

5. Lü W, Wang W, Fang T, Yang B, Xie Y, Shi W. Test Technology of Hybrid HVDC Circuit Breaker. Gaodianya Jishu/High Volt. Eng., 2018, doi: 10.13336/j.1003-6520.hve.20180430038.

6. Darwish HA, Izzularab MA, Elkalashy NI. Real-time testing of hvdc circuit breakers part I: Bench test development. 2004, doi: 10.1109/iceec.2004.1374591.

7. Zhao W. et al. Design and simulation of a new type of capacitance buffering hybrid HVDC circuit breaker,. Gaoya Dianqi/High Volt. Appar., 2015, doi: 10.13296/j.1001-1609.hva.2015.11.007.

8. Ding X, Tang G, Han M, Gao C, Wang G. Current-breaking test method based on LC source for hybrid HVDC circuit breaker. Dianli Jianshe/Electric Power Constr., 2017, doi: 10.3969/j.issn.1000-7229.2017.08.001.

9. Mokhberdoran A, Carvalho A, Leite H, Silva N. A review on HVDC circuit breakers. 2014, doi: 10.1049/cp.2014.0859.

10. Nguyen VV, Son HI, Nguyen TT, Kim HM, Kim CK. A novel topology of hybrid HVDC circuit breaker for VSC-HVDC application. Energies, 2017;10(10):1675. doi: 10.3390/en10101675.