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Power Electronics application in HVDC

Upendra Singh Yadav, Surya Prakash Sharma, Proff. S.K. Srivastava

Department of Electrical Engineering

Madan Mohan Malaviya University of Technology, Gorakhpur

upendrasingh5668928@gmail.com,022suryaprakash@gmail.com sudhirksri05@gmail.com

Abstract

Rapid advancement in converter technology (rectifiers and inverters) at higher voltages and greater current levels, DC transmission has become a crucial consideration when planning power transmission. Because of converter control, DC lines may be quickly regulated, which is a major advantage over AC transmission. The implementation of power electronics equipment, such as rectifier stations at the AC-DC transmission and inverters at the DC-AC transmission, to regulate HVDC transmission bridges. Refrigerant and inverter firing angles are used to manage voltage and power flow, respectively. For the purpose of reducing phone interference and filtering undesired harmonics, AC and DC filters are used.

Keywords, : *Power, Electronics, HVDC, FET, AC-DC.*

I. INTRODUCTION

Stability, power quality, and other transmission-related advantages (Joseph, 2018) are included. Using two positive and negative conductors, a DC line can transport the same power as an AC line with the same level of insulation.When usingthesamecurrentcarryingcapabilityofconductorsasin AC, it saves 67% (Mohammadi, 2021). It is extremely difficult and nearly impossible to maintain, however HVDC ties can overcome these problems. It is possible to join two DC links with different nominal frequencies because of their asynchronous nature. Basic voltage control system, which can manage the flow of power between terminal DC links linking AC systems, is the primary goal of this study. In the HVDC bridge model circuit, thyristor valve firing angles were tuned to determine the performance of power transfer. The focus of this study is on transformers with star-to-star and star-to-delta connections. This single-line schematic depicts a bipolar HVDC transmission system with two terminals.

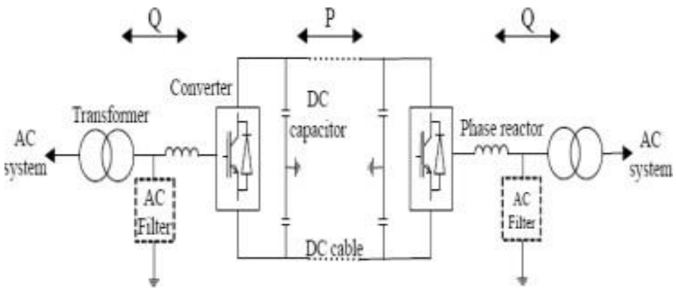

Fig. 1 HVDC Diagram

Thyristor valve converters are often used in commercial HVDC systems nowadays. The ac system voltage performs the commutation in a line-commutated converter. The line commutated converter based HVDC will continue to be employed for bulk power HVDC transmission above several hundred MW since this established technology delivers efficient, dependable and cost-effective power transmission for many applications (Tian, 2022).

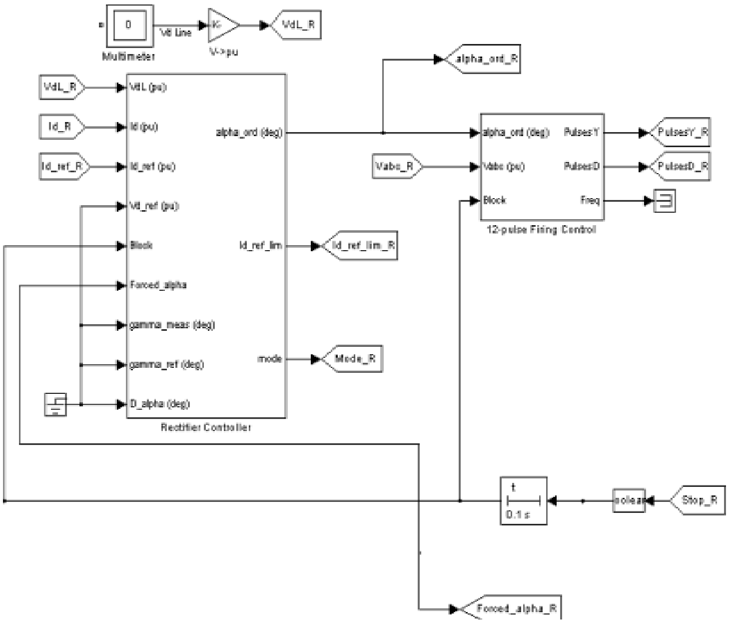

Fig. 2 HVDC controller

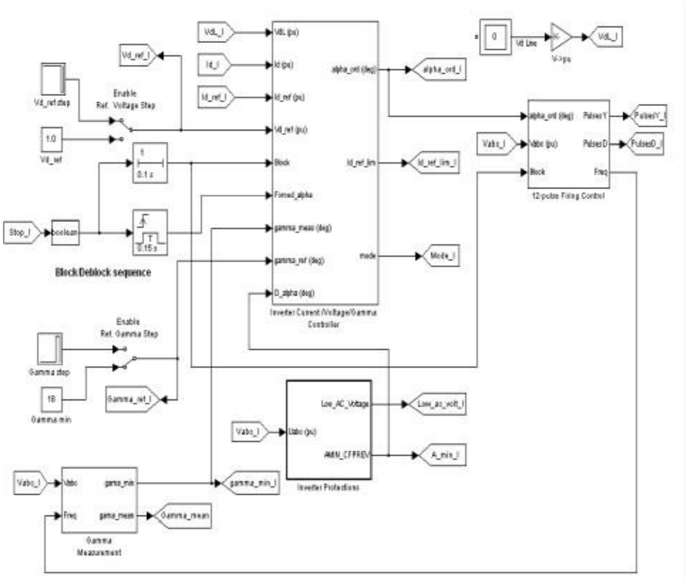

Fig. 3 HVDC Controller Connected to the Inverter Circuit

II. LITERATUREREVIEW

Many times HVDC is superior to AC when it comes to transmitting high voltages of direct current (HVDC). When it comes to transmitting power from offshore wind farms to shore, HVDC is typically the only option because ac cables can only be created about 100 kilometers long because of large capacitive currents. Until now, the vast majority of HVDC installations have been point-to-point. HVDC connections, on the other hand, will become more common in the future, making it more advantageous to link these to the dc grid. To further reduce switching losses, the high number of voltage levels available allows for a low switching frequency. Short-circuit faults can occur on the dc side of an MMC, just as they can on a conventional two-level voltage source converter. It is possible that the unipolar voltage provided by the cells would merely increase the dc side fault current during such a problem. A huge amount of current will flow through the converter's rectifier, hence the cells must be blocked to prevent this current from flowing into the dc side of the converter. As long as the problem can be repaired and the power lost is manageable, this unwanted behaviour can be tolerated in a point-to-point HVDC installation. For a converter station that is part of a DC grid, however, the controllability in case of dc grid problems will be more stringent.

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The dc grid's performance is closely linked to the second aspect. Because any converter is trying to maintain an adequate voltage level to keep the dc line operational, current will flow into the fault as long as there is an active line. The dc voltage will drop to a low level if the converters are equipped with a way to limit the current that goes to the dc side of the converter. Switchgear to reconfigure the dc network must be installed using disconnectors that can only operate under zero-current situations while dc breakers do not exist. Before the faulty line can be isolated and the converters reinserted, all currents running through the network must be eliminated. A few hundred milliseconds after the connectivity are restored, the entire dc grid is temporarily disabled [Queval, 2020]. All connected ac networks will be affected by a dc grid failure. Because of this, dc breakers should be provided in the same manner as AC breakers. There are some significant differences between interrupting direct current in dc grids and doing so in AC networks in terms of physics. Instead, the line current's zero crossings are used by the breakers in the latter situation. Dc system voltage is often the driving emf, which must be overcome in order to extinguish direct current. Consider a 500 kV dc voltage and a 10 kA extinguishing current as an example. The breaker may need to use a counter-emf that is 1.5 times the nominal voltage, or 750 kV, in order to reduce the current. In this case, the instantaneous output is 7500 MW. As a result, the breaker's energy buildup might reach 7.5 MJ per millisecond, demonstrating that breaking speed is critical to maintaining a manageable level of stored energy [Yu et al., 2020].

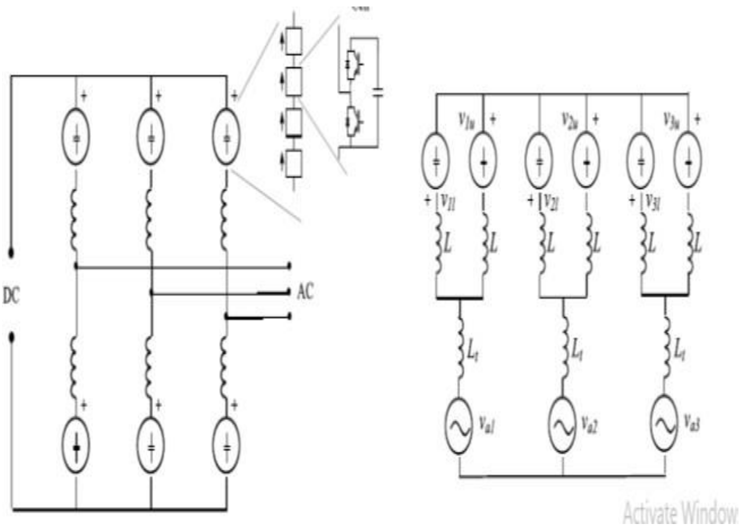

Fig. 4 Generic modular multilevel converter

No dc voltage is needed, therefore the converter's maximum output is 2Vd (the total cell capacitor voltage), which means that each converter arm must be appropriately sized to accommodate normal operation. The max driving voltage of the ac grid is greatly exceeded by this figure, making it more than adequate for managing currents. As a result, in the first approximation, the cost of semiconductors will be doubled because the same number of cells are required, but each cell has two phase legs. Even yet, the switching frequency of each valve can theoretically be cut in half while keeping the same output voltage and cell-capacitor voltage ripple in normal operation when the arms provide a unipolar voltage. Overall semiconductor loss will not double as a result of the half- bridge configuration.

III. STRATEGY OF MANAGED POWER ELECTRONICS IN HVDC

Maintenance of power converters is often performed by manufacturers for an initial term of five years in offshore wind farms, HVDC stations, and FACTS controllers. Either the operator or third parties will then take care of the work; otherwise, maintenance contracts with the OEM will be extended [Vozikis, 2020]. When it came to high-voltage power conversion, one of the key reasons for moving from mercury arc to thyristor valves and then to IGBTs was the added maintenance burden.

Many of the new and existing power electronic assets, on the other hand, are controlled by SCADA and CM systems. Allows for intelligent and device-dependent maintenance rules to be created. The adoption of a thyristor monitoring system can help with HVDC maintenance.

That's why corrective, preventive, dependability and PoF- centered maintenance is the next business need: building a good maintenance strategy that incorporates all four. Figure 6 depicts this in schematic form. When it comes to designing a power electronic asset maintenance policy, the use of PoF as a new indicator is still in its infancy compared to other options [Zou, 2018].

For low-cost machinery, this is probably the oldest and simplest maintenance approach yet deployed, and it has no effect on the reliability of the plant. Run-to-failure generally implies that the gadget must be refurbished or replaced once it has stopped working. As a result, working components are permitted to continue and are only replaced or fixed when they malfunction. Because the failure of large equipment would be far more costly than the maintenance itself, this technique cannot be used. Run-to-failure has long been the primary method of reducing HVDC converter downtime. Performing this type of maintenance on non-critical faults has been prohibited since the failure implications in some situations can be catastrophic.

As far as power converter device maintenance goes, this is the most widely used technique. By performing consistent intervals of maintenance and asset assessment [Bose, 2019], TBM can avoid a great deal of problems.

However, if the maintenance interval is too short, it might lead to unwanted outages, which wastes time, money, and effort. Additionally, if the intervals between maintenance procedures are too long, unforeseen problems may still occur [Bose, 2019]

Maintaining a component's condition is done in response to deterioration in its condition. As a result of these technologies, it is possible to determine the age of components and arrange maintenance accordingly. The technique is very responsive to the state of the equipment because maintenance is only conducted when it is absolutely necessary.

As an example, in an HVDC asset, there is a need for specific maintenance dependent on the converter topology.

Since it has more operational expertise and has a lower failure rate than CBM, TBM is typically used in older LCC-based HVDC systems. While CBM may be required in some instances following a scheduled maintenance, as described in (Bose, 2019), it is not always necessary. For VSC-based assets, CBM is favoured over TBM. Because of the limited number of projects, the environmental conditions, and the degrading processes of IGBTs, this is the case.

It is known as PoF-based maintenance when a device's failure can be explained in terms of its underlying physics (PoFBM). The key to creating a successful PoFBM plan is figuring out where the problem is and how to fix it. If you compare this to other maintenance techniques, this is a one-person exercise in which the various ways in which a component can physically fail are discovered or predicted. In other words, because the solution found using PoFBM can be applied to any other similar component, no matter where it is placed on the machine, it implies that the problem is of a universal nature. In order to achieve optimal operation and maintenance (O&M) for power electronic assets, the trade-off between dependability and criticality versus cost has long been a challenge. Managing the operational and maintenance costs of power electronic assets is becoming an increasing concern for utility companies as their warranties expire. This model can be used to identify the assets' damage indications and essential operational locations. It has been used in electronics [Quevval, 2020] and is being considered for use in wind turbines.

Because there are no moving parts, manufacturers have claimed that semiconductor devices can last indefinitely, despite the fact that they are still relatively new. Semiconductor devices do not wear out, although CIGRE reported [92]. It has come to a point when utilities and manufacturers alike are searching for ways to improve, renovate, and extend the lifespan of HVdc and FACTS control systems instead of just replacing them outright.

IV. CONCLUSION

The ac system's assets have been surpassed in terms of deployment by large-scale power converter assets in transmission networks. Asset managers and engineers have a hard time keeping track of them. In order to deal with these challenges, we've divided power electronic assets into three categories in this research. When developing an asset management system for HVDC and FACTS devices, there are a number of considerations to keep in mind. This has led us to believe that a shift in the way we monitor and evaluate power electronic components is on the horizon (from traditional methods to reliability or PoF-based ones).

When DC substations are integrated into AC networks, new maintenance methods may be required. PoF as a potential new guiding concept may be necessary.

The failure and degradation mechanisms in power semiconductor devices have a significant impact on their longevity. PoF and reliability-based methodologies can be used to meet the needs of a business owner in the newest innovations in power converter design, operation, and management. Additionally, the research roadmap for an effective management of power converter assets has been explored to provide some advice for future work—along with the identification of potential problems and opportunities— in order to create a framework for future study.

REFERENCE

[1] , T., Ugalde-Loo, C.E., Liang, J. and Coventry, P.F., 2018. Asset management strategies for power electronic converters in transmission networks: Application to HVDC and FACTS devices. IEEE access, 6, pp.21084-21102.

[2] Mohammadi, F., Rouzbehi, K., Hajian, M., Niayesh, K., Gharehpetian, G.B., Saad, H., Ali, M.H. and Sood, V.K., 2021. HVDC circuit breakers: A comprehensive review. IEEE Transactions on Power Electronics, 36(12), pp.13726-13739.

[3] Tian, Y., Wickramasinghe, H.R., Li, Z., Pou, J. and Konstantinou, G., 2022. Review, classification and loss comparison of modular multilevel converter submodules for HVDC applications. Energies, 15(6), p.1985.

[4] Rokrok, E., Qoria, T., Bruyere, A., Francois, B. and Guillaud, X., 2020. Classification and dynamic assessment of droop-based grid-forming control schemes: Application in HVDC systems. Electric Power Systems Research, 189, p.106765.

[5] Bakas, P., Okazaki, Y., Shukla, A., Patro, S.K., Ilves, K., Dijkhuizen, F. and Nami, A., 2020. Review of hybrid multilevel converter topologies utilizing thyristors for HVDC applications. IEEE Transactions on Power Electronics, 36(1), pp.174- 190.

[6] Tian, Y., Wickramasinghe, H.R., Li, Z. and Konstantinou, G., 2020, November. Modular multilevel converter sub-modules for hvdc applications. In 2020 IEEE 9th International Power Electronics and Motion Control Conference (IPEMC2020-ECCE Asia) (pp. 1510-1515). IEEE.
Xu, C., Yu, Z., Zhao, B., Chen, Z., Wang, Z., Ren,

[7] C. and Zeng, R., 2021. A Novel Hybrid Line Commutated Converter Based on IGCT to Mitigate Commutation

Failure for High-Power HVdc Application. IEEE Transactions on Power Electronics, 37(5), pp.4931-4936.

[8] Rao, H., Zhou, Y., Zou, C., Xu, S., Li, Y., Yang, L. and Huang, W., 2020. Design aspects of hybrid HVDC system. CSEE Journal of Power and Energy Systems, 7(3), pp.644-653.

[9] Asoodar, M., Nahalparvari, M., Danielsson, C., Söderström, R. and Nee, H.P., 2021. Online health monitoring of DC-link capacitors in modular multilevel converters for FACTS and HVDC applications. IEEE Transactions on Power Electronics, 36(12), pp.13489-13503.

[10] Asoodar, M., Nahalparvari, M., Danielsson, C., Söderström, R. and Nee, H.P., 2021. Online health monitoring of DC-link capacitors in modular multilevel converters for FACTS and HVDC applications. IEEE Transactions on Power Electronics, 36(12), pp.13489-13503.

[11] Langwasser, M., De Carne, G., Liserre, M. and Biskoping, M., 2018, October. Voltage-based load control for frequency support provision by hvdc systems. In IECON 2018-44th Annual Conference of the IEEE Industrial Electronics Society (pp. 311- 316). IEEE.

[12] Zhao, M., Wang, Z. and Xue, Y., 2018, June. An overview on application analysis of power electronic technology in smart grid. In 2018 Chinese Control And Decision Conference (CCDC) (pp. 5186-5189). IEEE.

[13] Quéval, L., Despouys, O., Trillaud, F. and Douine, B., 2020, September. Feasibility study of a superconducting power filter for HVDC grids. In 2020 22nd European Conference on Power Electronics and Applications (EPE'20 ECCE Europe) (pp. P-1). IEEE.

[14] Yu, P., Fu, W., Wang, L., Zhou, Z., Wang, G. and Zhang, Z., 2020. Reliability-centered maintenance for modular multilevel converter in HVDC transmission application. IEEE Journal ofEmerging and Selected Topics in Power Electronics, 9(3), pp.3166-3176.

[15] Zou, C., Rao, H., Xu, S., Li, Y., Li, W., Chen, J., Zhao, X., Yang, Y. and Lei, B., 2018. Analysis of resonance between a VSC-HVDC converter and the AC grid. IEEE Transactions on Power Electronics, 33(12), pp.10157-10168.

[16] Vozikis, D., Adam, G.P., Rault, P., Despouys, O. and Holliday, D., 2020. Enhanced modular multilevel converter for HVDC applications: Assessments of dynamic and transient responses to AC and DC faults. IEEE Journal of Emerging and Selected Topics in Power electronics,9(6),pp.6997-7008.

[17] Vozikis, D., Adam, G.P., Rault, P., Despouys, O. and Holliday, D., 2020. Enhanced modular multilevel converter for HVDC applications: Assessments of dynamic and transient responses to AC and DC faults. IEEE Journal of Emerging and Selected Topics in Power Electronics, 9(6),pp.6997-7008.

[18] Bose, B.K., 2019. Power electronics in renewable energy systems and smart grid: Technology and applications.