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Review of Modelling of Modular and design procedure of Multi-Level Converter based HVDC System

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Abstract-MMC'S are domain conversion technology of select for Voltage Source Converter High Voltage DC (VSC-HVDC) transmission schemes due to their very high efficiency. The primary goal of this work is to serve as a guide for modeling MMC-HVDC systems by providing an overview of the procedure for constructing a typical Multi-terminal (MT) MMC-HVDC (MTDC) model. This work provides a systematic design process for a modular multilevel converter high voltage direct current (MMC-HVDC) transmission system that takes into account both internal and external dynamics. In this paper, the reciprocal interactions between the parameters and their performance are examined.. Then, using a proposed systematic design procedure with the desired objectives and restricted conditions, we determine the parameter values, which can be cumbersome and time-consuming to arrive at proper and acceptable parameter values. As a consequence of this research, MMC-HVDC system engineers and project developers may be able to build sensible methods to the design parts of the technology requirement difficulties.

Keywords— *Modular Multilevel Converter (MMC), HVDC transmission*

I. Introduction- The demand for Voltage Source converter (VSC) High Voltage DC (HVDC) transmission schemes has grown significantly in recent times. This growth is primarily because of the advancements within the voltage and power conditions of insulated gate bipolar transistors and variety of rearmost VSC-HVDC operations. In general, there are main factors in MMC development similar as the energy storehouse capacity for capacitor voltage ripples and arm inductance for another harmonious circulating current reduction. The most important part of MMC design is the determination ofsub-module (SM) capacitance. MMC utilizes the stored energy in SM capacitors, which are needed during a larger number than conventional two- position VSC. MMC-HVDC system design should be supported a comprehensive analysis of the impact of fresh control ways of MMC like voltage balancing control with algorithm and CCSC. Likewise, voltage and current at AC and DC sides of the MMC-HVDC system should be took in various ways harmonious with the planning of the preliminarily introduced factors as well as MMC voltage position considering connected power system conditions. Thus, in this study, a methodical design procedure of MMC-HVDC system parameters is established regarding their characteristics for comprehensive and approachable development. The MMC has multiple benefits in comparison to two or three- position VSCs; chief among these is reduced motor losses. Moment, the most HVDC manufacturers offer a VSC-HVDC result which is rested on multi-level converter technology.

2. MMC

The main factor of MMC-HVDC systems is the converters. MMCs come in a variety of shapes and sizes, including half-ground (HB), full-ground (FB), and alternate Arm Converters (AAC), The FB-MMC and the AAC are appertained to as fault blocking transformers as they're suitable to block the current flowing through the motor in the event of a DC side fault. This can be particularly useful for HVDC schemes employing overhead transmission lines, still for HVDC grids using lines, a DC side fault is likely to be endless and hence the need for fault blocking transformers isn't yet apparent. Likewise, the HB-MMC is the only type of MMC which is commercially in operation. Considering that the maturity of proposed MTDC systems is dominated by submarine lines, this paper focuses on the HB-MMC.

The introductory structure of a three-phase HB-MMC is shown in Figure 2. Each leg of the converter is made up of two motor arms with a number of Sub-Modules (SMs) and a series-connected reactor, Larm. A two-position HB converter with two IGBTs and a parallel capacitor is included in each SM. A bypass switch is included to remove the module from the circuit if an IGBT fails, as well as a thyristor to protect the lower diode from over current in the event of a DC side malfunction. The bypass switch and thyristor are still largely ignored in most research.

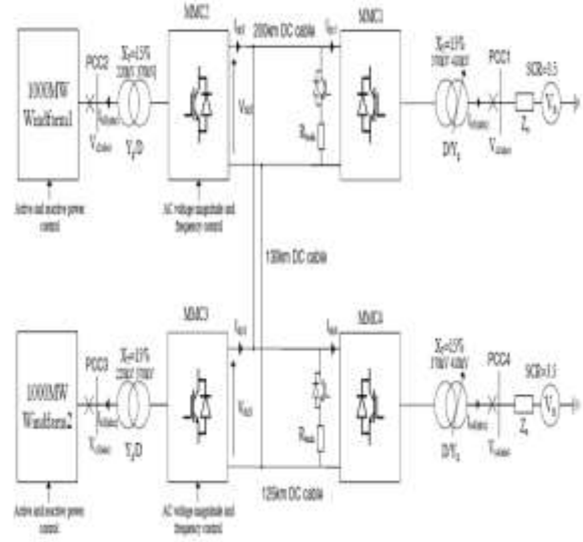

Figure 1: MT MMC-HVDC system model

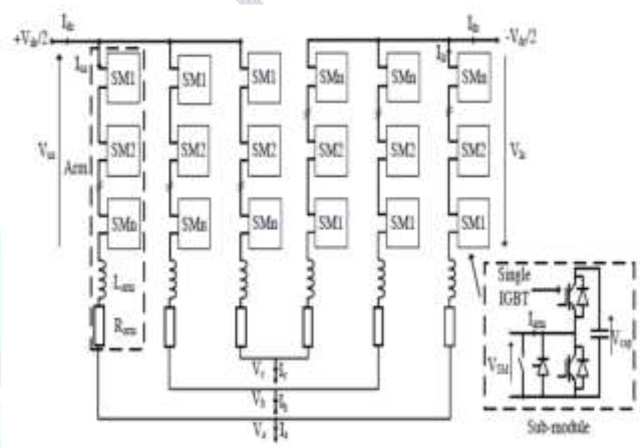

Figure 2: Three-phase HB-MMC

When the upper IGBT is switched on and the lower IGBT is switched off, the SM terminal voltage, VSM, is functionally equal to the SM capacitor voltage, Vcap. Depending on the current direction of the arm, the capacitor will charge or discharge. The SM capacitor is bypassed when the top IGBT is turned off and the lower IGBT is turned on, thus VSM is practically 0 volts. Each motor arm therefore functions as a programmable voltage source, with the lowest voltage change equal to the SM capacitor voltage. For phase A, the motor affair voltages, V (a, b, c), are successfully controlled by adjusting their respective upper and lower arm voltages, Vu (a, b, c) and Vl (a, b, c), as specified by equation (1). (8).

$$V_a=\frac{V_{la}-V_{ua}}{2}-\frac{Larm}{2}\frac{dI_a}{dt}-\frac{R_{arm}}{2}I_a$$

The converter arm currents correspond to three main factors as given by equation (2) for phase A. The circulating current, Icirc, is due to the unstable DC voltages generated by the three motor legs. The circulating current is a negative sequence (a-c-b) current at double the abecedarian frequency, which distorts the arm currents and increases motor losses.

$$I = \frac{I_{dc}}{3} + \frac{I_a}{2} + I \qquad I = \frac{I_{dc}}{3} - \frac{I_a}{2} + I$$

There are numerous different ways for modeling a MMC (2-4).

3. HVDC

High Voltage Direct Current, or simply HVDC, is an abbreviation for High Voltage Direct Current. It's sometimes referred to as an electrical or power superhighway. HVDC is an effective way to transmit the vast quantum of electrical power using DC (Direct Current) over long distances by overhead transmission lines, underground lines, or submarine lines.

HVDC system is also used to connect separate power system networks having different characteristics and frequentness where AC transmission isn't applicable. Power is transmitted across long distances using direct current in the High Voltage Direct Current (HVDC) transmission technology. The HVDC transmission system provides effective and profitable transmission of power indeed to veritably long distances that meet the conditions of growing cargo demands. Due to its simple constructional point and lower complexity, exploration and development authority discovered its operation in ultramodern power transmission.

By comparing ac and dc transmission, it's clear that for transmission of power over long distances ac isn't important suitable, and for generation and application of power, dc isn't favorable compared to ac. As a response, a terminal outfit is required for HVDC transmission at the transferring end to convert ac to dc, and a terminal outfit is required at the entering end to flip the dc force obtained into ac.

Principle of HVDC Transmission System:

The HVDC transmission system substantially consists of motor stations where transformations from ac to dc (therapy station) are performed at transferring end and at the entering end the dc power is reversed into ac power using an inverter station. Hence, the converter stations are the major element of the HVDC transmission system.

Also, by changing the part of the therapy to inverter and inverter to rectifier the power transfer can be reversed which can be achieved by suitable converter control.

II.Parameter Analysis of MMC-HVDC System

A. External Parameters of MMC-HVDC System

For achieving a stable operation and management of the MMC-HVDC system in Fig. 2, the MMC parameters to be considered are stated in Table 1. As a pre-established variable in the MMC-HVDC planning process, active power (Ps) is naturally dictated by line impedance as well as angle discrepancies between grid-side and MMC-side voltage. Reactive power (Qs) is also highly related to the modulation signal, which factors are influenced by internal and external conditions; thus, we will provide the guideline of parameter determination in this research. The value of reactive power (Qs) should be calculated as a result of voltage variation, and this type of reactive power should be evaluated by a power system analysis. In other words, active power is dictated by transmission power capacity, and reactive power design specifications may be derived using power system modelling. Although the transformer's main voltage is a preset parameter based on grid-side rating, the secondary voltage should be appropriately established and extensively examined, as it defines the PQ capacity features directly related to DC voltage and current. The secondary voltage also affects the modulation index, the number of SMs, SM capacitance, arm current, and arm inductance, and those factors should be considered for reliability, system loss, and stability requirements.

Parameter	Value	Description
Active power (P_s)	800 MW	Required value at steady state
Reactive power (Q_s)	80 MVar	Desired value for AC voltage control at point of connection (POC)
System frequency	60 Hz	Fundamental frequency
Transformer voltage @ grid side (V_s)	915.98 kV	Defined value
Transformer voltage @ valve side (V_c)	423.89 kV	For stable operation of MMC from Eq.(20) and Eq.(22)
DC voltage (V_{dc})	$\pm$400 kV	Estimated value without economical requirement
DC current (I_{dc})	1000 A	No consideration of DC cable distance
No. of SMs (N_0)	432 ea	From Eq.(9) with V_{sm}
Arm inductance (L_{arm})	87.865 mH	Initial parameter from Eq.(11) ($X_{Lpu} = 0.1$ [p.u] and $I_{2f} = 0.3$ [kA])
SM capacitance (C_{sm})	9275 μF	Initial parameter from Eq.(10) ($EP_0 = 50$ [kJ/MVA])
Maximum allowable modulation index (m_{max})	0.865	From Eq.(20)
Individual SM voltage (V_{sm})	1.85 kV	Arbitrary voltage rating = 3 [kV] and λ_v is 60 [%]
Arm current (I_{arm})	1.128 A	From Eq.(30)
Capacitor voltage ripple factor (k_{max})	$\pm$5%	Arbitrary voltage ripple requirement

TABLE 1 **The Key Parameters of MMC-HVDC Transmission System**

B. Internal Parameters of MMC-HVDC System

1) DC Voltage and Current

In Table 1, MMC main parameters and operation are shown. DC voltage and current are economic variables in relation to active power assuming that DC power is equal to AC power and additional power losses due to passive elements and power conversion. The DC voltage is inversely proportional to DC current for constant DC power, and it relates to switching device rating. As a result, both criteria might be taken into account in terms of economic needs. Because MMC terminal voltage (Vt) is governed by (mVdc)/2, which impacts PQ capability, DC voltage has a strong relationship with modulation index. The DC current should be examined in conjunction with the DC cable rating, which is connected to the cost of an essential component of an HVDC system where cost considerations must be made.

2) The Total Number of SMs and the Number of Redundant SMs

The number of SMs refers to a switching device's capacity to block specific SM voltages (Vsm) with a given DC voltage. It is a cost-effective consideration variable that may be set within a range to fulfill the DC link voltage and switching device rating. The number of redundant SMs depends on the redundancy methods [5]. For a passive mode (cold reserve state) for the redundancy, the number of redundant SMs is a variable independent of the MMC-HVDC system operation in which economics and reliability are to be considered together. After the system variables have been discovered, it may be determined through optimization to improve the MMC-HVDC system dependability. Otherwise, depending on power losses, an active mode (hot spinning reserve state) has an influence on capacitor voltage ripple and switching frequency [5]. In the case of the active mode, the number of redundant SMs should be considered with reliability and economical requirement as well as system loss evaluation.

3) Arm Inductance

Three elements should be considered while designing an arm inductor. These include lowering the second harmonic circulating current inside the MMC, lowering the fault current increase rate, and taking into account reactive power usage while preventing resonance in the MMC circuit. The arm inductor should be designed for MMC-HVDC system stability and reactive power loss since it is connected to the CCSC strategy. The arm inductor only has to address reactive power loss and stability for CCSC, and when CCSC is deactivated, the main goal is to reduce the second harmonic circulating current, which has been examined in much prior research.

4) SM Capacitance, Voltage Ripple, Switching Frequency

The ability of MMC to function in a stable location is dependent on its energy storage capacity. The SM capacitance, which is connected to voltage ripple and influences the SM capacitor's lifespan, is an essential quantity. As a result, it should be regulated such that it is generated within the voltage ripple factor limit (kmax). The switching frequency (fsw), which affects the power conversion loss and power quality, is connected to voltage ripple control. As a result, energy storage capacity should be developed with reliability and cost in mind, while ensuring that MMC operating parameters are met [58].

5) PQ Capability

The modulation index of conventional VSC is related to the operating point for desired active and reactive powers. Furthermore, MMC has additional factors affecting the modulation index, which are the compensation signal generated due to the control to reduce the second harmonic circulating current and additional reactive power consumption by the arm inductor. In this paper, the physical factors discussed in the previous research are not considered because their influences could be negligible [6], [7].

6) Arm Current

Arm current is related to the rating of the switching device and includes AC and DC currents. When the above-mentioned main parameters are determined, it can be selected by the modulation index (k) of AC current over DC current. In this study, even though the second harmonic circulating current increases the peak value of the arm current, it is assumed that it becomes zero by CCSC strategy.

Conclusion- This paper has described the modelling process for a MT MMC-HVDC system, including the structure of the system, determining the value of crucial parameters, the different modelling ways available and the multitudinous control functions which are needed. Its crucial donation is that the main aspects of MMC-HVDC modelling have been brought together and described in a compact and intertwined manner. The main ideal of this paper was to dissect the current technologies used for transmitting power, fastening on HVdc systems. The enabling objects were to make a simulation model of an HVdc system between to power grids, to apply a sensorless regulator for grid synchronization of an MMC- grounded HVdc terminal, and to dissect the impact of a high-voltage, presto- switching IGBT's on an MMC- grounded terminal. A theoretical background was given of HVdc technologies, fastening on MMCs. From this background it was concluded that the MMC has several advantages over other HVdc-VSC topologies so it's a feasible volition for HVdc-VSC links, especially when trying to connect to weak ac grids.

References

[1] M. M. C. Merlin, T. C. Green, P. D. Mitcheson, D. R. Trainer, R. Critchley, W. Crookes, and F. Hassan, "The Alternate Arm Converter: A New Hybrid Multilevel Converter With DC-Fault Blocking Capability," *Power Delivery, IEEE Transactions on,* vol. 29, pp. 310-317, 2014.

[2]H. Saad, S. Dennetie, J. Mahseredjian, P. Delarue, X. Guillaud, J. Peralta, and S. Nguefeu, "Modular Multilevel Converter Models for Electromagnetic Transients," *Power Delivery, IEEE Transactions on,* vol. 29, pp. 1481-1489, 2014.

[3] U. N. Gnanarathna, A. M. Gole, and R. P. Jayasinghe, "Efficient Modeling of Modular Multilevel HVDC Converters (MMC) on Electromagnetic Transient Simulation Programs," *Power Delivery, IEEE Transactions on,* vol. 26, pp. 316-324, 2011.

[4] J. Xu, C. Zhao, W. Liu, and C. Guo, "Accelerated Model of Modular Multilevel Converters in PSCAD/EMTDC," *Power Delivery, IEEE Transactions on,* vol. 28, pp. 129-136, 2013.

[5] Y. Li, X. Shi, B. Liu, F. Wang and W. Lei, "Maximum modulation index for modular multilevel converter with circulating current control", *Proc. IEEE Energy Convers. Congr. Expo. (ECCE)*, pp. 491-498, Sep. 2014.

[6] S. Sim, C. Kim and J. Kang, "Optimal design method for maximum modulation index of VSC HVDC based on MMC considering compensation signals and AC network conditions", *Proc. 10th Int. Conf. Power Electron. ECCE Asia (ICPE-ECCE Asia)*, pp. 3235-3239, May 2019.

[7] K. Ilves, A. Antonopoulos, S. Norrga, L. Ängquist and H. Nee, "Controlling the ac-side voltage waveform in a modular multilevel converter with low energy-storage capability", *Proc. 14th Eur. Conf. Power Electron. Appl.*, pp. 1-8, Aug./Sep. 2011.

[8] S. Du, J. Liu, and T. Liu, "Modulation and Close-loop based DC Capacitor Voltage Control for MMC with Fundamental Switching Frequency," *IEEE Trans. Power Electron*., vol. 30, no. 1, pp. 327 - 338, Jan. 2015.

[9] H. Saad, J. Peralta, S. Dennetiere, J. Mahseredjian, J. Jatskevich, J.A, Martinez, A. Davoudi, M. Saeedifard, V. Sood, X. Wang, J. Cano, and A. Mehrizi-Sani, "Dynamic Averaged and Simplified Models for MMCBased HVDC Transmission Systems," *IEEE Trans. Power Del*., vol. 28, no. 3, pp. 1723 - 1730, July. 2013.

[10] M. Saeedifard, and R. Iravani, "Dynamic Performance of a Modular Multilevel Back-to-Back HVDC System," *IEEE Trans. Power Del*., vol. 25, no. 4, pp. 2903 - 2912, Oct. 2010.

[11] A. Beddard, M. Barnes, and R. Preece, "Comparison of Detailed Modeling Techniques for MMC Employed on VSC-HVDC Schemes," *IEEE Trans. Power Del*., vol. 30, no. 2, pp. 579-589, April. 2015.

[12] L. Harnefors, A. Antonopoulos, S. Norrga, L. Angquist and H-P Nee, "Dynamic Analysis of Modular Multilevel Converters," *IEEE Trans. Industrial Elec*., vol. 60, no. 7, pp. 2526 - 2537, July. 2013.

[13] P. Hu, and D. Jiang, "A Level-Increased Nearest Level Modulation Method for Modular Multilevel Converters," *IEEE Trans. Power Electron*., vol. 30, no. 4, pp. 1836 - 1842, April. 2015.

[14] Bipin Patil, Alka Thakur ,"Use of UPSC in mitigating harmonics From A 53 kv Distribution Lane," INTERNATIONAL JOURNAL OF SCIENTIFIC PROGRESS AND RESEARCH (IJSPR) Volume 22, Number 03, 2016

[15] Devendra Singh,Alka Thakur," MIMO-OFDM Based Power Line Communication Systems Using 50Hz Transmission Technique", *Vol-6 Issue-2 2020*

[16] B. Li, R. Yang, D. Xu, G. Wang, W. Wang, and D. Xu, "Analysis of the Phase-Shifted Carrier Modulation for Modular Multilevel Converters," IEEE Trans. Power Electron., vol. 30, no. 1, pp. 297 - 310, Jan . 2015.