Improve the voltage level in HVDC systems by using modular multilevel converter

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Abstract: This paper proposed a finest intend scheme of Modular-Multilevel-Converter (MMC) levels for move towering the practical conciliation flanked by the precision and divisional competence. The whole process is standard by a Thevenin-equivalent 133-level MMC model. Firstly the computation scheme of the fundamental limit imitation time step is offered to dependably signify respectively voltage level. Secondly the earlier industrial Improved Analytic Hierarchy Process (IAHP) is assumed toward combine the virtual faults of all the input electrical factors interested in one complete virtual fault on apiece converter level. Thirdly the stable AC and DC ephemeral condition in virtual faults effects of all the forms stabilize and curve integral stand on the standard form. Finally the finest MMC levels take by the drown curves and the give individual weights allowing for the precision and competence. And the competence and potency of the propose scheme is validate by model on MATLAB simulink.

Keywords: Modular Multilevel Converter (MMC), Improved Analytic Hierarchy Process (IAHP), ac and dc transient, HVDC, voltage sourced converter

1. Introduction

Modular-multilevel-converter stand high-voltage-direct-current-transmission system (MMC-HVDC) is person commonly used and has exposed large production views in the voltage-source-converter (VSC) [1, 4]. Though the bulky quantity of controlling mechanism in modular-multilevel-converter creates thorough imitation taking place an electro-magnetic-transient (EMT) model program enormously unhurried [5, 6] and the exclamation task to accurately launch the electronic devices can also increase the calculation immensity of the form [7, 8]. Freshly new modular-multilevel-converter models have proposed that loom the precision of a meticulous model.

Still the capability of admittance to the modular-multilevel-converter inner performances is gone and the cell capability must be examined and the limitations must be cautiously intended to correctly create the strict AC and DC side mistakes such as the DC side ensuing storage element size of the automated valuation models [10]. Therefore the consumers could require a practical conciliation among the precision and competence of the modular-multilevel-converter cells for EMT studies. In organize to characterize complete changing information of the control electronic converters such as voltage-source-converter and modular-multilevel-converter on EMT type series and still high frequency swells of the AC and DC regions be able to calculated [15].

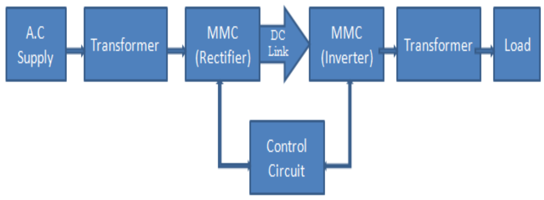


Fig.1. Block diagram of HVDC system with MMC

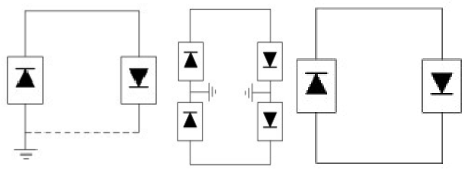
Consequently an additional vital topic must be deal with the time step after creating modular-multilevel-converter with a extra number of power levels. Which a 133-level modular-multilevel-converter be roughly created through an 11-level modular-multilevel-converter and demonstrates comparable active performances [7]. The 133-level modular-multilevel-converter cannot explain the complete changing information and so cannot be observing as the target cell. The recommend clarification of high calculation competence nearly shut to the easy average value cells and the finest Thevenin equivalent modular-multilevel-converter cell is able to great aspirant pro the design and model functions in HVDC.

Voltage sourced converter (VSC) based HVDC systems exhibit many attractive features over the conventional line commutated converter (LCC) based systems in high voltage high power applications [1]. These unique features such as free control of VAR [2], maneuver in scrawny AC systems [3], black start capability [4], and multi terminal connection [5] have led to their increased adoption in modern schemes. Till recently, two-level or three-level VSC topologies were used for HVDC transmission applications, with pulse-width-modulation control to ease the lower harmonic content. The ratings were typically limited to below 400 MW because of the higher switching losses inherent in such topologies. Numerous multi-level topologies and inflection strategies have been introduced for machine force appliances [6, 8]. Diode clamped multilevel converters [7], produce a stepped AC waveform like a sine wave by mounding set scale voltage paces on crest of apiece further. This topology typically has lower losses than two level PWM converters. However, the number of levels has been limited to 3 (in HVDC applications) due to the circuit complexity. Also capacitor voltage balancing is a critical and challenging issue. Modular-multilevel-converter is a most important tread advance in voltage-source-converter equipment for high-voltage-direct-current-transmission [9]. This topology is designed to make lower switching frequency, avoid connecting the devices in series. The modular structure easily scales to higher voltage and power levels, with the addition of more modules. A rating of 1GW and more than feasible. While the modular-multilevel-converter topology has been in attendances [9, 10], the conversation taking place power schemes is light. It disputes power looms and study their concert using electromagnetic-transients imitation and also investigates the run and piece of a high-voltage-direct-current-transmission.

2. Construction of HVDC Transmission

Depending on practical characteristics major HVDC constructions shown in Figure 2.1 are used.

- Mono polar construction (a) - connects both switching operations using a terminal among the prospect to control by mutually DC polarities. Marine instrumentalist tin be used pro come back path.
- Bipolar construction (b) - connects both switching operating at reverse polarities. This result in two free DC charged at half power every one. For the duration of one pole a mono polar function can be used. The mainly regular construction for present high-voltage-direct-current-transmission.



(a) (b) (c)

Fig. 2.1 High-voltage-direct-current-transmission system constructions.

(a) Mono polar. (b) Bipolar. (c) Back-to-back

- In Back-to-Back construction (c) - the DC sides of two stations are unswervingly attached having refusal DC line. This preparation is utilized pro the interconnection of asynchronous AC systems.

While conventional current-source-converter with HVDC on form recognized for large watts and volts ratings, it is expected converter beginning on the voltage-source-converters resolve foremost in the potential large high-voltage-direct-current-transmission interconnections suitable to several merits in financial and practical description. The focal merits of VSC with HVDC over CSC with HVDC are potted below.

- To observed four quadrant operation and voltage & current in paths (Fig. 2.2). The exclusion of reactive power return apparatus effect in important footstep drop.
- Prospect of relationship to the feeble and submissive networks. Near to the ground short circuit aptitude necessity of the A.C networks. Because a voltage-source-converter is measured as a practical synchronous-generator.
- Prospect of protected error ride through and ability.
- Fast-active-power-reversal.
- Special converter transformers are not required.
- Fast operating and control.

The emblematic construction of present HVDC with VSC system is shown in Fig. 2.3. Both D.C performers of converse division connect two switching control. The polarization of the DC link voltage residue similar though the D.C current is overturned as the way of shift phase.

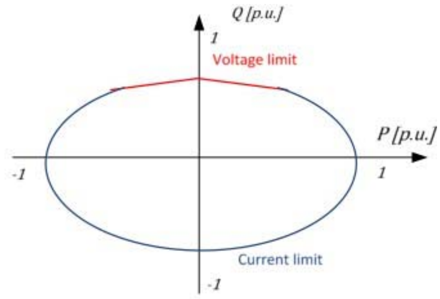


Fig. 2.2 Locus diagram of VSC with HVDC

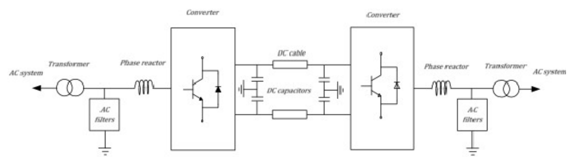


Fig. 2.3 VSC with HVDC system configuration

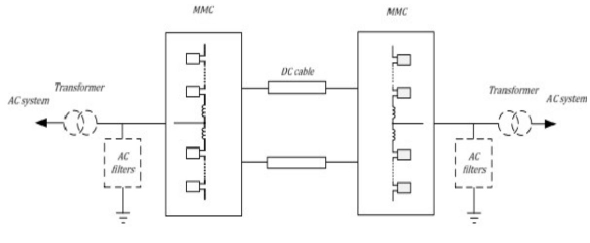


Fig. 2.4 MMC with HVDC system configuration

The D.C region capacitors make sure carry and functioning of the D.C voltage. The phase-A, B &C terminals certify run of control swap over connecting the converter and A.C system the control of defect presents and obstructing of current disturbance materializing suitable to pulse-width-modulation. The A.C cleans decrease disturbances pleased taking place the A.C voltage. Power transformers are utilized to procession the A.C system, acclimatizing operation and A.C system in control parameter by means of tap changers.

3. Modular multi level Converter

The modular-multilevel-converter topology is stand taking place a sequence association of equal essentials called sub module. Each sub module symbolizes the fundamental component of the modular-multilevel-converter shown in Fig. 3.1. Given that the segment capacitors distribute a regular D.C link electrical energy around is not require of large D.C link capacitors as in crate of two-level NPC. Inductors are located in the limbs to boundary it.

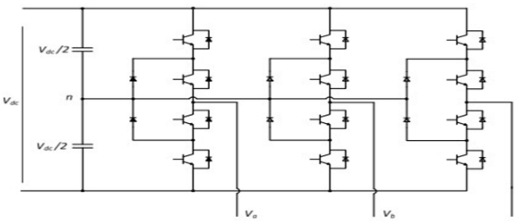


Fig. 3.1 Topology of three levels NPC converter

Different cells topologies can be pertinent to the modular-multilevel-converter depending taking place the function. The dissimilarity in the unit arrangement effects in changed practical voltage level sits the terminals of the sub module. Conversely by enhance of factors the capacitor valuation grow to more difficult. According to the investigational studies achieved voltage level sit the incurables of the sub module. Conversely amid enhance of aspects the capacitor balancing grow to be more problematical. The time sub module delivers to a half bridge produced by both converter switches with anti parallel diodes and a D.C capacitor as shown in Fig. 3.3. The capacitor works as voltage barrier and phase-A. The controls carry out the supplement of the sub-module into the limb circuit while the anti parallel diodes guarantee uninterruptable current flow.

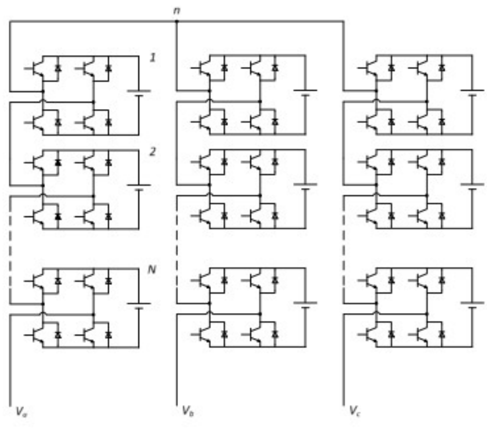
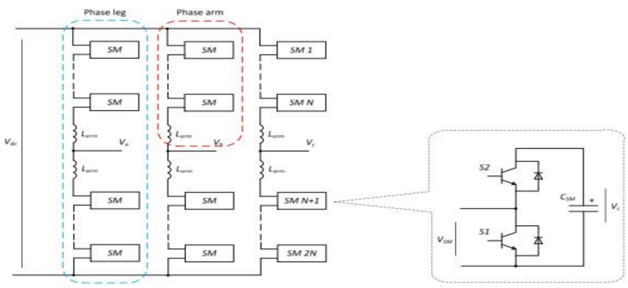


Fig. 3.2 - Topology of cascaded H-bridge inverter

While every cells are like the purpose view of modular-multilevel-converter should be saved to the voltage level process. All sub modules have both statuses depending on the control locations. In topology s1 is on and s is off, so the terminal voltage is same as the capacitor across voltage in fig. 3.3(b).

Than the s2 is on and the s1 is off, so the terminal across voltage is zero. Since cell can be received beginning the cell control points by switches function in corresponding approach at not required the capacitor. The course of the limb current influences the capacitor voltage summary. Current flow through the capacitor from sub model as bypass the changing current to diode and oppose the change in voltage. The main benefits of the modular-multilevel-converter can be concise as follows:

- Modularity
- Increased output quality
- Reliability
- Increased competence
- Reduced footstep



(a) (b)

Figure 3.3 (a) Topology of three-phase M M C

(b) Half bridge sub module

Due to its prospect to be magnitude to high voltage levels, practicable skill, relieve of operation, less disturbance results and dependability the modular-multilevel-converter demonstrates very comfortable techniques in new appliances.

a. Half bridge sub module:

The half bridge sub module includes two IGBT/diode switches and capacitor *C* as shown in Fig. 3.3. The power loss of the half–bridge sub–module capacitor is characterized by the resistor. In regular function precisely one of *S1* and *S2* is active at a instant time. Haughty the charge of V_c is a constant the output voltage each half-bridge cell can take on one of two different voltage levels V_c or zero. With *S1* in the 'ON' state, voltage V_{hb} is equal to V_c, and when *S2* is 'ON', V_{hb} is zero. Therefore, it is probable to selectively and independently control each of the being half-bridge cells in the converter to supply a voltage which is either V_c or zero.

b. Modulation techniques of MMC:

Multilevel modulations schemes can be split into two categories are space-vector-modulation and voltage-level-based-modulation i.e. Carrier P W M and nearest-level-modulation.

Table-1

Parameters of the M M C system:

A.C-system	
A.C-voltage U-bus (L-L-rms) = 230kV	
Real-power	*P* = 1000MW
Transformer-capacity	*S*TN = 1060MVA

Winding type Y/Δ turn ratio k = 230 kV/333.14 kV

Leakage-reactance LT = 0.15p.u.

M M C

Arm-reactance $L0$ = 0.085H

Capacitance C = 11250μF

Sub module number N = 450

Level-reduction-principle C/N = 25μF

D.C system

D.C voltage U-dc = 320kV

4. Analysis of Simulation Results

Inside categorize toward authorize the precision of the finest modular-multilevel-converter cell here complete setting the inclusive finest 25 level modular-multilevel-converter cell with w = 1 is calculated and match up to the standard 133 level modular-multilevel-converter cell. The reproductions embrace 3 states are first single terminal M M C trial, second three terminal MMC with HVDC trial with hereditary values and third single terminal M M C trial with new values. Following the time logic based on 3 states in below:

1) The MMC with HVDC attains stable at t = 1.2s.

2) A 100ms three phase to ground short circuit fault arises at time t = 1.5s.

3) The AC switches turn off disturbance line at time t = 1.58s, that is allowing for 80ms exposure and angle.

4) The AC switches turn on productively at time t = 1.8s as the provisional ac short circuit fault is left at time t = 1.6s.

5) The MMC with HVDC get well to typical action at time t = 2.4s.

6) A stable DC extremity disturbance take places at time t = 2.6s. Switches are uncreative at time t = 2.603s, that is allowing for 3ms delay.

Single terminal MMC test system:

Model and simulated the active-power and modular-multilevel-converter inside s1 and s2 limb currents are correspondingly exposed in fig. 4.1 and graph.4.1 to 4.3. The graphs are 4.1, 4.2 and 4.3 it can be observed that the relative faults connecting 133 level modular-multilevel-converter and the standard 133 level are acceptably diminutive to development of investigate the full state. Therefore if uses the thevenin equivalent cell the 133 level modular-multilevel-converters must be the finest M-M-C cell in complete states to alternative the 133 level M-M-C if the magnitude of the cell precision and competence is set to be the same.

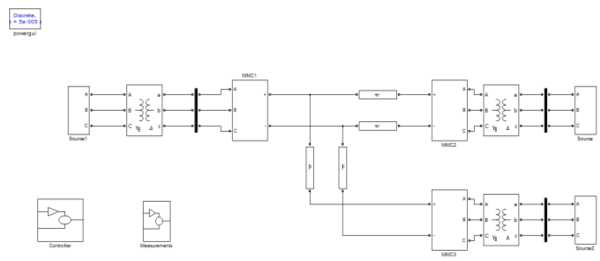
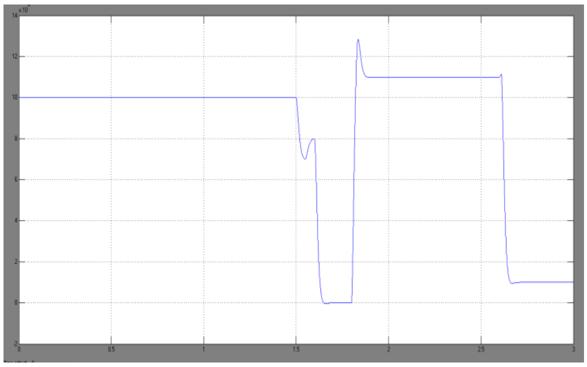
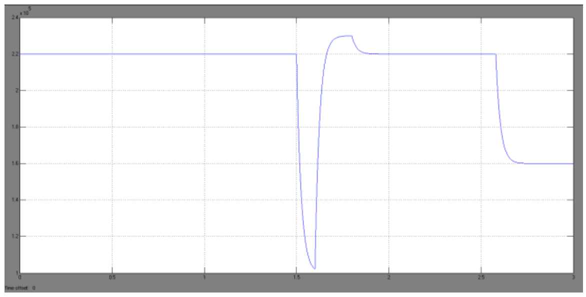


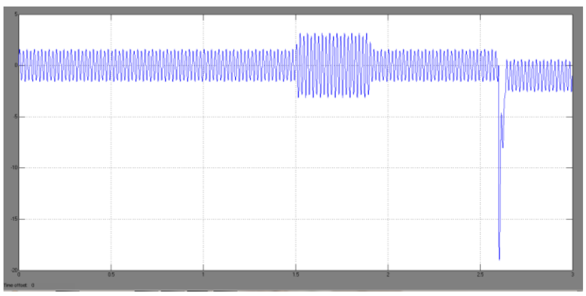
Fig: 4.1- Simulation diagram of single terminal MMC



Graph: 4.1 Waveform of active power.



Graph: 4.2 Waveform of the ac phase voltage.



Graph: 4.3 Waveform of top limb current in phase-A.

Three terminal MMC-HVDC systems:

In the three terminals M-M-C with HVDC be utilized as observed in fig. 4.4. M M C controls the DC link voltage and the reactive power. In model the active power and upper arm currents of M M C are correspondingly exposed in graph 4.4 and 4.5. From the below virtual effects, it is create that the maximum faults don't adjust a lot and a practical and suitable transmission systems also turn off single terminal M M C trial with new values.. It demonstrates that the recommend scheme can be comprehensive from single terminal test to multi-terminal M M C models.

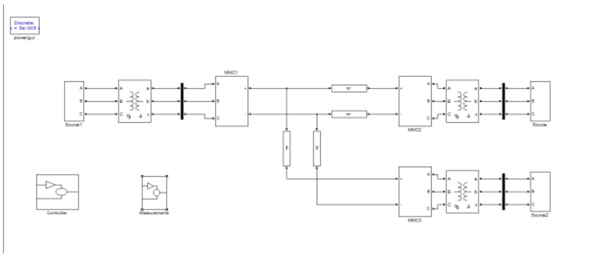
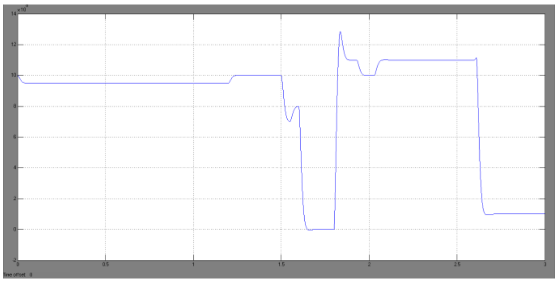
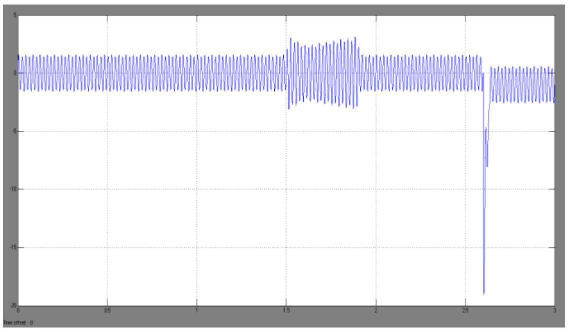


Fig: 4.2 Simulation diagram of three terminals MMC



Graph: 4.4 Waveform of active power.



Graph: 4.5 Waveform of top limb current in phase-A.

Single terminal MMC-HVDC systems with new parameter:

Model and simulated the active power and modular-multilevel-converter inside factor are top limb phase current correspondingly exposed in fig. 4.3. The graphs are 4.6 and 4.7 it can be observed that the virtual errors between 133 level modular-multilevel-converter and the standard 133 level are acceptably diminutive to development of investigate the full state. Observed the below virtual effects it is create that the maximum faults.

Table-2

Parameters of the new *MMC* system

A.C-system

A.C-voltage U-bus (L-L-rms) = 230kV

Real-power		P = 1600MW
Transformer	Capacity	STN = 1800 MVA
Winding type	Y/Δ Turn ratio	K = 230 kV/341.3 kV
Leakage reactance		LT = 0.15 p.u.

H-MMC

Arm reactance	*L*0 = 0.096 H
Capacitance per SM	C/N = 30 μF

DC system

DC voltage	U-dc = +320 kV

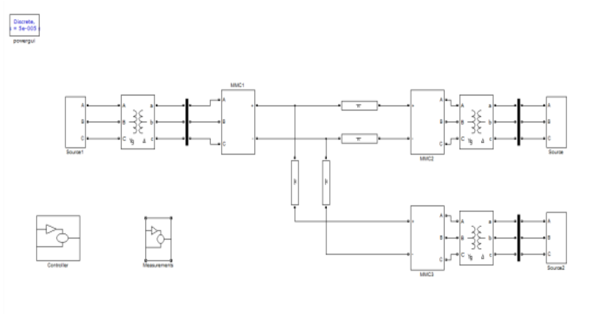
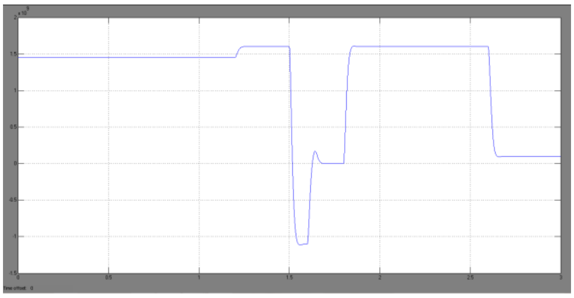
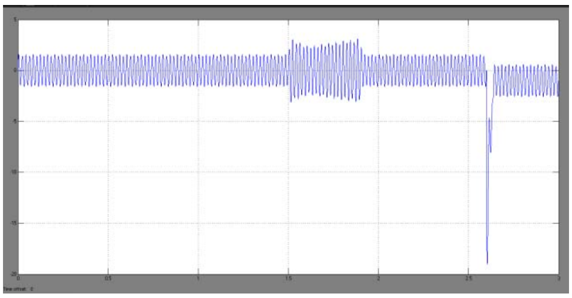


Fig: 4.3 Simulation diagram of single terminal M.M.C system with new parameter



Graph: 4.6 Waveform of active power



Graph: 4.7 Waveform of top limb current in phase-A.

5. Conclusion

The proposed scheme comprises the primary division of the vital model time step for modular-multilevel-converter and the complete propose scheme of finest modular-multilevel-converter levels for electro-magnetic transient reading. The anticipated period choice scheme can authentically illustrate the entire $N + 1$ modular-multilevel-converter potential intensity with modulation ratio $k = 1$ and the time step can't be several crest to circumvent drop potential intensity, it is the initial involvement of scheme. Observed finest modular-multilevel-converter levels are designed by arc normalized from the purpose virtual faults of stable, AC and DC transient confiscations with the individual user given consequence weights.

The thevenin equivalent modular-multilevel-converter cell use in the future elucidation will be fulfill both the *HVDC* system and control design together with the inside sub module fault states and analogous lower level security and idleness arrangement approach devise, etc.,

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