Output voltage regulation of Modular Multilevel Converter used for HVDC transmission

Dr. S. Prakash, Professor/E.E.E Department, BIHER-BIST, Chennai, E-Mail: prakash.eee@bharathuniv.ac.in,
Dr.A.suresh, Professor, Amet University, Chennai. E-Mail : drsuresha@ametuniv.ac.in
B. Arulmozhi, P.G.Scholar, BIHER - BIST, Chennai, E-Mail: arulmozhinehru@gmail.com

Abstract—**In this paper, the main idea is to describe the operation of this converter system mathematically, and suggest a control method that offers stable operation in the whole operation range. Voltage Sourced Converters (VSC) are being used in High Voltage Direct Current (HVDC) power transmission to convert electrical power from AC to DC and vice versa and has the significant proportion of future DC transmission schemes. Therefore, this project presents a high-performance Genetic algorithm based PID control in order to control the output voltage of the three phase MMC under various conditions and loads. Two modular multilevel topologies are proposed to step up or step down dc in medium- and high-voltage dc applications. The MMC is built up by identical, but individually controllable sub module. Therefore the converter can act as a controllable voltage source, with a large number of available discrete voltage steps. The control methods are then implemented on a model with model is built up to show the presentation of this converter and the results experimented in MATLAB/SIMULINK, in order to obtain the controllable voltage at the output.**

Keywords—MMC, output voltage regulation, GA based PID

I. INTRODUCTION

With the pattern of expanding in the entrance of distributed energy resources, the VSC (Voltage Source Converter) is turning into a key job player in coordinating these sustainable power source assets with the grid system in conventional. Additionally, it is being utilized as a key module in various power electronic based gadgets, to understand contrast difficulties in the power system; beginning from incorporating renewable power source assets to HVDC (High Voltage Direct Current) applications. In any case, to satisfy the rising needs of power abilities and consonant execution of converters, a VSC based innovation, MMC (Modular Multilevel Converter) is rising as an ideal answer for a wide scope of utilizations[1-4]. The particular topology of MMC empowers to manufacture high voltage converters with a higher versatility and adaptation to internal failure. By expanding the quantity of voltage levels in the yield utilizing more sub modules, the power capability can be expanded and the exchanging frequency can be adequately decreased[5-8]. Besides, as the harmonics of the yield voltage in output side are decreased because of expanded voltage levels, less filtering is required thus improving the smallness of the system is achieved.

The first MMC based HVDC transmission venture, the Trans Bay Cable, was charged in 2010 by Siemens. Notwithstanding HVDC transmission applications, the MMC innovation is being researched for a wide scope of uses, for example, railroad nourishing interties and medium voltage mechanical drives for its various advantages[9-12]. Subsequently, it is a current research area where examinations focusing on a profound understanding and ideal answers for model development, modulation plans, control methodologies, issue investigation.

As a model is the structure obstruct for all examinations and investigation, this proposition will concentrate on displaying of MMC. Up until this point, various topologies of MMC have been proposed tending to explicit concerns. The main component of MMC-HVDC systems are the converters. There are several types of MMC, including but not limited to: Half-bridge (HB), Full-bridge (FB) and Alternate Arm Converter (AAC) [13]. This can be particularly useful for HVDC schemes employing overhead transmission lines, however for HVDC grids using cables, a DC side fault is likely to be permanent and hence the need for fault blocking converters is not yet apparent.

Furthermore, the HB-MMC is the only type of MMC which is commercially in operation. The FB-MMC and the AAC are referred to as fault blocking converters as they are able to block the current flowing through the converter in the event of a DC side fault. Be that as it may, a few suspicions in the model, for example, overlooking the harmonics of the switches, were made and along these lines it has a misfortune for it can't model the elements of the system. Thusly, it can't be utilized for additional control system examination, for example, in the structure and assessment of the closed loop control for constant voltage regulation of the output voltage [14-15].

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II. PROPOSED SYSTEM

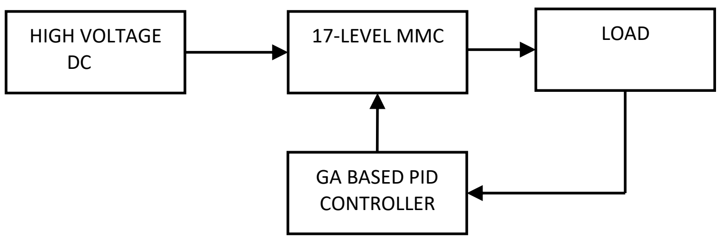

Fig 1. Block diagram of proposed system

This paper proposes the 17-level MMC with closed loop regulation of output voltage shown in fig 1. The High voltage of DC is given to the MMC which converter DC to AC of 17-level. The required load voltage has been done by the GA based PID controller along with multilevel control strategy.

III. Material and Methods

In this section the implementation of output voltage regulation of MMC is explained in detail.

A. MMC

The main component of MMC-HVDC systems are the converters. There are several types of MMC, including but not limited to: Half-bridge (HB), Full-bridge (FB) and Alternate Arm Converter (AAC). The FB-MMC and the AAC are referred to as fault blocking converters as they are able to block the current flowing through the converter in the event of a DC side fault. This can be particularly useful for HVDC schemes employing overhead transmission lines, however for HVDC grids using cables, a DC side fault is likely to be permanent and hence the need for fault blocking converters is not yet apparent. Furthermore, the HB-MMC is the only type of MMC which is commercially in operation. Considering that the majority of proposed MTDC systems are dominated by submarine cables, this paper focuses on the HB-MMC. The basic structure of a three-phase HB-MMC is shown in fig 2.

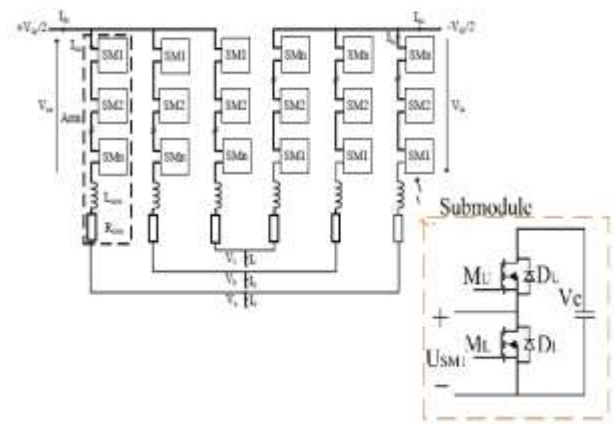

Fig 2. MMC structure

Since the MMC is a multi-level converter, the voltage harmonics generated are smaller than in a two-level converter, thus reducing the values of the reactive components of the filter, which can even be eliminated in some cases

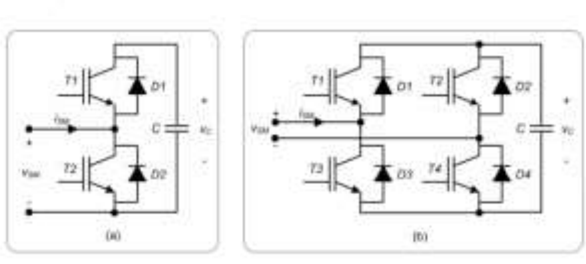

Fig 3. Switching module (SM) topologies: (a) half bridge; (b) full bridge

The number of discrete voltage levels the MMC is able to produce is dependent upon the number of SMs in the converter arms. the harmonic content of the output waveform decreases but the computational efficiency of the MMC converter model also decreases. Commercial MMC-HVDC schemes contain hundreds of SMs per converter arm. Determining the number of converter levels to model is therefore typically a compromise between harmonic content of the output waveforms and the computational efficiency of the model. In our studies a 17-level MMC was found to offer a good compromise by meeting the IEEE519 harmonic voltage limits without having a significant impact on the simulation time.

IV. Control strategy

The proposed control scheme shown in fig 4.3 provides the output voltage control from 17 level MMC converter. The grid voltage is taken as input and they are converter D-Q component by parks transformation.

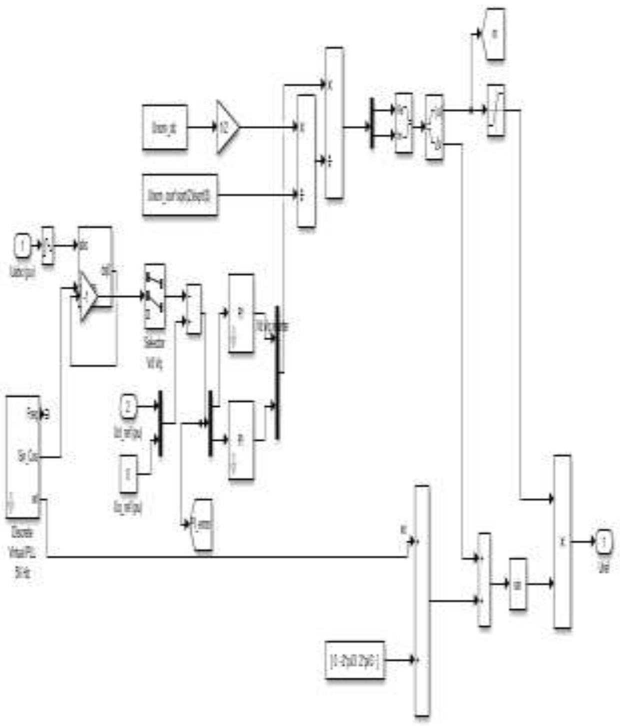

Fig 3. Control scheme for output voltage control

A. Park Transformation:

The abc_to_dq0 Transformation block computes the direct axis, quadratic axis, and zero sequence quantities in a two-axis rotating reference frame for a three-phase sinusoidal signal. The following transformation is used:

$$V_d = \frac{2}{3}(V_a \sin(\omega t) + V_b \sin(\omega t - 2\pi/3) + V_c \sin(\omega t + 2\pi/3)) \quad (1)$$

$$V_q = \frac{2}{3}(V_a \cos(\omega t) + V_b \cos(\omega t - 2\pi/3) + V_c \cos(\omega t + 2\pi/3)) \quad (2)$$

$$V_0 = \frac{1}{3}(V_a + V_b + V_c) \quad (3)$$

The transformation is the same for the case of a three-phase current; you simply replace the Va, Vb, Vc, Vd, Vq, and V0 variables with the Ia, Ib, Ic, Id, Iq, and I0 variables. This transformation is commonly used in three-phase

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electric machine models, where it is known as a Park transformation. It allows you to eliminate time-varying inductances by referring the stator and rotor quantities to a fixed or rotating reference frame. In the case of a synchronous machine, the stator quantities are referred to the rotor. Id and Iq represent the two DC currents flowing in the two equivalent rotor windings. winding directly on the same axis as the field winding, and q winding on the quadratic axis), producing the same flux as the stator Ia, Ib, and Ic currents.

One can use this block in a control system to measure the positive-sequence component V1 of a set of three-phase voltages or currents. The Vd and Vq (or Id and Iq) then represent the rectangular coordinates of the positive-sequence component. The converted d-q component is compared with the reference value of d-q component through the PI controller.

B. PID controller:

A variation of Proportional Integral Derivative (PID) control is to use only the proportional and integral terms as PID control. The PID controller shown in fig 4 is the most popular variation, even more than full PID controllers. The value of the controller output is fed into the system as the manipulated variable input.

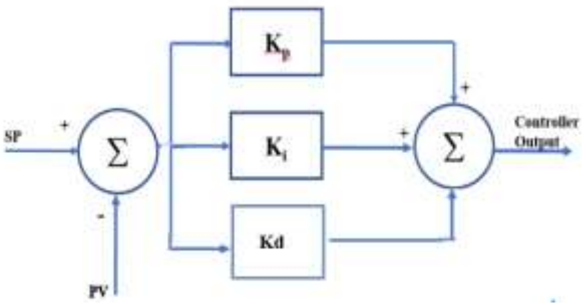

Fig 4. PID control block diagram

The tuning parameters of PID control i.e.,Kp,Ki and Kd is tuned by genetic algorithm based optimization.

C. Genetic algorithm

Genetic Algorithm was envisaged by John Holland at the university of Michigan, in the 1970s. It is based on the Darwinian evolution theory of survival of the fittest which states that the fitter and stronger individuals in a population have a higher chance of creating off springs for the next generation by random mutation and natural selection.

The pivotal contribution of genetic algorithm is a methodology for systematized random search and optimization. Researchers attempt to simulate complex biological evolutionary processes to discover how evolution can propel living beings towards a higher level of intelligence which has resulted in the concept of the genetic algorithm. The flow chart for this algorithm which is based on the evolutionary principle of natural selection has been shown in fig 5 .

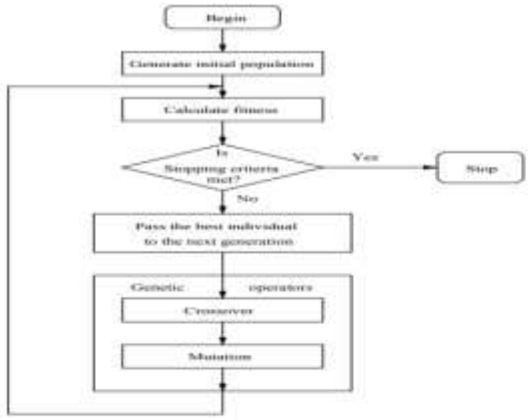

Fig 5. Flowchart of genetic algorithm

V. SIMULATION RESULTS

Fig 6 shows the overall simulation diagram. The input voltage of HVDC transmission line is shown in fig 7. The MMC output voltage and current is shown in fig 8 & 9 respectively. The MMC output voltage is measured in pu (1pu= 2.5107e+04V). The 17 level voltage of MMC converter with 20 MOSFETs is shown in fig 10. Fig 11 & 12 shows the grid output voltage and current. The output grid voltage also measure in pu (1pu= 1.5*MMC output voltage) The Total Harmonics Distortion (THD) is shown in fig 13.

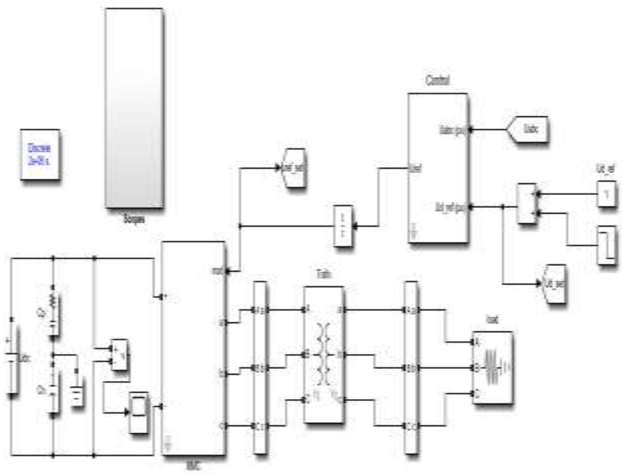
Fig 6. Overall simulation diagram

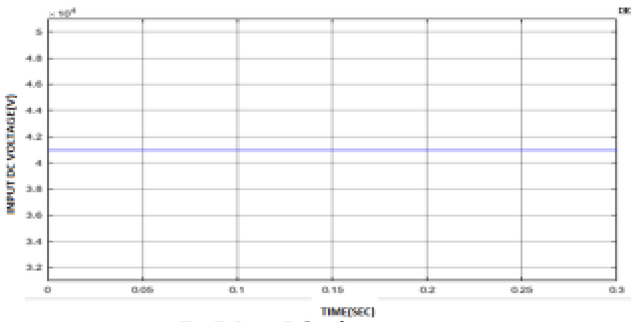

Fig 7. Input DC voltage

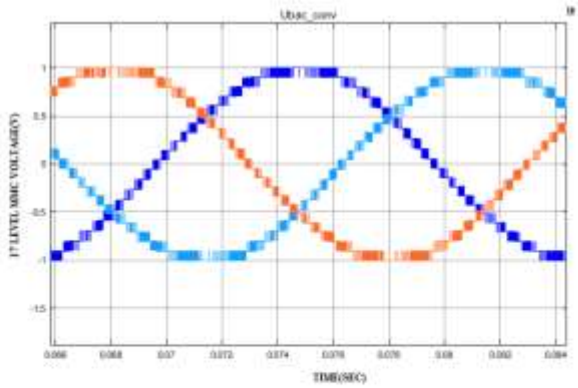

Fig 7. MMC 17 level output voltage

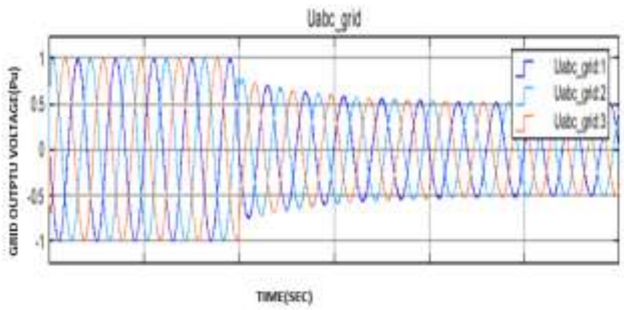

Fig 8. Grid output voltage with step response of 1-0.5 pu with step time of 0.1

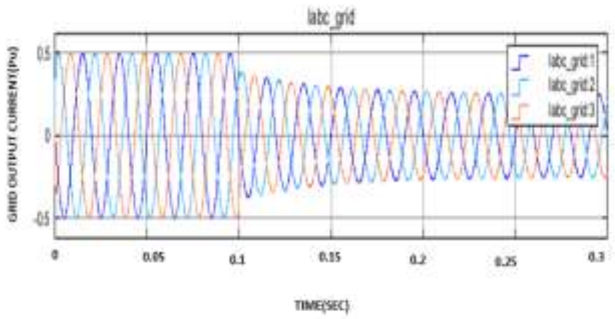

Fig 9. Grid output current

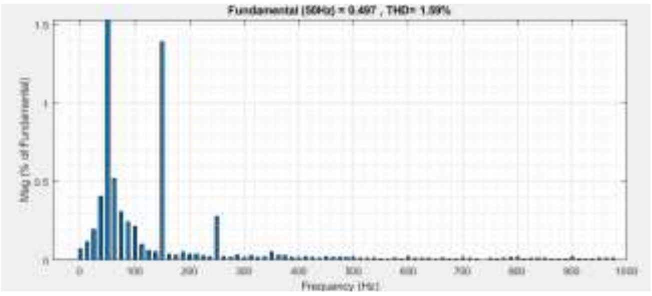

Fig 10. THD

VI. Conclusion

The proposed paper implements the output regulation of MMC output voltage for different load conditions. The GA based PID controller is chosen to implement the control strategy using d-q transformation. The simulation results shows the proposed methodology lessens the inaccuracy in tuning of PID gains. The less ripples makes the SRM motor to run with less noise and smoothness. The proposed 17 level MMC converter has the ability low leakage current as well as decrease in switching losses with less harmonics distortion. The THD value of grid current is determined by using FFT analysis which is 1.59%.

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