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Generation of High Voltage Using Modular Multilevel Converter

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Abstract: To generate high voltage AC pulses, series connected semiconductor devices can be considered with equal voltage sharing between them. The VSI can employ to generate high AC voltage from HVDC supply. To reduce the complexity introduced by series connected devices in VSI the modular multi level converter can be used. For proper operation of MMC capacitor voltage must be balance. The no. of voltage levels of MMC can be determined by the HVDC supply voltage and the voltage rating of semiconductor devices used in MMC. The measuring devices must be connected across capacitors to sense the balanced voltage. It causes the complexity and increases the cost of the system. In this paper the generation of high voltage AC pulses using MMC with pulse displacement technique is proposed. It decreases the requirement of measuring devices, system sensitivity and complexity. A detailed explanation of the proposed system is presented in this paper. The simulation results are validated.

Keywords— MMC, PWM technique, Pulse Disposition, VSI

I. Introduction

A great development in the power electronic devices field with turnoff capacity, like GTO and IGBT makes the voltage source converter [1] getting more important for high voltage direct current transmission. This is called VSC-HVDC. It provides substantial technical and economical advantages for different applications compared to normal HVDC transmission system based on [2] thyristor technology. VSC is more essential part of VSC-HVDC transmission system. For high power and high voltage applications, [3] self turnoff devices are used. In these VSC a series connected devices are used which cause the stress on VSC valves and EMI at higher level in improper control conditions.

To reduce these switching power losses multilevel VSC introduced it includes [4] diode clamped, capacitor clamped type and cascaded H bridge type. The design of diode clamped and capacitor clamped have higher complexity, increases with no. of voltage levels. The cascaded H Bridge [7] can be used for high voltage generation but the main drawback of it is the requirement of high numbered separate DC supplies. The push pull inverter can also be used to produce [8] high voltage pulses but in real time applications it requires a high voltage switch at the load side of the system.

The capacitor diode voltage multipliers in the modular switched capacitor pulsed power generators were maintained the voltage ratings and number of components as minimum as possible [9]. This generates the output pulse as unipolar. To get bipolar pulses the H Bridge has to be connected at the load side. The modular multilevel converter has become popular in [10] high power transmission, distribution systems and also in industrial applications. In this paper MMC with pulse displacement technique used to generates the high voltage AC pluses. The basic structure of MMC is cascade connected of cells or sub modules per arm.

MMC can generate high ac voltage with low voltage series connected capacitors and relatively low voltage semiconductor devices. Due to this it can handle the high power. The best merits of proposed system are defined as:

1) The ability to control the output voltage magnitude.
2) The ability to generate different shapes of output pulses.
3) Without sensing the capacitor voltage it is balanced.
4) Decreases the system sensitivity and complexity.
5) High efficiency.

A simulation of seven levels MMC is used to generate the HVAC pulses with pulse disposition technique. The simulation results are effective.

II. Modular Multilevel Converter

Modular multilevel converter is one of the new technologies that are developed for the multilevel converter topology. It has some advantages over the conventional converters such as high capacity, high efficiency and low total harmonic distortion.

MMC consists of two arms one as upper and other as lower per phase leg, where each arm has series connected, identical sub modules and series inductor having internal resistance. The Sub Modules in each arm has to be controlled to produce the required ac voltage. The inductor reduces the circulating currents and high frequency components in each arm. The half bridge sub module consists of two valves and a capacitor. The valves are made up of an IGBT and a freewheeling diode in anti parallel. In normal operation, only one of the valves is switched on at a given instant in time. Depending on the current direction the capacitor can charge or discharge.

For n level converter, 2(n-1) SMs are necessary where n is no of levels. For example 7 level converter requires 12 SMs. To obtain low capacitance voltage ripples at higher loading conditions the SMs capacitance must be selected. The capacitor voltages must be balanced for the successful operation of MMC.

MMC can operate at fundamental and high switching frequency PWM. The high efficiency can obtain with lower switching frequency which causes lower switching losses. Keeping in mind the end goal to create yield at multilevel AC voltage through different levels of DC inputs, operation of semiconductor devices must be done in such a way, to the point that the normal basic voltage is accomplished with lower harmonic distortion.

The voltage of every SM capacitor is $\left[V_c = \frac{V_{dc}}{(n-1)}\right]$. The SM voltage (V_{sm}) can be zero or V_c. The arm reference voltages are given by

$$V_u = \frac{V_{dc}}{2} - V_0$$

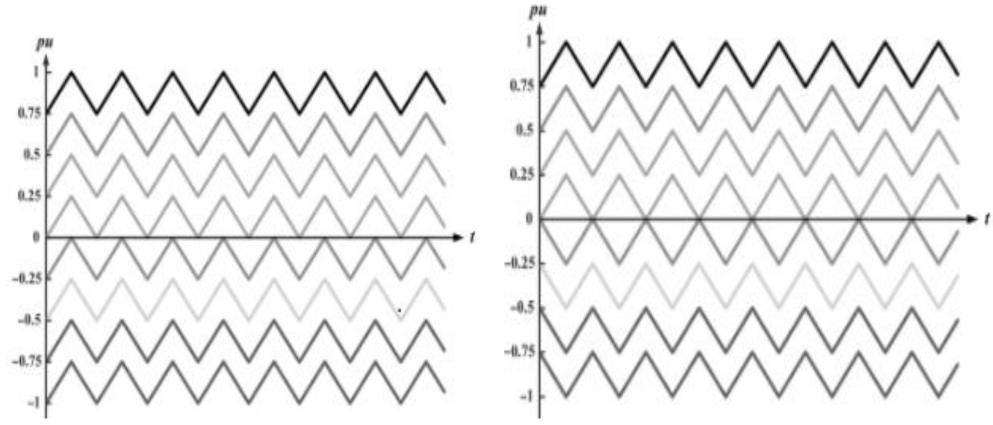
$$V_l = \frac{V_{dc}}{2} + V_0$$

Where V_c is capacitor voltage, V_1 is lower arm voltage, V_u is upper arm voltage, V_{dc} is dc source voltage and V_O is output voltage.

III. Modulation of The MMC

Modulation Techniques

Various pulse-width modulation (PWM) techniques, based on using a single reference waveform, that have been developed/proposed for the MMC include: Carrier-disposition PWM techniques (CD-PWM). These techniques require *n* identical triangular carrier waveforms displaced symmetrically with respect to the zero axis. The comparison of the phase voltage reference waveform with the carriers produces the desired switched output phase voltage level. Voltage transitions corresponding to a triangular carrier are associated with the insertion/bypass of a particular SM. Based on the phase shift among the carrier waveforms, these techniques are further classified into: (a) phase disposition (PD), (b) phase opposition disposition (POD), and (c) alternate phase opposition disposition (APOD).



(a)Phase Disposition *(b) Phase Opposite Disposition*

Fig.1. Carrier Signals

The disadvantages of using these techniques include unequal distribution of voltage ripple across the SM capacitors, which impact the harmonic distortion of the ac side voltages and large magnitude of circulating currents. To improve the harmonic distortion of the ac-side voltages, a simple carrier rotation technique, a modified carrier rotation technique, or a signal rotation technique is used to equalize the voltage distribution across all the SM capacitors. In spite of the proposed Sub Module capacitor voltage balancing techniques, the output voltages have a relatively high Total Harmonic Distortion (THD).

In this paper pulse disposition (PD) pulse width modulation technique is proposed for high voltage generation using MMC, to balance the voltage across SMs capacitor without sensing it and to reduce the complexity introduced by the measuring devices. The principle and operation of the seven level modular multilevel converter is to generate high voltage Ac pulses is described.

In Phase Disposition (IPD)

In the proposed method, the carrier based implementation the phase disposition PWM scheme is used. In seven level MMC the reference phase modulation signal is compared with six (n -1 in general) triangle waveforms. The rules for the in phase disposition method, when the number of level N = 7, are

- The N –1 = 7-1=6 carrier waveforms are arranged so that every carrier is in phase.
- The converter is switched to $+V_{dc}/2$ when the reference is greater than both carrier waveforms.
- The converter is switched to zero when the reference is greater than the lower carrier waveform but less than the upper carrier waveform.
- The converter is switched to - $V_{dc}/2$ when the reference is less than both carrier waveforms.

In the carrier based implementation, at every instant of time the modulation signals are compared with the carrier and depending on which is greater, the switching pulses are generated.

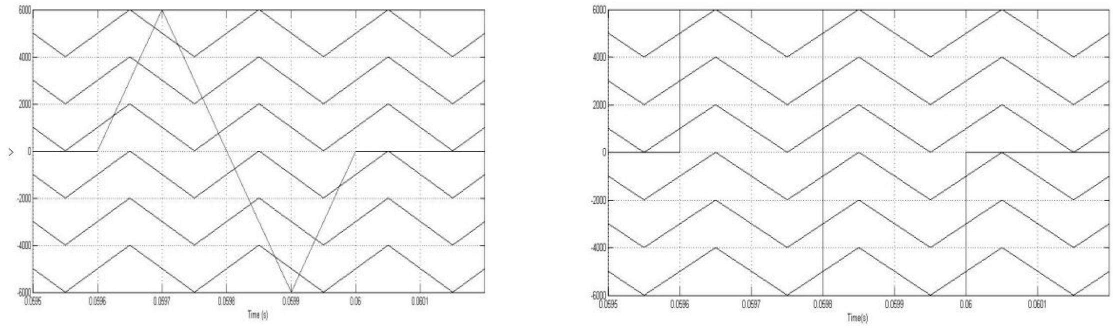


Fig.2. PD Pulses Generation for an Output Voltage Magnitude of $V_{dc}/2$.

IV. Proposed seven level MMC for high voltage generation

In this paper, a seven level modular multi level converter is proposed to generate the high voltage AC pulses. In this system, the pulse produced by the Pulse Disposition balance strategy is traded every fundamental cycle of the output voltage among the Sub Modules to ensure the introduction of the Sub Modules to a similar loading conditions resulting in capacitors' voltages.

Principle of Operation

The proposed seven-level modular multilevel converter works with pulse disposition pulse width modulation. In this the gate pulses of the devices are given by switching circuit. The activated cells per leg is (n-1) where n is number of converter voltage levels.

The seven level MMC based high voltage AC pulse generator have two arms one is upper arm and other is lower arm. Each arm consists of six SMs and one inductor (L). The main requirement in this is to ensure that the capacitor of each SM should be pre charged to a certain value for the successful operation of MMC and to prevent the starting transients. The capacitor voltage is $\left[V_c = \frac{V_{dc}}{(n-1)}\right]$.

In proposed system, the PD modulation technique compares the reference signal with carrier signals and generates the pulses m_1 – m_6. To obtain require stepped output voltage the triangular or sinusoidal signals should consider. The frequency of the carrier signal is $\left[f_s = \frac{1}{T_s}\right]$.

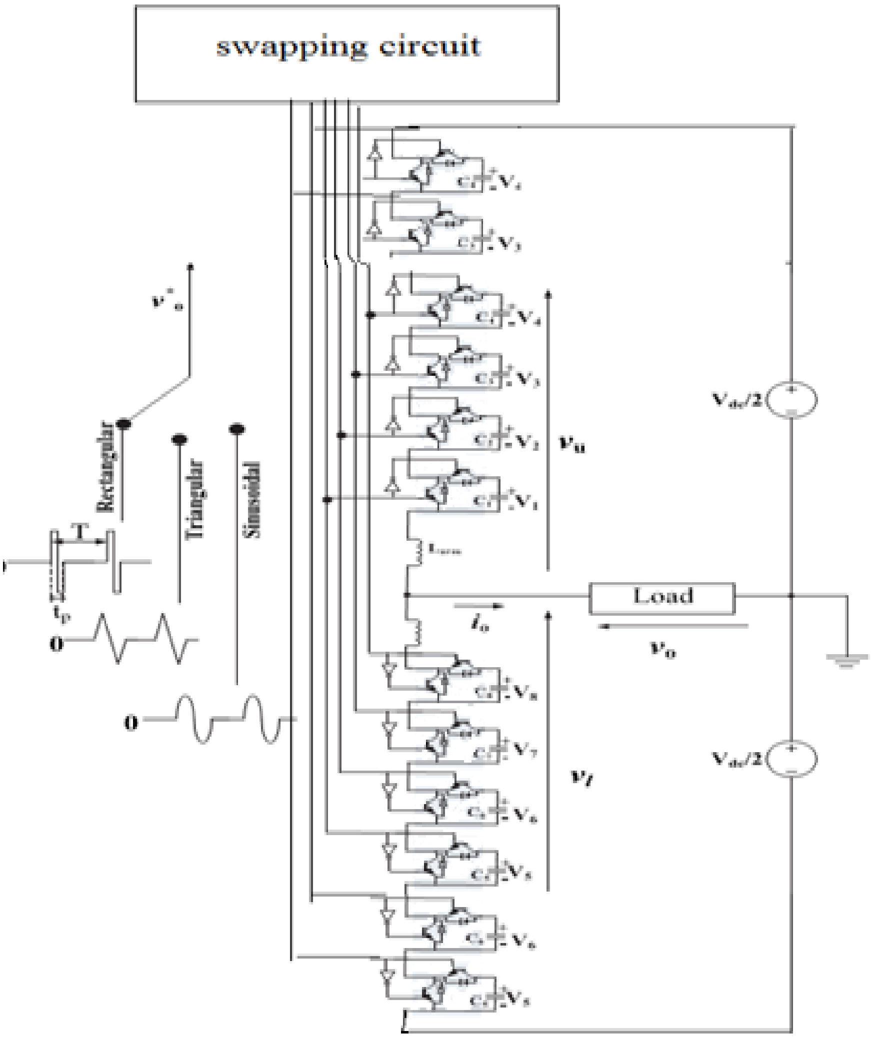


Fig.3. Seven Level Modular Multilevel Converter

The generated pulses m_1 – m_6 are considered with each fundamental cycle (T) between SMs these are the switching signals s_1 – s_6 . These switching signals and their compliment signals are used to operate the SMs upper and lower arms. The switching pattern will obtain in complete rotation of six fundamental cycles. The switching cycles will get a complete rotation of every fundamental cycle (n-1) for n level inverter

Switching circuit

The desired switching pattern is shown in table. This circuit is developed on controlled chip with a program. A set of signals must be generated i.e. pulsed signals S_{T1} – S_{T6} internally in controller to get desired functionality of devices. The pulse width and period of each pulsed signal is T and (n-1) T. where T is raising edge span between two pulses. The set of pulsed signals S_{T1} – $S_{T6,}$ PD signals m_1 – m_6 are developed as digital logic circuit to get desired switching signals s_1 – s_6 can explained as

$$s_1 = m_1S_{T1} + m_2S_{T2} + m_3S_{T3} + m_4S_{T4} + m_5S_{T5} + m_6S_{T6}$$

$$s_2 = m_2S_{T1} + m_3S_{T2} + m_4S_{T3} + m_5S_{T4} + m_6S_{T5} + m_1S_{T6}$$

$$s_3 = m_3S_{T1} + m_4S_{T2} + m_5S_{T3} + m_6S_{T4} + m_1S_{T5} + m_2S_{T6}$$

$$s_4 = m_4S_{T1} + m_5S_{T2} + m_6S_{T3} + m_1S_{T4} + m_2S_{T5} + m_3S_{T6}$$

$$s_5 = m_5S_{T1} + m_6S_{T2} + m_1S_{T3} + m_2S_{T4} + m_3S_{T5} + m_4S_{T6}$$

$$s_6 = m_6S_{T1} + m_1S_{T2} + m_2S_{T3} + m_3S_{T4} + m_4S_{T5} + m_5S_{T6}$$

The generated gate pulses s_1 – s_6 are identical, but shifted in time by using the switching circuit. This technique balances the capacitor voltage.

Gate pulses	1stT	2ndT	3rdT	4thT	5thT
S_1	m_1	m_2	m_3	m_4	m_1.....
S_2	m_2	m_3	m_4	m_1	m_2.....
S_3	m_3	m_4	m_1	m_2	m_3.....
S_4	m_4	m_1	m_2	m_3	m_4.....

Table 1: Swapping of PD Pulses with Fundamental Signals

V. Simulation

A simulation model for seven-level MMC has developed.

Dynamic Performance

By using PD pulses, various shapes of pulses like triangular and rectangular pulses are generated by comparing the output voltage reference with carrier signals. The pulse widths of generated PD pulses have different shapes. The gating signals are similar but shifted in time, which maintains the balanced capacitor voltage of SMs. The triangular and rectangular pulses are obtained in simulation results. Those are shown in figs.

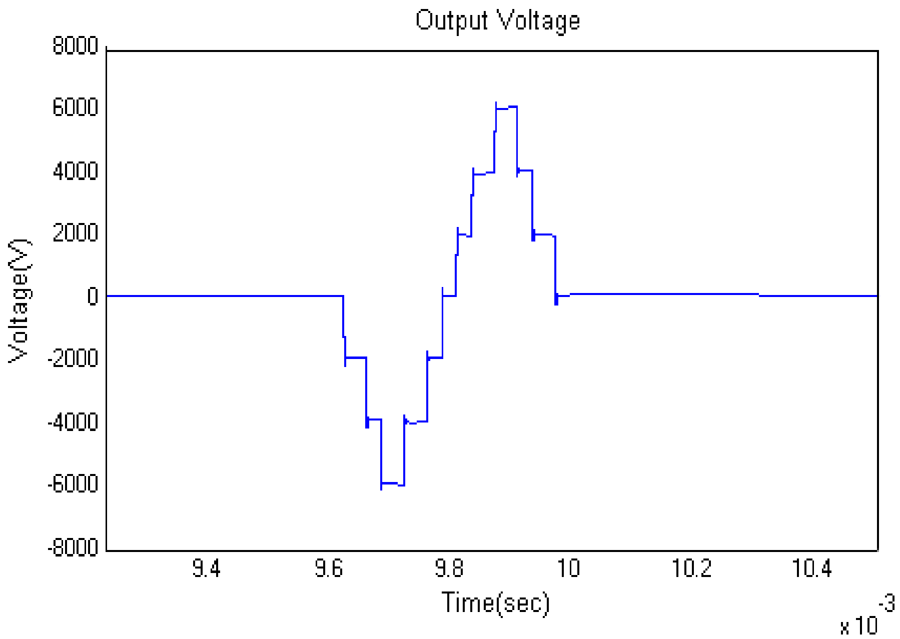


Fig.4. Output Voltage for Triangular Reference Wave

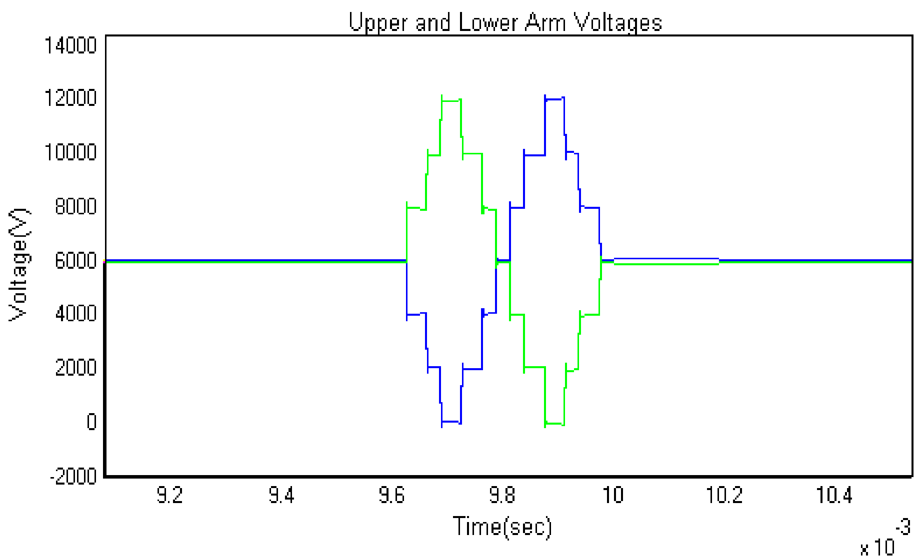


Fig.5. Upper and Lower Arm Voltages for Triangular Reference Wave

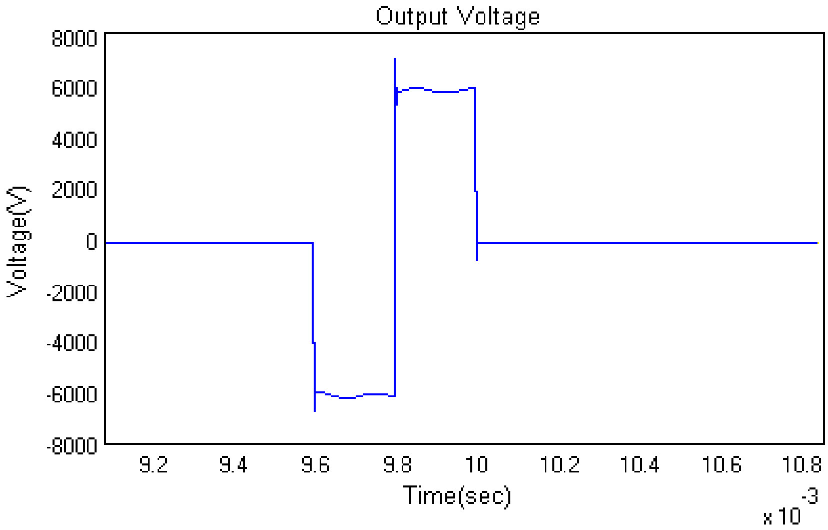


Fig.6. Output Voltage for Rectangular Reference Wave

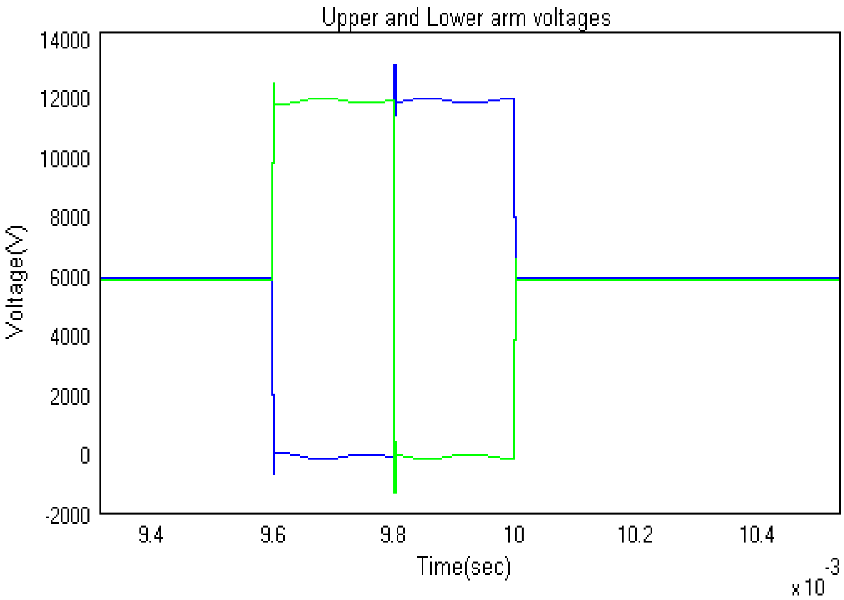


Fig.7. Upper and Lower Arm Voltages for Rectangular Reference Wave

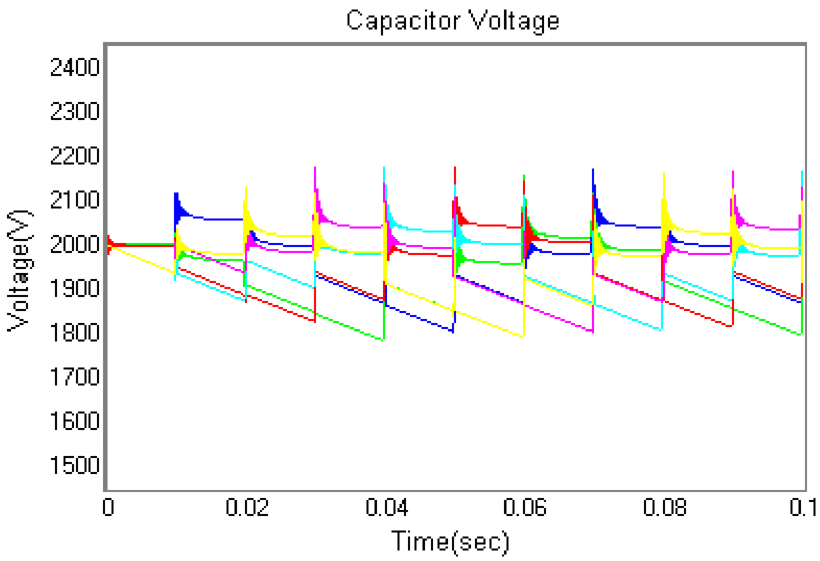


Fig.8. Capacitance Voltages for Rectangular Reference Wave

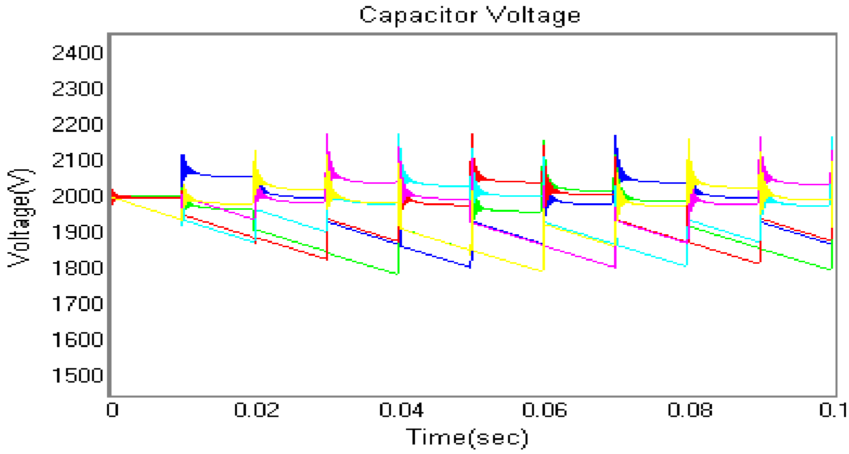


Fig.9. Capacitance Voltages for Triangular Reference Wave

Deactivation Effect of Proposed System

In this the signals will deactivate and activate for some time. In proposed system at t=0.2 s the PD signals deactivated and they are directly connected to the gate signals without switching. Then it is again activated at t=0.7 s by switching circuit. At the deactivating time some SMs will suffer due to unbalanced load on capacitor from higher voltage. If the voltage increases beyond the limits the SMs may get damage. At activating time capacitor voltage regains to its normal position.

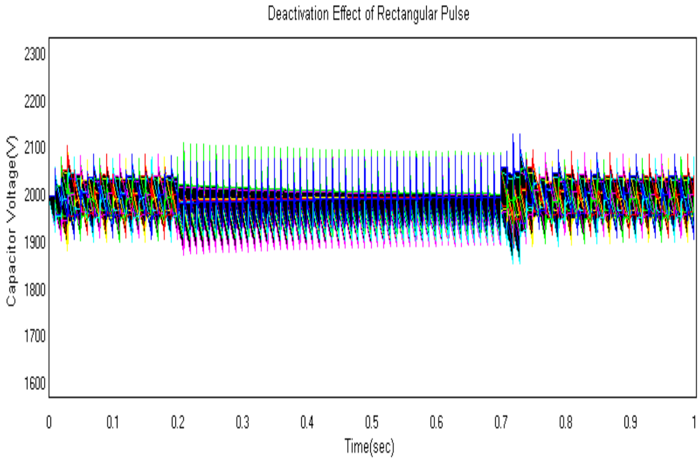


Fig.11. Capacitance Voltages for Deactivation Effect with Triangular Reference Wave

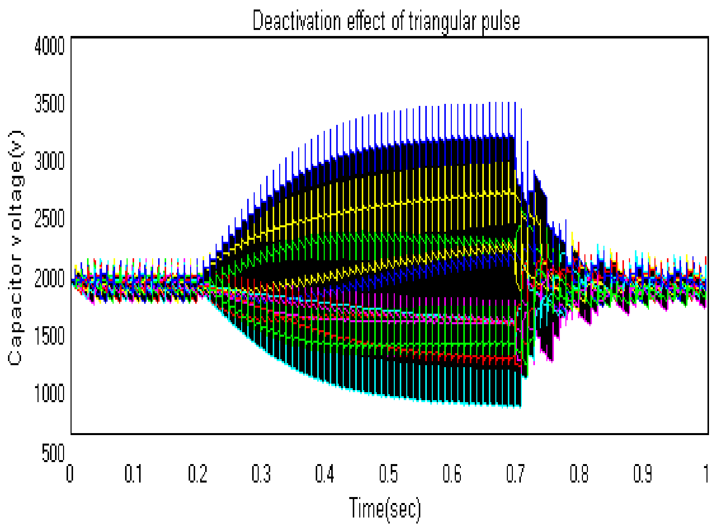


Fig.12. Capacitance Voltages for Deactivation Effect with Rectangular Reference Wave

VI. Conclusion

In this paper, High voltage AC pulse is generator by using MMC is proposed. In this pulse disposition technique is used to balance the capacitor voltage without any measuring devices and also reduces the complexity of the system. The proposed system generates high voltage with low voltage rating devices. It can also generate different types of pulses and also it can control the output magnitude. The proposed seven level modular multilevel converter is explained. The proposed system simulation results are more effective in HV pulse applications. The capacitance value must be selected. The major advantage is that the output waveform is more close to sinusoidal. Higher the number of the levels, more approximate is the waveform to sine wave. So for the motor, it is as good as a supply directly from grid. This reduces the stress on the insulation level of the motor. While increasing the number of levels in multilevel inverter THD value will get reduced.

REFERENCES

[1] G. Ding, G. Tang, Z. He and M. Ding, *"New Technologies of Voltage Source Converter (VSC) for HVDC Transmission System Based on VSC"*, in proc. IEEE power and energy society general meeting, 2008, pp.1-8.

[2] B. R. Andersen, L.Xu, P. Horton, and P. Cartwright, "*Topologies for VSC Transmission,"* IEEE Power Engineering journal, vol. 16, pp.142-150, June 2002.

[3] N. S. Choi, J. G. Cho, and G. H. Cho, "*A General Circuit Topology of Multilevel Inverter*," in Proc. 1991 IEEE Power Engineering Society Transmission and Distribution conf., pp. 96-103.

[4] J.S. Lai, and F. Z. Peng, "*Multilevel Converters a New Breed of Power Converters*," IEEE Trans. Ind. Applicat., vol.32, pp.509-517, May/June 1996.

[5] L. Tolbert, F.Z. Peng, and T. Habetler, "M*ultilevel Converters for Large Electric Drives*," IEEE Trans. Ind. Applicat., vol. 35, pp. 36-44, Jan/Feb.1999.

[6] T. F. Cronje and P.T. Gaynor, *"High Voltage and Frequency Bipolar Pulse Generator Design for Electroporation Based Cancer Therapy,"* in Proc.Austral. Univ. Power Eng. Conf. (AUPEC), Sep./ Oct. 2013, pp.1-7.

[7] J. H. Kim, I.W. Jeong, H.J. Ryoo, S. Shenderey, J. S. Kim, and G.H. Rim, "Semiconductor Switch-Based Fast High-Voltage Pulse Generators;" in 14th IEEE Int. Pulsed Power Conf. Dig. Tech. papers. (PPC), vol. 1. Jun.2003, pp. 665-668.

[8] J. H. Kim, S. C. Lee, S. V. Shenderey, J. S. Kim, and G.H. Rim, "A High Voltage Bi Polar Pulse Generator Using Push Pull Inverter," in Proc .Conf. Ind. Electron. Soc., vol. 1. Nov. 2003, pp. 102-107.

[9] M. Rezanejad, A. Sheikholeslami, and J.Adabi, "High Voltage Modular Switched Capacitor Pulsed Power Generator," IEEE Trans. Plasma Sci., vol. 42, no.5, pp. 1373-1379, May 2014.

[10] A. Lesnicar and R. Marquardt, "An Innovative Modular Multilevel Converter Topology Suitable For A Wide Power Range," in Proc. IEEE Bologna Power Tech Conf., Bologna, Italy, Jun. 2003, pp.1-6.