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Simulation of SPWM based Multilevel DC-DC Converter with Photovoltaic System

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Abstract: This paper explains SPWM based multilevel DC-DC converter with photovoltaic system. This system consists of isolated power processing unit, series and parallel switching circuits and filter circuit. Isolated power processing unit has one half bridge circuit, 2 full bridge circuit and 3 winding transformers based as primary and secondary part. Half bridge circuit is switched continuously to produce two output dc voltages through secondary transformer. And the series & parallel circuit used to control dc output voltages generated in full bridge circuits. The applied input voltage can be boosted triple times, and the switching pulses for controlled switches are generated using sinusoidal pulse width modulation (SPWM) technique. The simulation results of SPWM based multilevel DC-DC converter with photovoltaic system verified using matlab/simulink.

Keywords: Isolated power processing unit, Half & Full bridge circuit, sinusoidal pulse width modulation (SPWM), DC-DC converter.

1. INTRODUCTION

The main causes of switching losses, switching harmonics and electromagnetic interference (EMI) is voltage jump occurs during switching condition [1], [2]. With the help of multilevel converter, the voltage jumps can be avoided. The output filter purpose also minimized to increase the power density of generated output voltage [3]. Multilevel DC-DC converters can be used for isolated and non-isolated applications. To improve the power efficiency, to minimize the switching devices and to increase power density many multilevel DC-DC converters were implementated in recent years [4].

Modular multilevel power converters widely used in dc-dc conversion, dc-ac conversion and ac-dc conversion applications. The intrinsic functioning machine general between these topologies is to circulate ac currents in order to attain energy balance among their modules structures [5]. Two diode clamped multilevel inverters are applied at both sides of isolation transformer to generate multilevel voltages at both full bridge circuits. The voltage variation is caused by switching of these isolated multilevel dc to dc converters are less than that the conventional isolation multilevel dc to dc power processing circuit. So the usage of L-C or C filters is minimized, at the same time power density also increased [6].

Solar energy reception can be captured and either stored for heating purposes or it can be converted to electricity [7].Solar cells or PV arrays can be installed in open spaces, building rooftops for this purpose. But the ever evident fallacy of PV arrays is in not being operable during overcast conditions. Other major problem in PV system is of parasitic capacitance which exists between the array base and the ground [8]. This results in leakage currents which could enter the inverter and disrupt its functioning. PWM (Pulse width Modulation) techniques can be used to control the power in these cases. In high power medium voltage applications, power losses need to be reduced as their magnitude tends to increase. SPWM technique is useful for that [9].It is a very simple and accurate modulation technique for multilevel inverters. Here, a sinusoidal modulation waveform is compared to a triangular carrier waveform to produce pulses for the MLI switches. As stated earlier, it has lower harmonic distortion, lesser stresses on switches and hence lower losses [10].

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2. PV SYSTEM

A photovoltaic cell or array is a semiconductor device that converts light to electrical energy by photovoltaic effect principle [11]. A PV array consists of several photovoltaic cells in series and parallel connections. Series connections are responsible for increasing the voltage of the module whereas the parallel connection is responsible for increasing the current in the array. Typically a solar cell can be validated by a current source and an inverted diode connected in parallel to it. It has its own series and parallel resistance. Output current from the Photovoltaic array is,

$$I = S_{ic} - I_d (1)$$

$$I_d = I_g(\exp(hVd/jT) - 1) \quad (2)$$

Where I_g is reverse saturation current of diode, h is the electron charge, V_d is the voltage across diode, *j* is Boltzmann constant, T is junction temperature.

A. MPPT (Maximum Power Point Tracking)

MPPT is the technique to get maximum power out of the PV arrays. Thevenin's theorem is applied here, according to which maximum power is dissipated in the load when the load impedance is equal to the circuit impedance [12]. Here P&O (Perturb and Observe) technique of MPPT is used. The controller adjusts the PV array voltage every time it undergoes a change, or perturbation. For the voltage increment, if the calculated change in power is greater than zero, then it keeps on shifting the voltage in that direction till the change in power becomes negative. When the incremental power increases, then a pulse is sent by the MPPT controller to the switch so that the power is delivered to the load. Flow chart of P&O algorithm is shown in Figure 1.

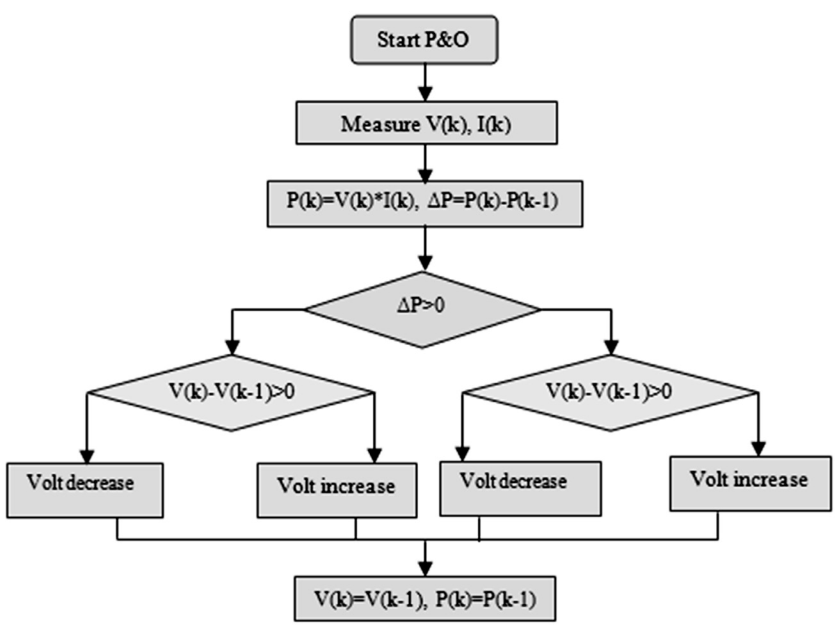

Figure 1: Flow chart of Perturb & Observe algorithm

3. STRUCTURE OF MULTILEVEL DC-DC CONVERTER

The structure of Multilevel DC-DC converter is shown in Figure 2. it consists of isolated power processing unit, series and parallel switching circuits and filter circuit. Isolated power processing unit has one half bridge circuit with C1 & C2 capacitors and S1 & S2 switches, 2 full bridge circuits with 4 diodes & 1 capacitor. 3 winding transformers based as primary and secondary part (Na, Nb1 & Nb2).

The isolated power processing unit switched continuously to generate 2 output voltages from the secondary transformer side (Nb1 & Nb2, which consists of equal number of windings). And series & parallel switching circuit has 2 diodes (Da & Db) and switch S3. The multilevel dc output in the system depends providing appropriate gating pulses to the switches S1, S2 & S3. The switching frequency of the switch S3 is twice that of switches S1 & S2. The operation of this proposed system in 4 modes, based on switching of S1, S2 & S3 switches.

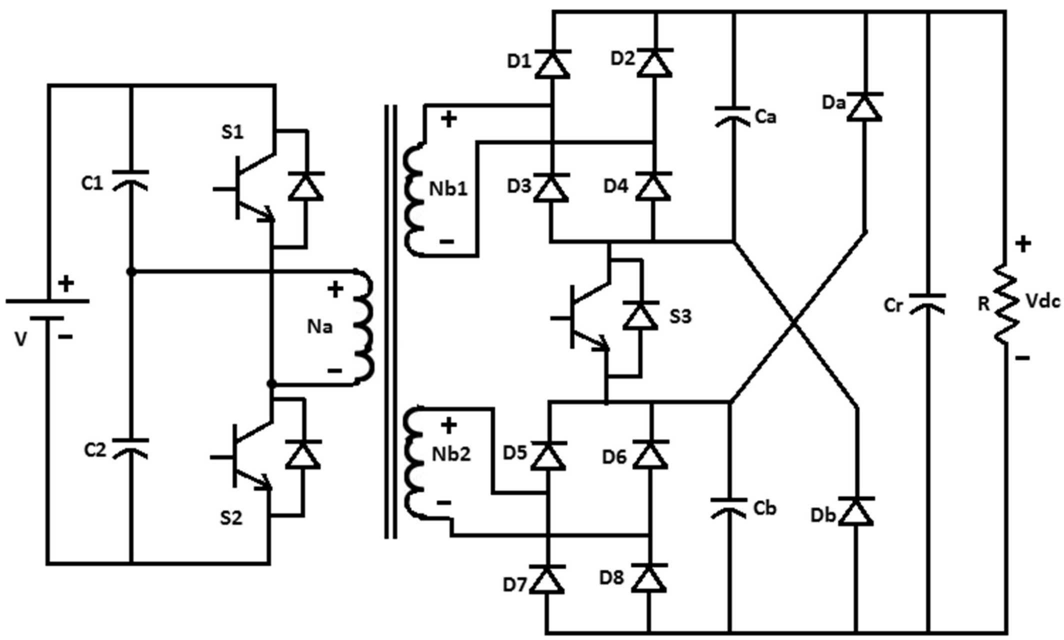

Figure 2: Structure of Multilevel DC-DC converter

Mode 1: Switch S1 is turned ON, switches S2 & S3 off condition. Two output dc voltages from the two full bridge circuits are connected in parallel.

Mode 2: Switches S1 & S3 is turned ON, switch S2 off condition. Two output dc voltages from the two full bridge circuits are connected in series.

Mode 3: Switch S2 is turned ON, switches S1 & S3 off condition. Two output dc voltages from the two full bridge circuits are connected in parallel.

Mode 4: Switches S2 & S3 is turned ON, switch S1 off condition. Two output dc voltages from the two full bridge circuits are connected in series. The proposed system with photovoltaic array as an input is shown in Figure 3 in that MPPT algorithm used to track the maximum power from the PV system. And the output of MPPT provides pulse to the boost converter to increase the input voltage applied to the multilevel dc to dc converter scheme.

4. SINUSOIDAL PULSE WIDTH MODULATION (SPWM)

PWM (Pulse Width Modulation) refers to adjusting the duty cycles (on and off periods) of inverter switch components so that they convert the dc input into ac output. [13] It is advantageous as it reduces the harmonic

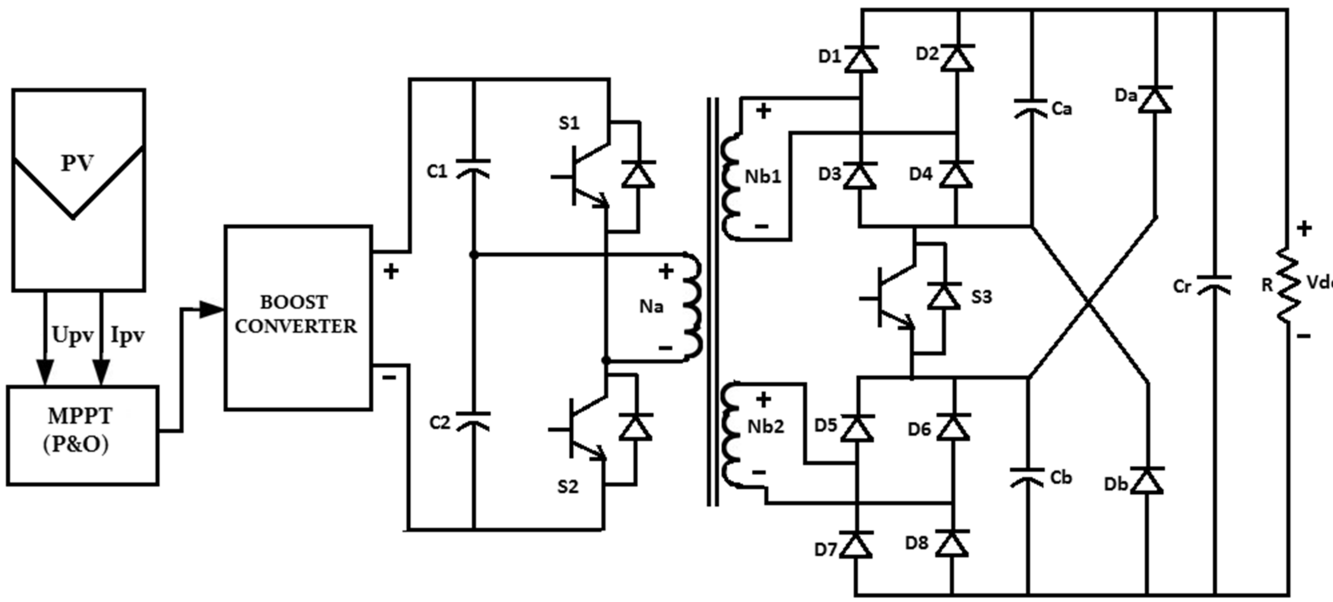

Figure 3: Multilevel DC-DC converter with photovoltaic system

level in the output waveform. Sinusoidal PWM (SPWM) is one such technique where the pulse width varies sinusoidally with respect to its position angle in a switching cycle [14]. A Reference wave is compared with a carrier wave and the resultant pulse is generated. Here a sinusoidal and triangular waveform is the reference and carrier waveform respectively. A comparator gives an output signal whenever the sinusoidal wave amplitude at that time instant is higher than that of the triangular waveform and a pulse is generated according to the comparator output.

Basically in sinusoidal PWM there are two modes; one where the carrier wave is present in both the positive and negative halves. It is called bipolar mode of operation. The second mode is unipolar as shown in figure below where the carrier used unipolar mode of SPWM is shown in Figure 4.

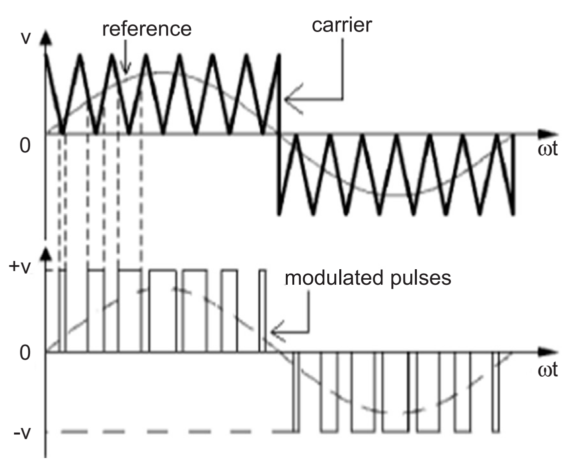

Figure 4: SPWM control

5. SIMULATION RESULTS

The simulation diagram of SPWM based multilevel DC-DC converter with photovoltaic system is shown in Figure 5. The dc output of the PV array which has variations of solar irradiation from 400 W/m^2 to 1000 W/m^2, which is 100V dc output. And it is applied to the proposed multilevel dc-dc converter to generate 3 times of applied input voltage.

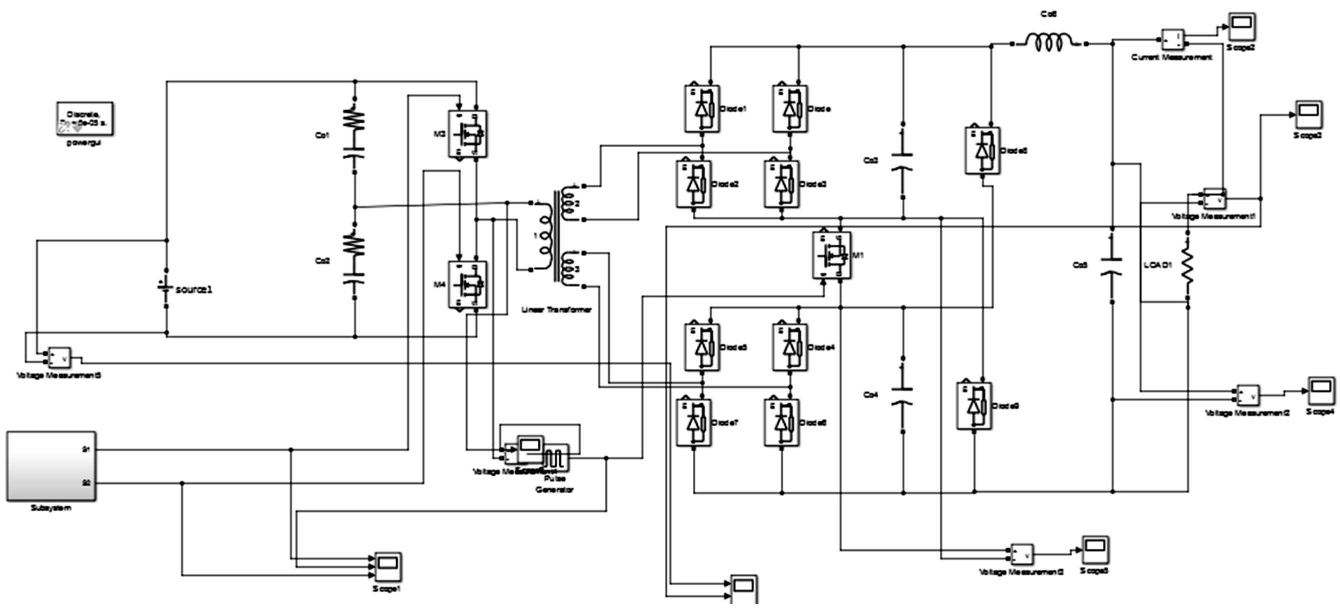

Figure 5: Simulation diagram of SPWM based multilevel DC-DC converter with photovoltaic system

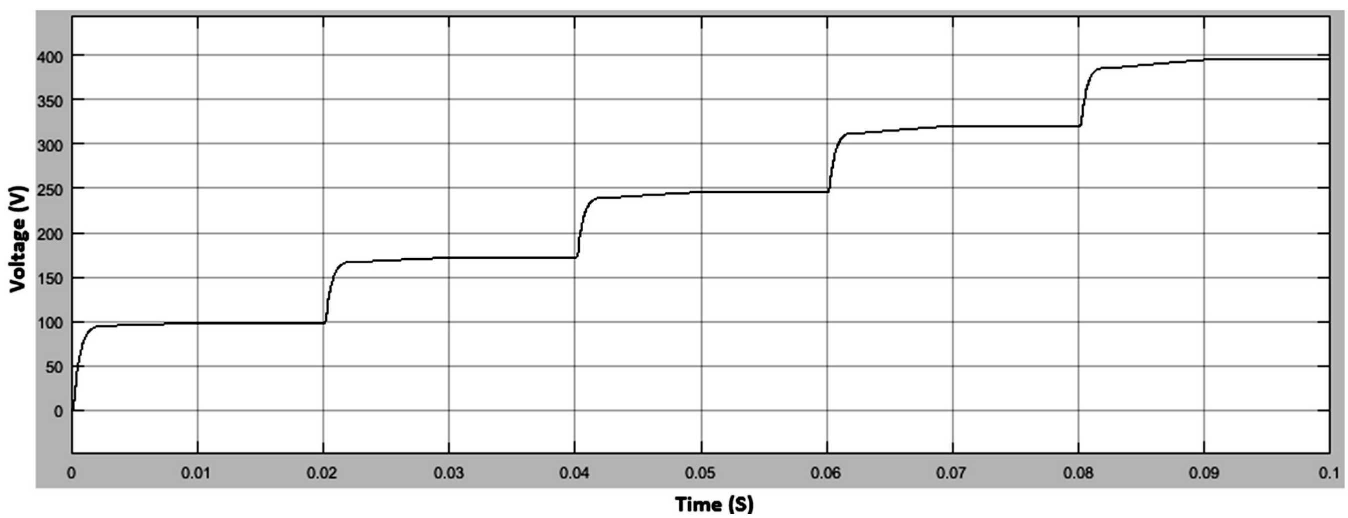

Figure 6: Output voltage of multilevel dc-dc converter in isolated system

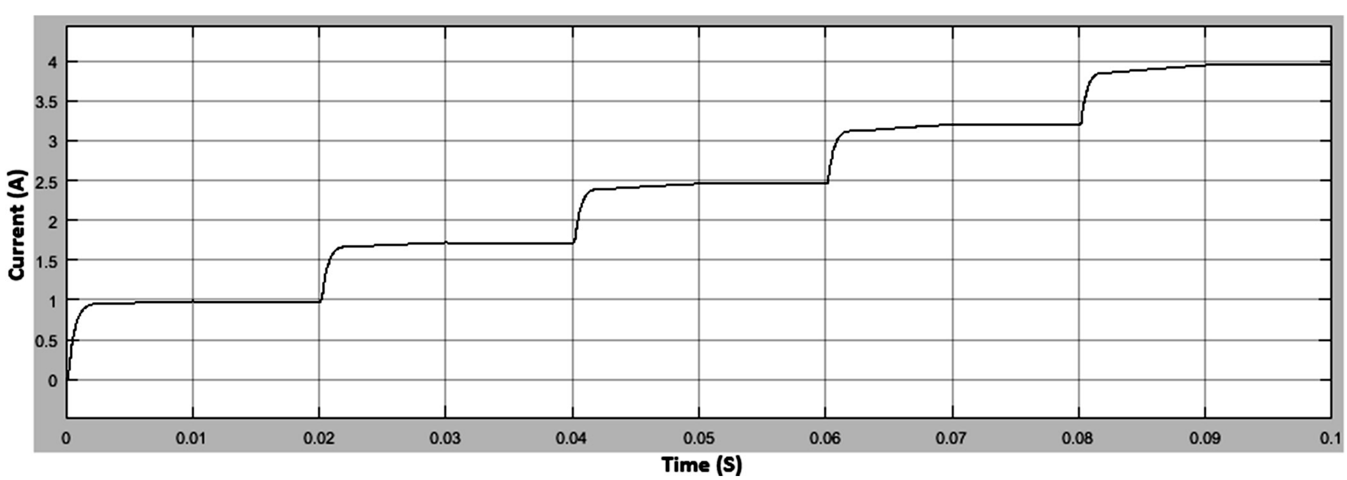

Figure 7: Output current of multilevel dc-dc converter

In Figure 6 shows output voltage of multilevel dc-dc converter in isolated system with is 390 V, which is 3times more than the applied input voltage. And the current flowing through the proposed system is 4A,

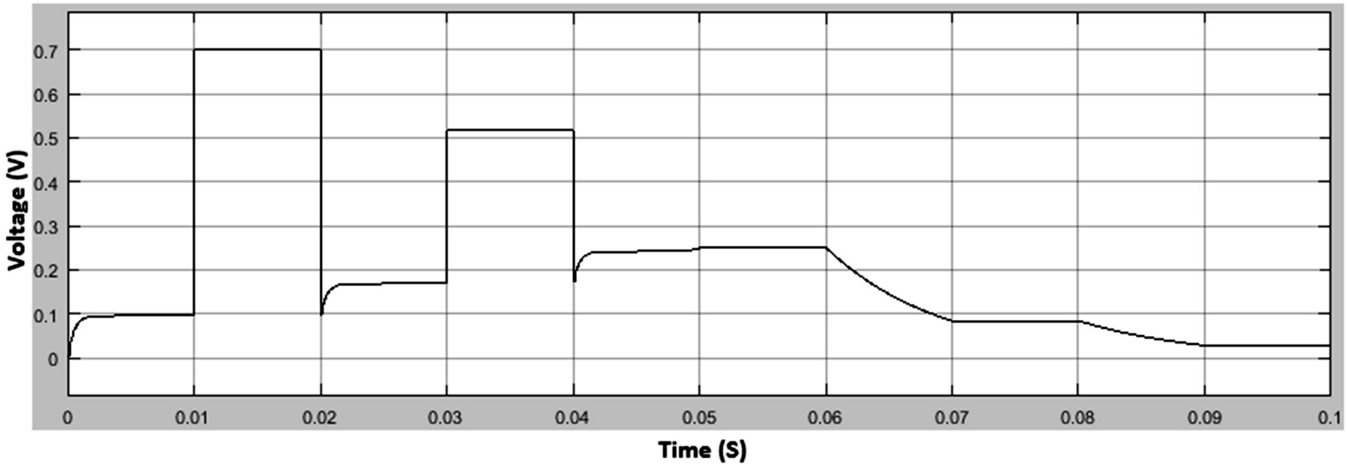

Figure 8: Voltage across the switch S3 in multilevel dc-dc converter

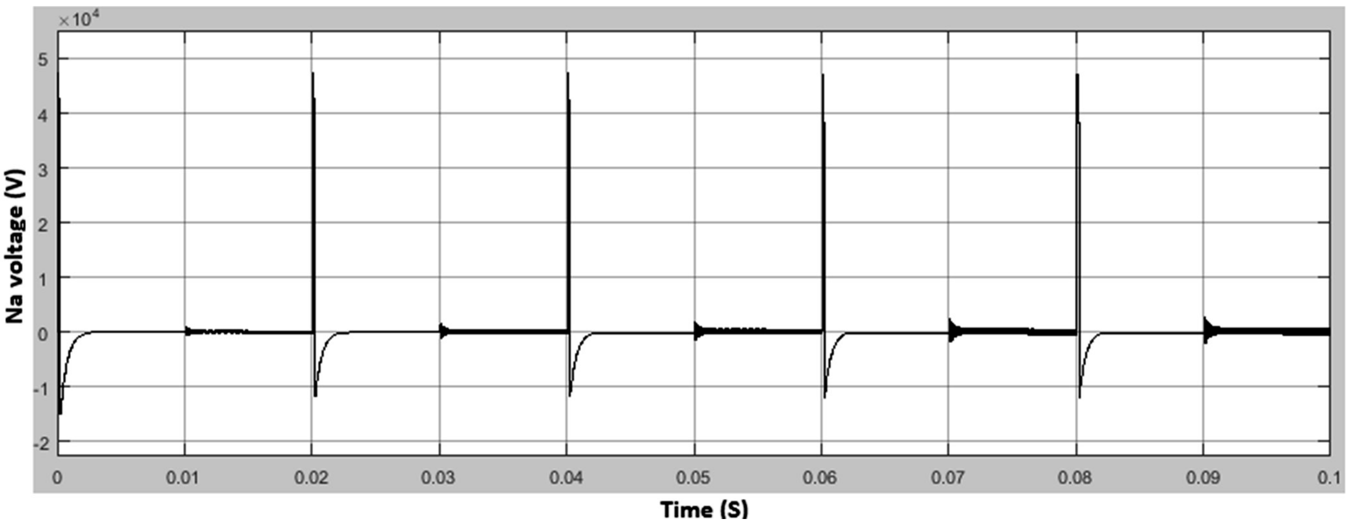

Figure 9: Voltage across primary transformer in multilevel dc-dc converter

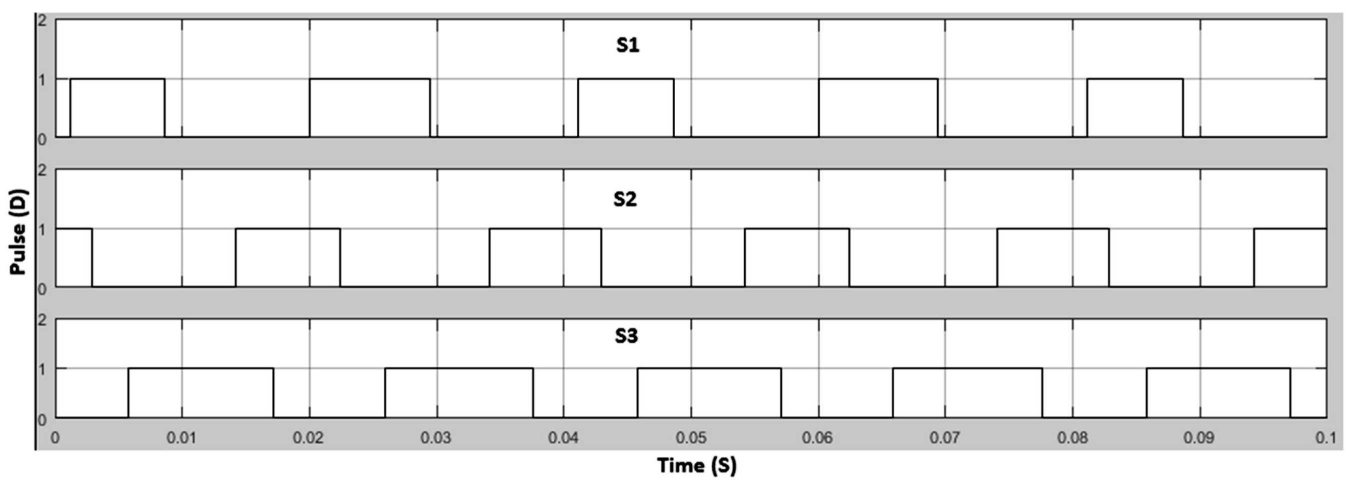

Figure 10: Switching pulses for S1, S2 & S3 (using SPWM)

which is shown in Figure 7 and in Figure 8 & 9 demonstrate the voltage across the switch S3 and voltage across primary transformer in multilevel dc-dc converter respectively. The proposed system switching pulses are generated using SPWM method, which is shown in Figure 10.

6. CONCLUSION

This proposed system explained SPWM based multilevel DC-DC converter with photovoltaic system. The three winding transformer in this system replaces the conventional two winding transformer, which generate 2 output dc voltages. The series and parallel switching circuit used to control the dc outputs generated from the isolated power processing unit. And which reduces the filter circuits and increased the power density of the circuit, reduces switching harmonics and switching losses. The output voltage of proposed system increased 3 times of applied input voltage, with providing appropriate switching pulses using SPWM scheme. This multilevel dc-dc converter generally used for electric vehicle, micro grids and small battery applications. The simulation results of SPWM based multilevel DC-DC converter with photovoltaic system was verified using matlab/ simulink.

References

1. Hemanthakumar, R., Raghavendrarajan, V., AjinSekhar, C.S., Sasikumar, M. "A novel hybrid negative half cycle biased modulation scheme for cascaded multilevel inverter", *International Journal of Power Electronics and Drive Systems*, Vol. 4, Issue 2, June 2014, Pages 204-211.
2. L.D'Errico,A. Lidozzi, G. Lo Calzo,A. Romanelli, and L. Solero, "Multilevel configurations for three-phase AC-DC 48V power supply," in *Proc. IEEE Int. Symp. Ind. Electron.*, Jul. 4–7, 2010, pp. 945–950.
3. F. Zhang, F. Z. Peng, and Zhaoming Qian, "Study of multilevel converter in DC-DC applications," in *Proc. IEEE 35th Annu. Power Electron. Spec. Conf.*, Jun. 2004, Vol. 2, pp. 1702–1706.
4. J. Lee, U. Choi, and K. Lee, "Comparison of tolerance controls for open switch fault in a grid-connected T-type rectifier," *IEEE Trans. Power Electron.*, Vol. 30, No. 10, pp. 5810–5820, Oct. 2015.
5. R. Palanisamy, K. Vijayakumar, S. Abhinav, R. Prasanna and T. Yogesh, "Voltage Controller for 3 Level NPC-MLI Based HSVM With *Grid Connected PV System" Indian Journal of Science and Technology, Vol. 9(35), DOI: 10.17485/ijst/2016/v9i35/101865, September 2016.*
6. Z. Zheng, Z. Gao, C. Gu, L. Xu, K.Wang, and Y. Li, "Stability and voltage balance control of a modular converter with multiwinding high-frequency transformer," *IEEE Trans. Power Electron.*, Vol. 29, No. 8, pp. 4183–4194, Aug. 2014.
7. J. C. Wu and C. W. Chou, "A solar power generation system with a seven-level inverter," *IEEE Trans. Power Electron.*, Vol. 29, No. 7, pp. 3454–3462, Jul. 2014.
8. R. Palanisamy, K. Vijayakumar, Komari Nikhil, Madhumathi Iyer, Ramachandar Rao,"A Proposed SVM for 3-level Transformer-less Dual Inverter Scheme for Grid Connected PV System", *Indian Journal of Science and Technology*, 2016 Nov, 9(42).
9. Y. Cai, C. Wang, F. Zhao, and R. Dong, "Design of a high-frequency isolated DTHB cLLC bidirectional resonant DC-DC converter," in *Proc. IEEE Conf. Transp. Electrification Asia-Pac.*, 2014, pp. 1–6.
10. D. Y. Kim, J. K. Kim, and G.-W. Moon, "A three-level converter with reduced filter size using two transformers and flying capacitors," IEEE Trans. Power Electron., Vol. 28, No. 1, pp. 46–53, Jan. 2013.
11. Palanisamy R, Vijayakumar K, Misra S, Selvakumar K, Karthikeyan D. A Closed Loop Current Control of PV-Wind Hybrid Source Fed on Grid Connected Transformerless Diode Clamped-Multi Level Inverter. International Review on Modelling and Simulations, 2015 Aug; 8(4):122-29.
12. Poh Chiang Loh, Feng Gao, FredeBlaabjerg, and Sokweilim. Operational Analysis and Modulation Control of Three Level Z-Source Inverters With Enhanced Output Waveform Quality. *IEEE Transaction on Power Electronics*, July 2010. Vol. 24, No. 7.
13. SamirKouro, Pablo Lezana, Mauricio Angulo and José Rodríguez. Multicarrier PWM with Dc-Link Ripple Feed forward Compensation for Multilevel Inverters. *IEEE Transactions on Power Electronics*,Vol. 23, No. 1, January 2010.
14. R. Palanisamy, A.U Mutawakkil, K. Vijayakumar "Hysteresis SVM for coupled inductor z source diode clamped 3-level inverter based grid connected PV system", *International Journal of Power Electronics and Drive Systems*, Vol. 7, Issue 4, Dec 2016.