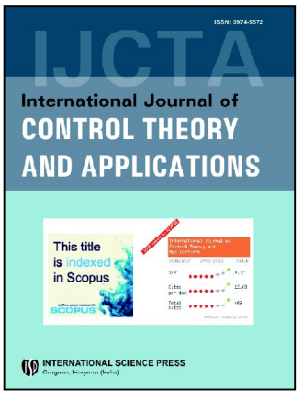

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Implementation of PV based High-step-up DC-DC Converter with Different Cascade H-bridge (CHB) Topologies

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Abstract: Solar energy is the one of the most and universal source of energy from sun shines throughout. By using photovoltaic (PV) technology the solar energy can be converted into useful electrical energy. The PV energy is the most important technology to generate the electrical energy. The renewable energy sources are connected through DC system with high step up DC-DC converter, the renewable energy sources best suitable for the DC-DC converters for connecting the AC loads through an inverter. By using voltage doublers cell its doubles the voltage value of the converter, the voltage doublers cell acts like as a transformer. To convert the low voltage to high voltage conversion of the doublers circuit to leads the all the switching losses, current ripples of the system. By using the soft switching technique we can reduce the switching losses, ripples of the double circuit with boost converter. The converter voltage integrated by multilevel inverter with different topologies; in this inverter topology used as the PWM control technique for control that of the inverter output voltage. The inverter output voltage is applicable for the standalone application. The total system is modeled using Matlab/Simulink software and results are displayed.

Keywords: High-step-up converter, Photovoltaic system, Renewable energy sources, Voltage doublers cell.

1. INTRODUCTION

In many industrial applications high gain DC-DC converters are used. Renewable sources are useful to generate the power to PV integrated DC-DC converter [1] with voltage doublers circuit. The PV connected high step up converter boost the low input voltage (48V) to high output voltage (230V) for standalone multilevel inverters.

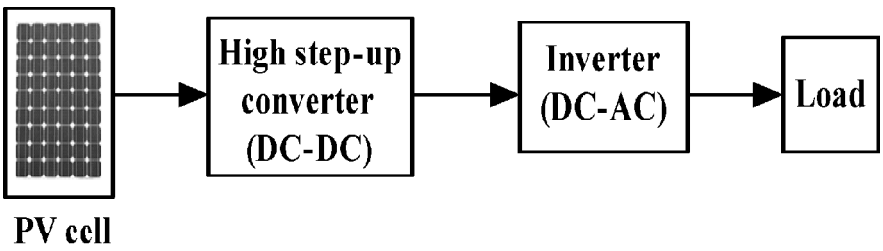

Figure 1: Typical Photovoltaic system with high step up multilevel inverter

The multilevel inverters are developed by based on the application purposes in various technologies, such that the renewable energy systems and voltage application of the system in high voltage level. The classification of the multilevel inverters are classified by multilevel inverters are classified by three types; cascade H-bridge multilevel inverter [2], diode clamped inverter, flying capacitor.

Out of those three types of inverters based on the cost and losses of the system cascade H-bridge is best one. The switching losses also very less in h-bridge multi level inverter system when compared to the diode and flying capacitor inverter, the number of diodes increased in the diode clamped inverter and number of capacitors increased in the flying capacitor so that the switching losses of the system is very high.

The renewable energy sources are not suitable to convert the hundred volts to thousands volts, so voltage doublers circuit is used to convert the high voltage, the step up DC-DC [3,4] converter improves the voltage gain and reduces the losses of the system. The voltage doublers cell integrated with high voltage boost converter with DC-DC conversion to reduce input current ripple and also power switching losses of the system, so we can increase the PV [5, 6] arrays life time of the system.

The high step up DC-DC converter with soft switching technique based PV inverter, in that there are two cases first one is converter case and second one. By using zero voltage [7-8] switching all the converter and inverter switches turned on and turned off at zero switching voltage level, by using this we can reduce the switching losses of the system.

2. VOLTAGE DOUBLERS CELL WITH STEP UP DC-DC CONVERTER

Fig. 2 shows the high step up DC-DC converter with voltage doublers circuit with soft switching technique. The voltage multiplier circuit is also called as a coupled inductor or voltage doublers circuit, this circuit is provide to get the high voltage gain through low input voltage value, low voltage stress on the power switches and improve the output voltage at high duty ratio. The main advantages of boost converter with voltage multiplier improve the ratio of step up DC-DC converter voltage value.

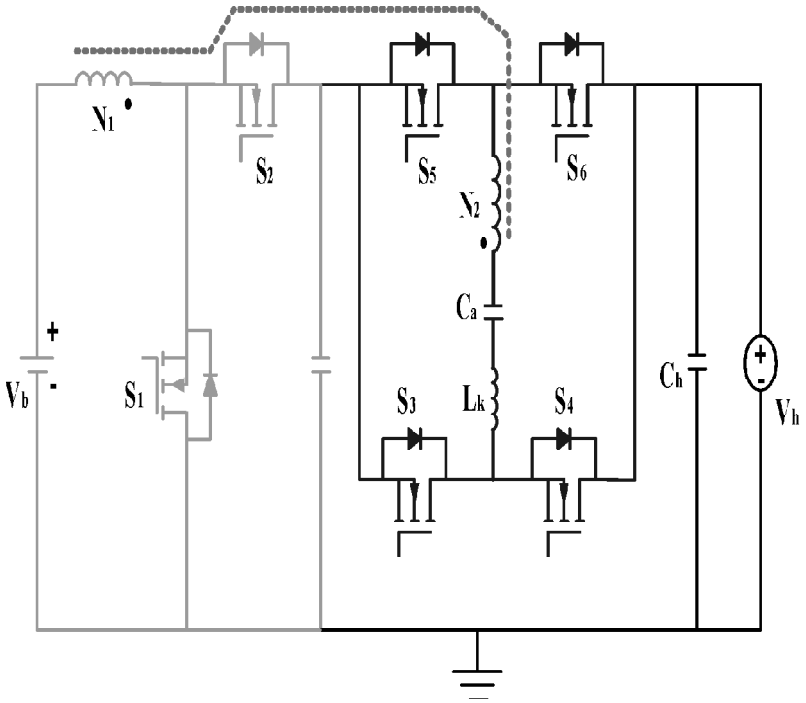

Figure 2: Voltage multiplier cell with high voltage step up DC-DC converter

The voltage multiplier also provided with the capacitors and diodes, by using diodes and capacitors in the high step up conversion process switching losses will be very high and gain of the voltage is also low. So by using soft switching technique reduce the losses and improve the output voltage.

The voltage multiplier circuits is nothing but acts as a transformer, so present the transformer leakage inductance by using soft switching technique useful to the system to gain the high level of voltage value, decreases the switching losses of the overall converter.

3. PROPOSED CONVERTER TOPOLOGY

In proposed converter topology explain the PV connected high step up voltage doublers circuit with cascade H-bridge multilevel inverter for 3, 5 and 7level topologies for standalone applications. The renewable energy sources are key elements for the PV connected multilevel inverter to get the output voltage waveform is sinusoidal and boosting the input voltage by high step up converter.

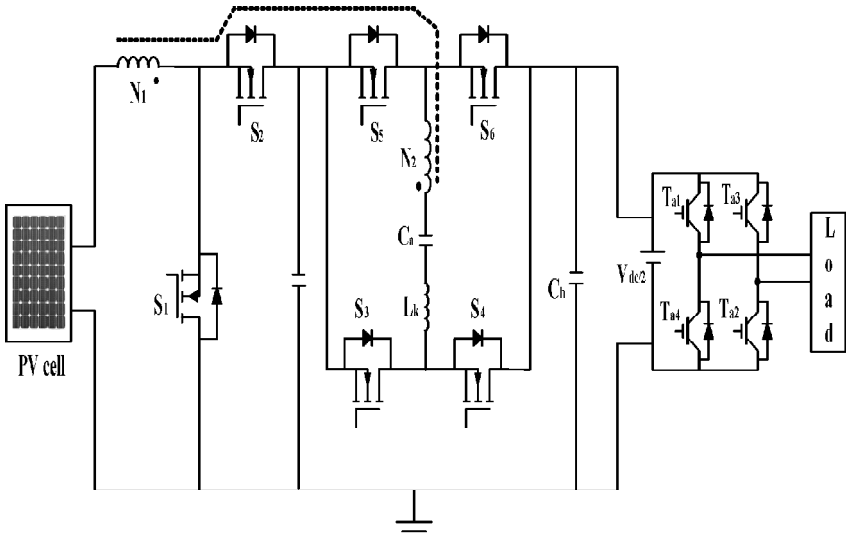

Figure 3: PV cell based high step up DC-DC converter for 3-level inverter

Fig. 3 shows the PV based high step-up DC-DC converter for 3-level inverter with load connected system. The PV cell is integrated to the high step up DC-DC converter with voltage doublers circuit to double the converter voltage; the converter voltage is given to the 3-level H-bridge inverter to convert the DC-AC voltage for standalone applications such as micro grid, load and motor applications.

In three level cascade H-bridge multilevel inverter has three output voltages such as V, 0, -V. The best advantages of cascade H-bridge inverters have less number of components, small size circuit and PWM control technique is applied. The switching sequence operation table for the 3-level inverter is shown in table 1

Table 1
switching sequence for 3-level inverter

Output voltage levels	*Switching sequence operation*			
	Ta1	*Ta2*	*Ta3*	*Ta4*
Vdc/2	1	1	0	0
0	1	0	1	0
-Vdc/2	0	0	1	1

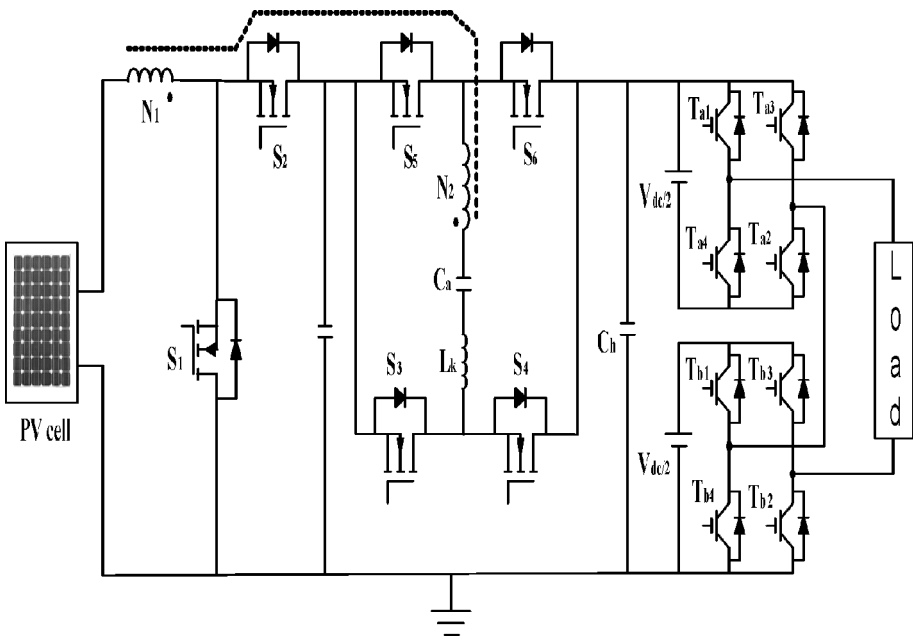

Figure 4: PV cell based high step up DC-DC converter for 5-level cascade H-bridge multilevel inverter

Fig.4 shows the PV cell based high step up DC-DC converter for 5-level H-bridge multilevel inverter for load connected system. The high step up voltage is given to the 5-level cascade H-bridge inverter. The 5-level inverter connected by the two series connected H-bridge cells. The 5-level H-bridge inverter consists of two voltage sources which are fed by the independent voltage sources, the sources are connected in series connection. The 5-level inverter output voltage value is the sum of the two independent voltage sources. The output voltage value of the 5-level inverter is

$$V = \frac{V_{dc}}{2} + \frac{V_{dc}}{2}$$

Here the output voltage of the first cell is represented by $\frac{V_{dc}}{2}$ and the output voltage of the second cell is denoted by $\frac{V_{dc}}{2}$. In five level H-bridge inverter consists of five level output voltages such as $\frac{V_{dc}}{2}$, V, 0, -V, $\frac{-V_{dc}}{2}$ The switching sequence operation of the 7-level H-bridge inverter with different voltage levels are shown in Table 2

Table 2
Switching sequence for 5-level H-bridge multilevel inverter

Output voltage levels	*Switching sequence operation*							
	Ta1	*Ta2*	*Ta3*	*Ta4*	*Ta5*	*Ta6*	*Ta7*	*Ta8*
Vdc/2	1	1	0	0	0	0	0	0
Vdc	1	1	0	0	1	1	0	0
0	1	0	1	0	1	0	1	0
-Vdc/2	0	0	1	1	0	0	1	1
-Vdc	0	0	1	1	0	0	0	0

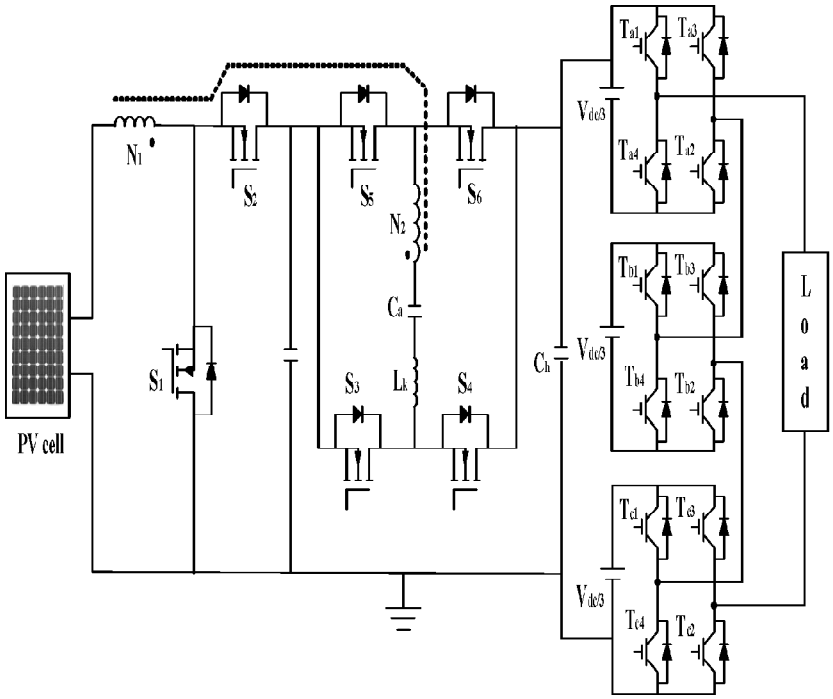

Figure 5: PV cell based high step up DC-DC converter for 7-level H-bridge multilevel inverter

Fig. 5 shows the PV based high step up DC-DC converter for 7-level inverter with load connected system. The 7-level inverters with three H-bridge inverters are connected by in series. The three voltage sources are operated at individual voltage sources, the output voltage of the 7-level H-bridge inverter is the sum of the all the three sources. The output value of the 7-level inverter is represented by

Table 3
Shows the switching sequence of the 7-level H-bridge inverter operation

Output voltage levels	*Switching sequence operation*											
	Ta1	*Ta2*	*Ta3*	*Ta4*	*Ta5*	*Ta6*	*Ta7*	*Ta8*	*Ta9*	*Ta10*	*Ta11*	*Ta12*
2Vdc/3	1	1	0	0	0	1	0	1	0	1	0	1
Vdc/3	1	1	0	0	1	1	0	0	0	1	0	1
Vdc	1	1	0	0	1	1	0	0	0	1	0	1
0	0	1	0	1	0	1	0	1	0	1	0	0
-2Vdc/3	0	1	0	1	0	1	0	1	1	1	0	0
-Vdc/2	0	1	0	1	0	0	1	1	0	0	1	1
-Vdc	0	0	1	1	0	0	1	1	0	0	1	1

Here the output Voltage of three individual cells is denoted by $\frac{V_{dc}}{2}$. The 7-level inverter output voltage levels are seven those 7-levels are represented by $\frac{V_{dc}}{3}, \frac{2V_{dc}}{3}, V_{dc}, 0, \frac{-V_{dc}}{3}, \frac{-2V_{dc}}{3}, -V_{dc}$..

4. MATLAB/SIMULATION RESULTS

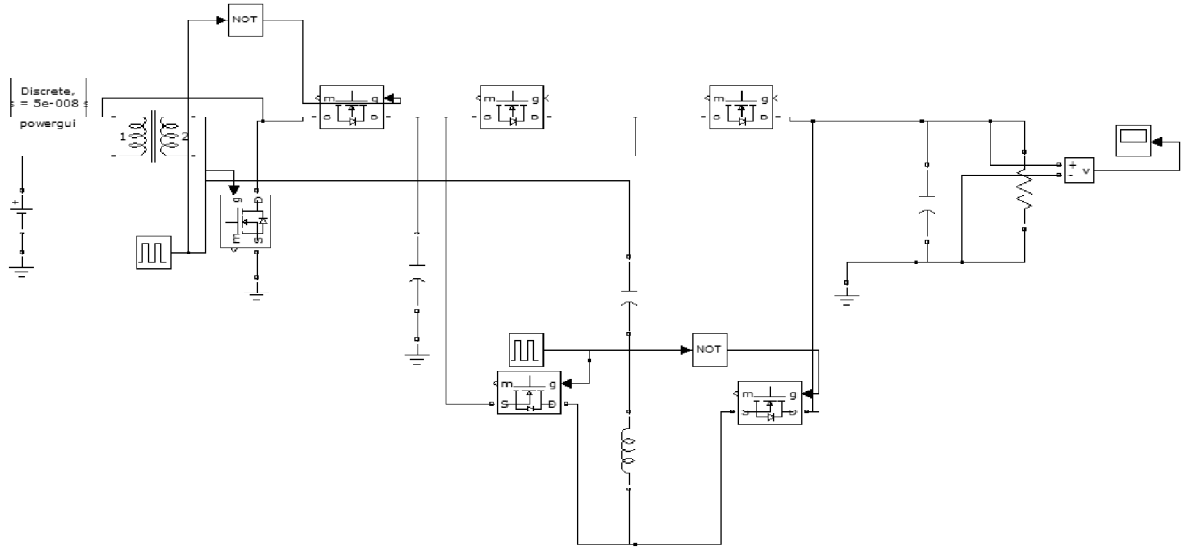

Figure 6: MATLAB/SIMULINK diagram of step up voltage DC-DC converter based voltage double circuit

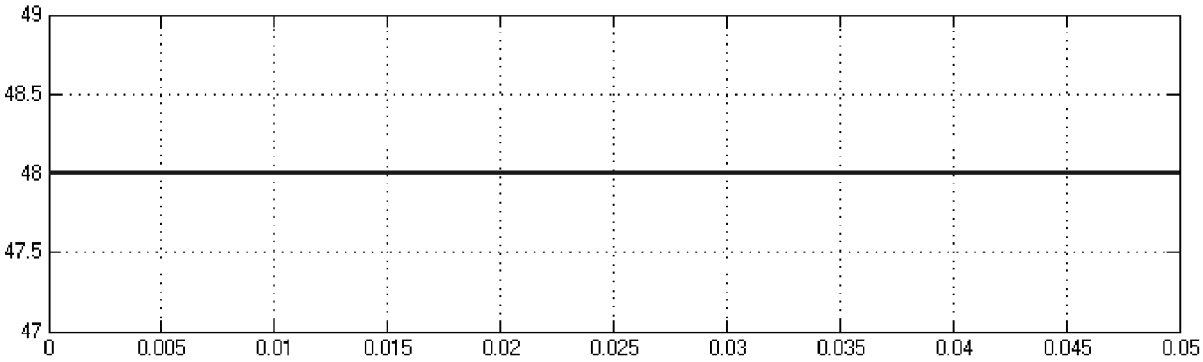

Figure 7: Input voltage of the converter

Fig. 7 shows the input voltage waveform of the high step up DC-DC with voltage double circuit. The input voltage of the system is 48V.

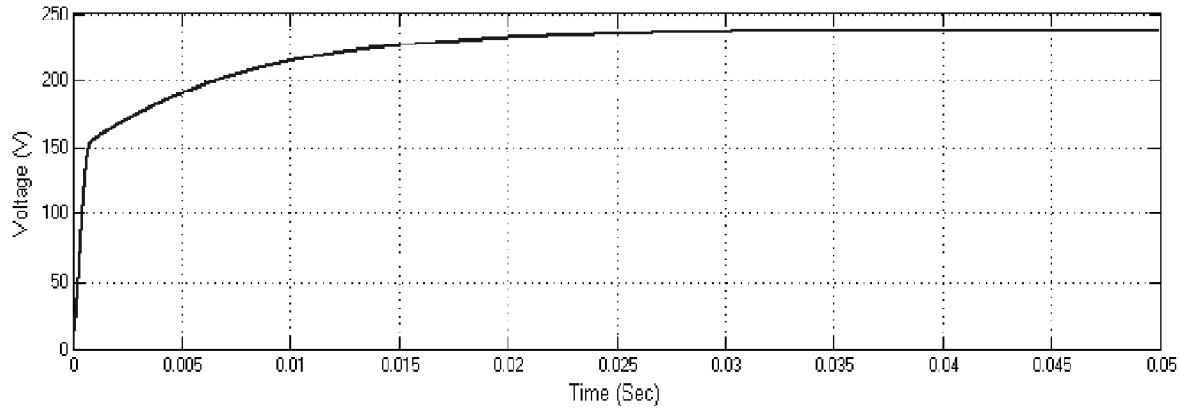

Figure 8: Converter output voltage

Fig. 8 shows the voltage waveform of the converter with high step up DC-DC conversion based voltage doublers circuit. The converter output voltage value is 230V.

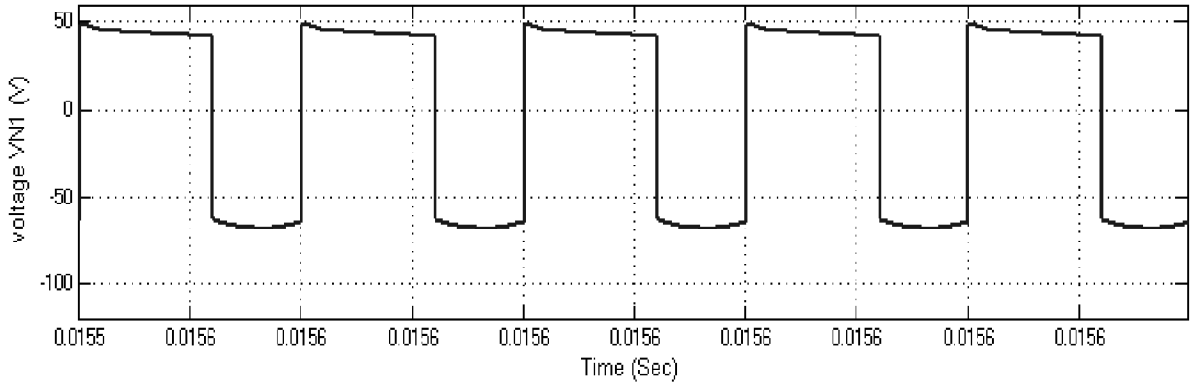

Figure 9: Coupled inductor voltage VN1 (V)

Fig.9 shows the output waveform of coupled inductor voltage VN1. The output voltage value of the coupled inductor is 48V.

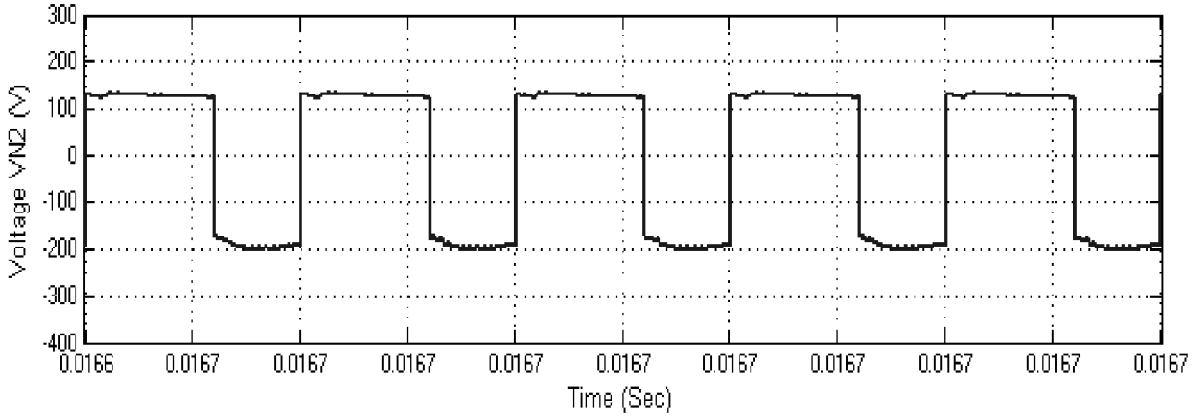

Figure 10: Coupled inductor voltage VN2 (V)

Fig.10 shows the output voltage waveform of the coupled inductor VN2. The value of the coupled inductor voltage is 144V.

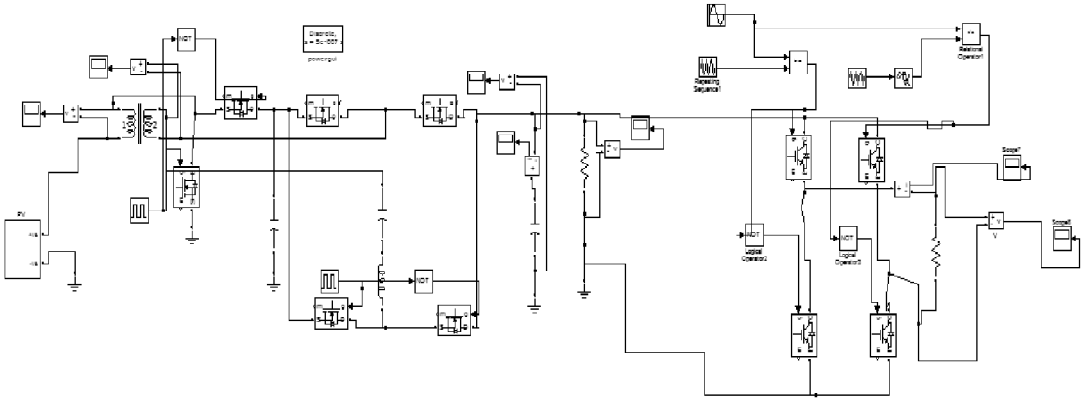

Figure 11: MATLAB/SIMULINK circuit of PV based step up high voltage DC-DC converter with 3-level H-bridge inverter

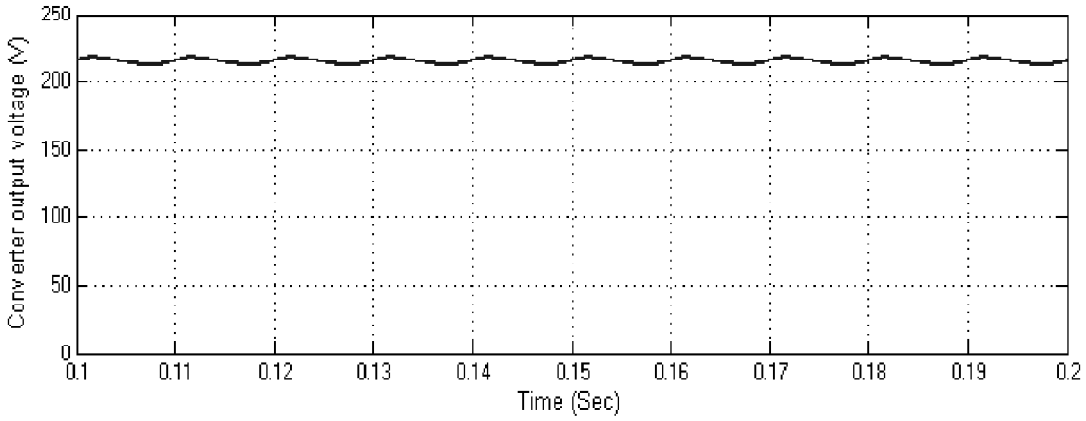

Figure 12: Converter output voltage

Fig. 12 shows the converter output voltage, the value of the converter voltage is 230V.

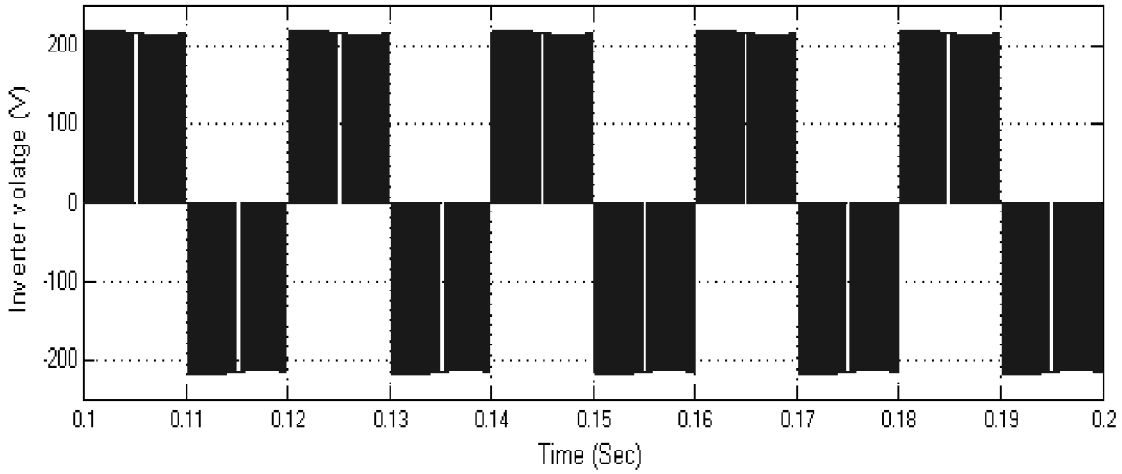

Figure 13: three-level inverter voltage

Fig. 13 shows the output voltage waveform of the 3-level inverter. The output value of the 3-level converter is 230V.

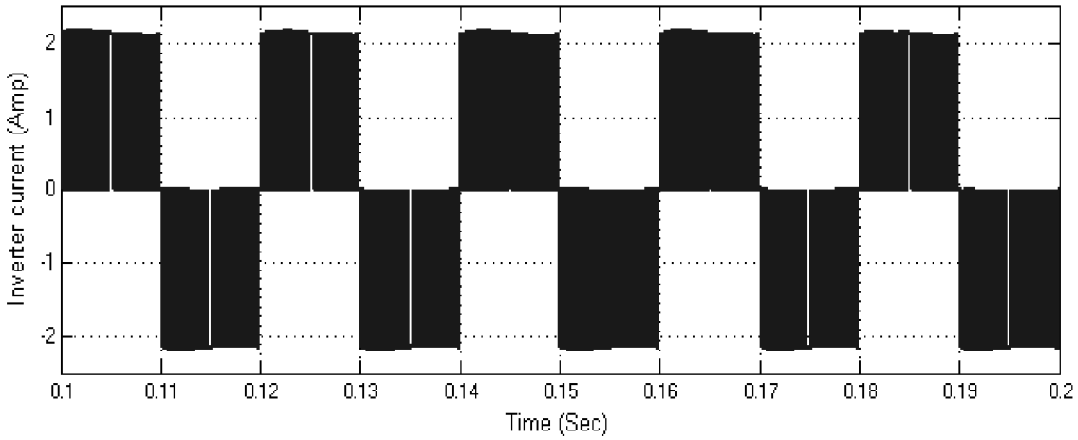

Figure 14: 3-level inverter output current

Fig.14 shows the output current waveform of the 3-level inverter.

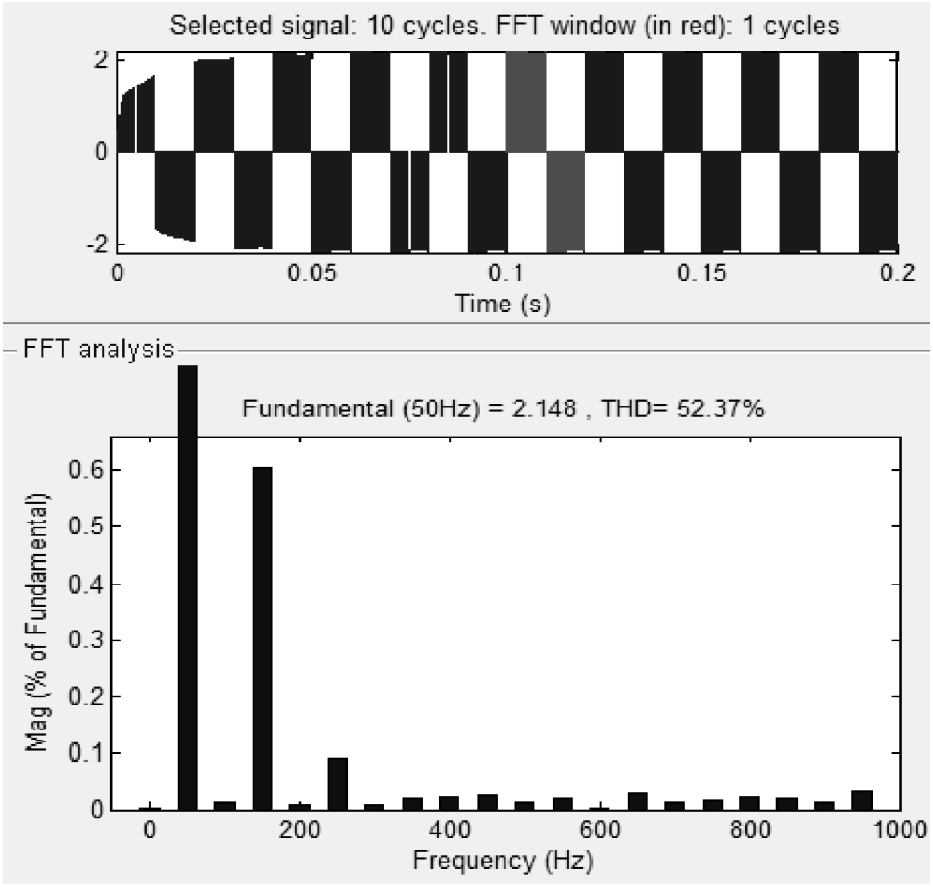

Figure 15: THD plot of 3-level inverter

Fig.15 shows the THD plot of the 3-level invertr. The output THD value for 3-level inverter is 52.37%.

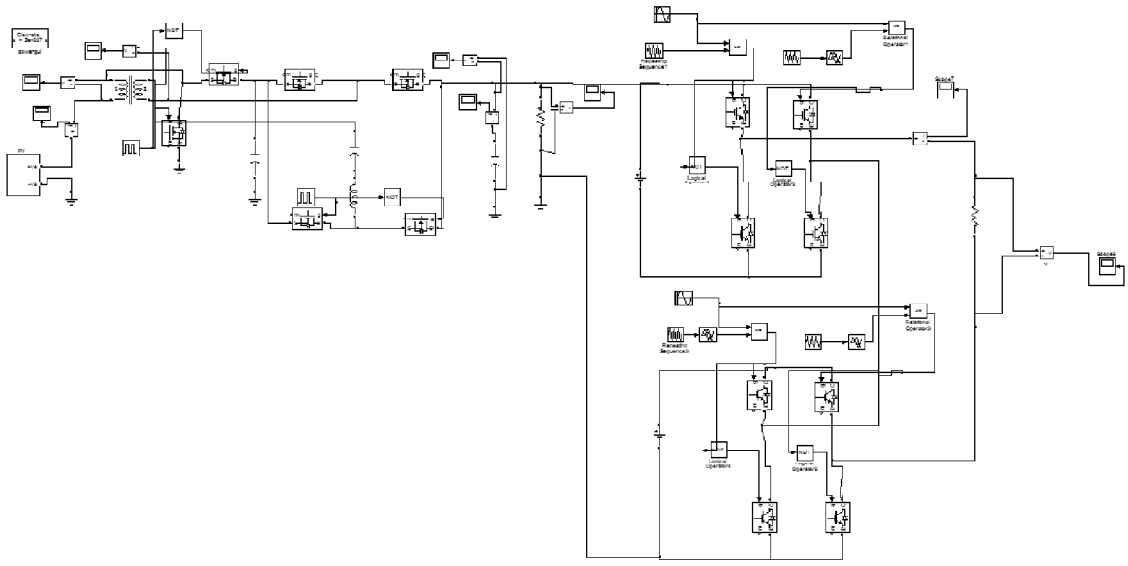

Figure 16: MATLAB/SIMULINK circuit model for 5-level cascade H-bridge multilevel inverter

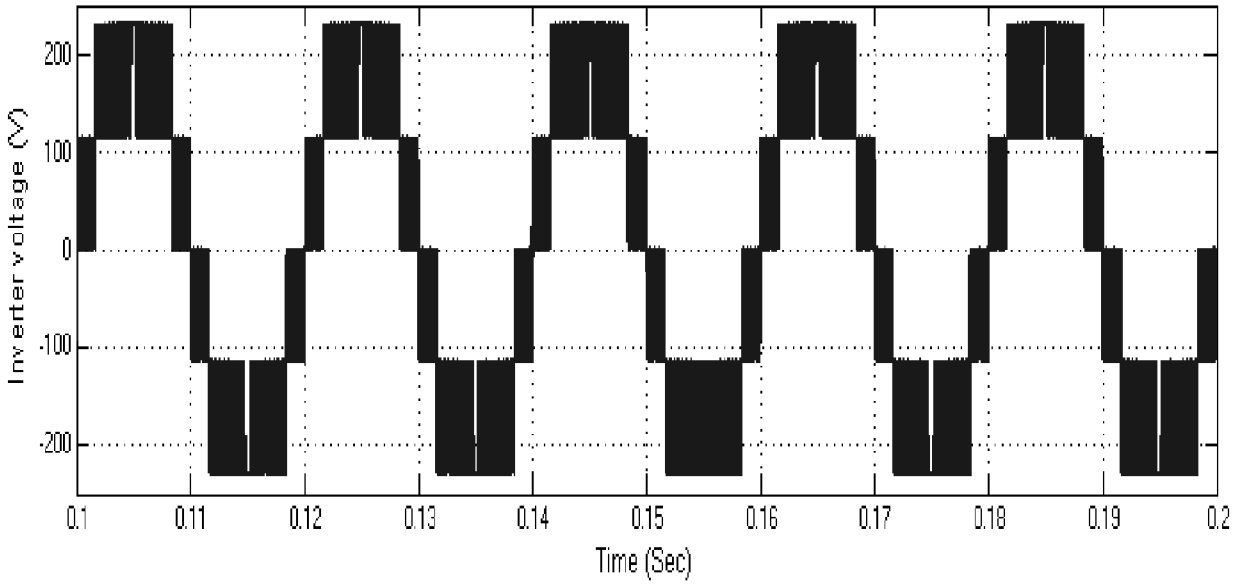

Figure 17: 5-level inverter Output voltage

Fig.17 shows the waveform of the output voltage 5-level h-bridge multilevel inverter. The output voltage of the 5-level H-bridge inverter is 230V.

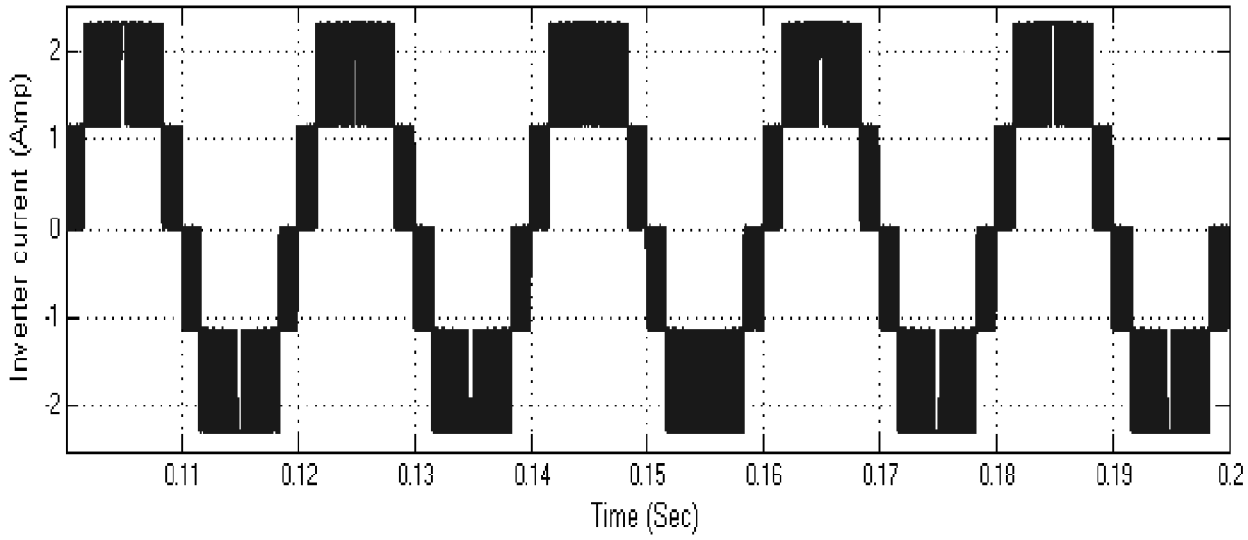

Figure 18: Inverter output current

Fig.18 shows the inverter output current of the 5-level inverter

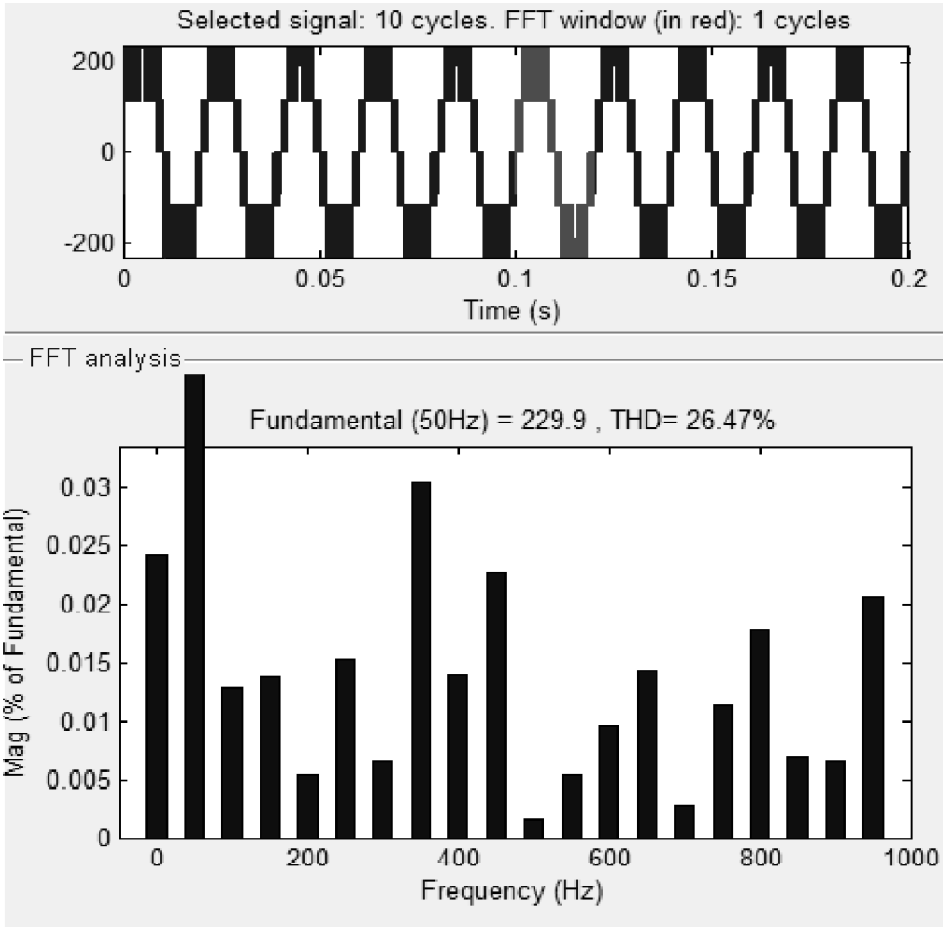

Figure 19: THD plot of 5-level H-bridge multilevel inverter

Fig.19 shows the THD plot of the 5-level inverter. The %THD value of 5-level inverter is 26.4. When compared to the 3-level inverter %THD value reduces.

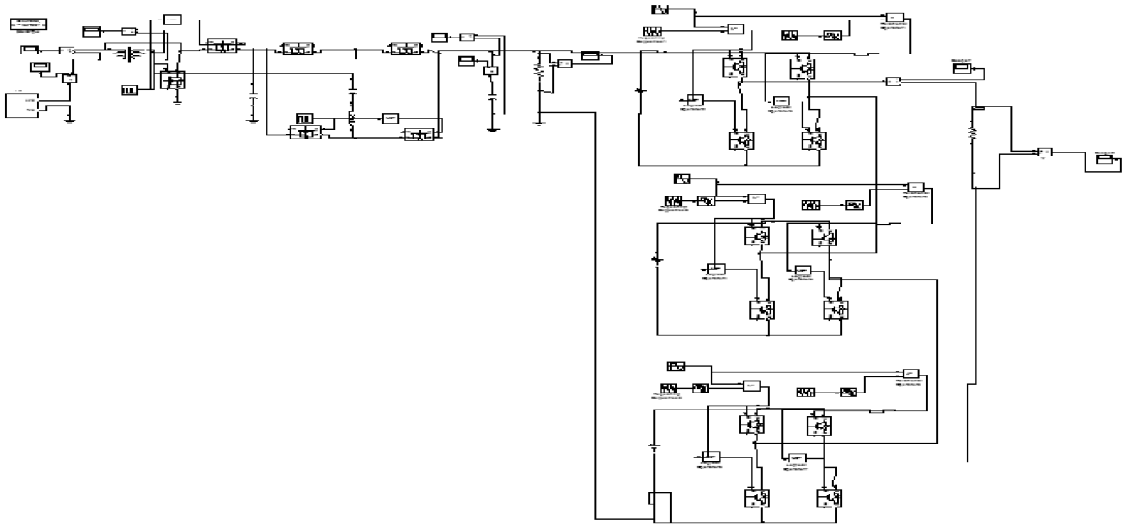

Figure 20: MATLAB/SIMULINK circuit for PV based step up high voltage DC-DC converter with 7-level H-bridge multilevel inverter

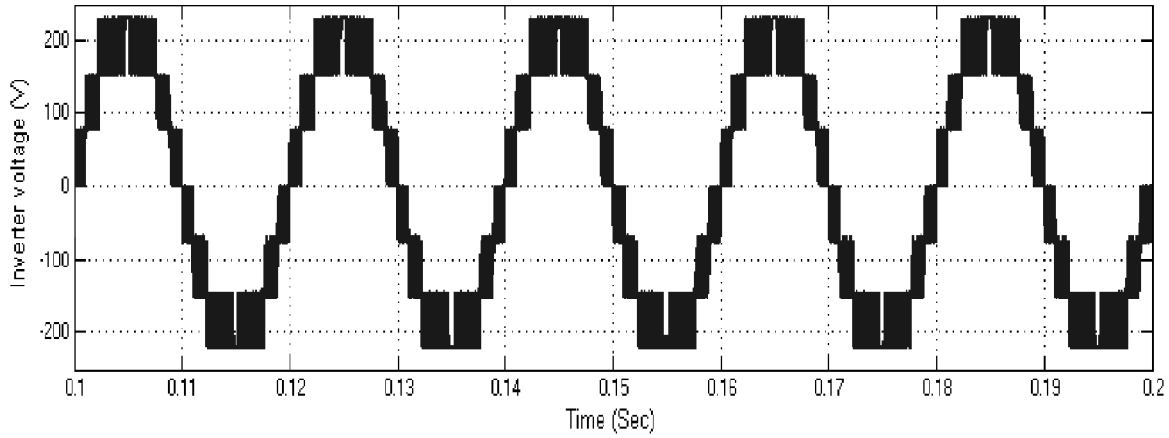

Figure 21: 7-level inverter output voltage

Fig.21 shows the output voltage waveform of the 7-level H-bridge multilevel inverter. The output voltage value of 7-level inverter is 230V

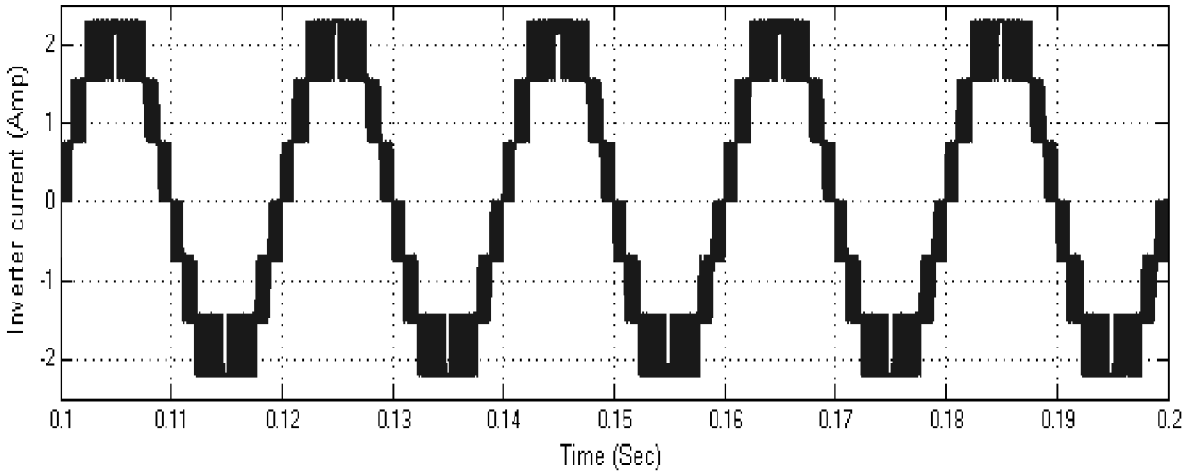

Figure 22: Shows the 7-level inverter output current

Fig. 22 shows the output current waveform of the 7-level inverter.

Fig. 23 shows the %THD plot for 7-level H-bridge multilevel inverter. The THD value of the 7-level inverter is 16.99%. The 7-level H-bridge inverter %THD value is decreased when compared to the %THD value 3-level, 5-level H-bridge inverters.

Table 4
shows the %THD comparison of different multilevel inverters

S.no	*Type of inverter*	*%THD*
1	3-level	52.37
2	5-level	26.47
3	7-level	16.99

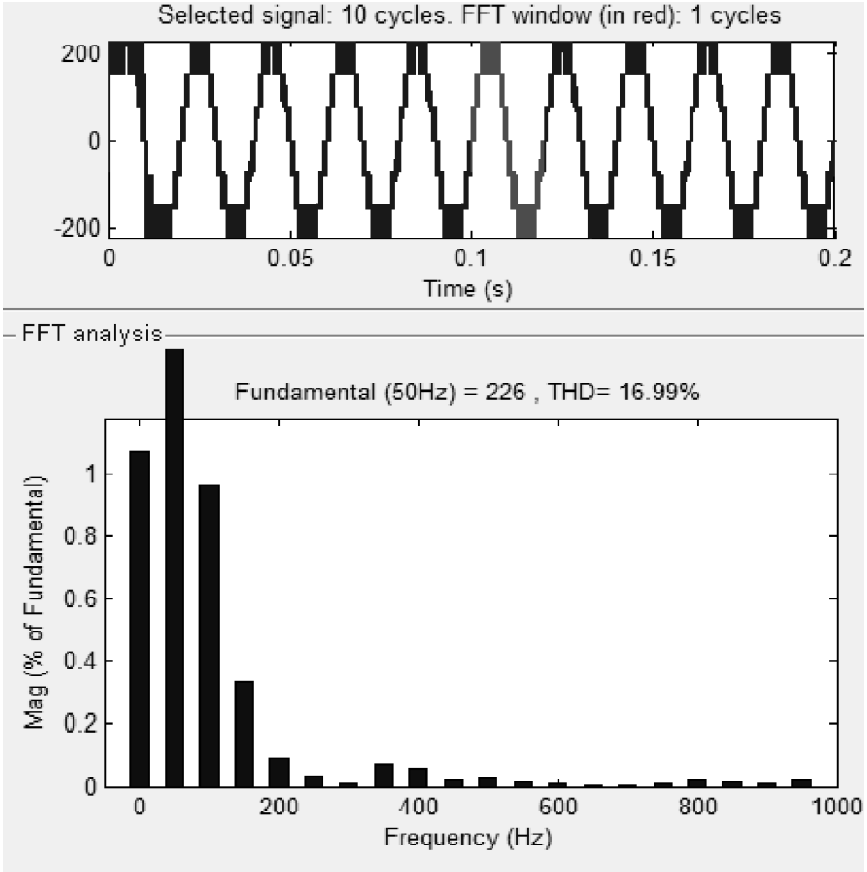

Figure 23: THD plot of 7-level H-bridge multilevel inverter

5. CONCLUSION

The DC-DC converters with step up voltage conversion is the best suitable one to the front-end converters to step from moderate level voltage to high voltage level to required a high step up conversion ratio value. The proposed converter employs the turns ratio of the coupled inductor to achieve high step up voltage gain based on the floating switch structure of the boost converter, this design successfully isolates the energy from the PV panel. Thus the multilevel inverter and DC-DC converter is aching very high step up voltage gain which is suitable for high voltage applications. The voltage multiplier with soft switching technique reduces the ripples and the stress in the switches. Thus the multilevel inverter and DC-DC converter is achieving very high step up voltage gain, which is suitable for the high voltage applications.

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