International Journal of Power Electronics and Drive System (IJPEDS)
Vol. 8, No. 4, December 2017, pp. 1494~1502
ISSN: 2088-8694, DOI: 10.11591/ijpeds.v8i4.pp1494-1502

MSPWM Based Implementation of Novel 5-level Inverter with Photovoltaic System

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Article Info

Article history:

Received Aug 20, 2017
Revised Sep 5, 2017
Accepted Sep 29, 2017

Keyword:

Electromagnetic interference (EMI)
Multi-carrier Sine-wave Pulse Width Modulation (MSPWM)
Multilevel inverter (MLI)
Novel 5-level inverter
Total Harmonic Distortion (THD)

ABSTRACT

This paper proposes a novel 5-level DC-AC converter circuit using with 6 power semiconductor switches. The proposed multilevel inverter generates five-level ac output voltage by implementing Multi-carrier sinusoidal pulse width modulation (MSPWM) technique with reduced number of switches. The voltage stress on each switching devices and common mode voltage can be minimized from the suggested system. The designed system gives better controlled output current and improved output voltage with diminished total Harmonic Distortion value. The operating principles of the proposed inverter are discussed. DC Input for the proposed system is obtained from PV System. Finally, an experimental prototype of the proposed system with 12-V input voltage and 20 V/5 W output is implemented along with simulation output of the waveform to the load. The efficiency and the reduction of harmonic content are discussed.

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1. INTRODUCTION

Renewable energy is energy generated from natural resources—such as sunlight, wind, rain, tides and geothermal heat—which are renewable (naturally replenished). Renewable energy technologies range from solar power, wind power, hydroelectricity/micro hydro, biomass and biofuels for transportation. Alternative energy is a term used for an energy source that is an alternative to using fossil fuels. Generally, it indicates energies that are non-traditional and have low environmental impact. The term alternative is used to contrast with fossil fuels according to some sources. By most definitions alternative energy doesn't harm the environment, a distinction which separates it from renewable energy which may or may not have significant environmental impact.

The sun is probably the most important source of renewable energy available today. Traditionally, the sun has provided energy for practically all living creatures on earth, through the process of photosynthesis, in which plants absorb solar radiation and convert it into stored energy for growth and development. Scientists and engineers today seek to utilize solar radiation directly by converting it into useful heat or electricity.

The unique advantages of using power electronic couplings have been discussed throughout the paper and can be summarized in the following features like flexibility to integrate energy storage units, Maximum power point tracking for PV and wind energy systems, Dispatching capabilities with energy storage units, Improved efficiency, Variable speed operation ability allowing for fuel usage optimization. Renewable generation units are Wind energy system, Photovoltaic system, wave energy system. The above systems the power electronic devices can be used in place of traditional power devices such as switches, capacitors, inductors etc. and can perform several of these functions with a single device. The power electronic coupling accepts power from distributed energy sources and converts it as desirable power with frequency and voltage.

In recent day's Multilevel inverter (MLI) technologies become a incredibly main choice in the area of high power medium voltage energy control. Though multilevel inverter has a number of advantages it has drawbacks in the vein of higher levels because of using more number of semiconductor switches. This may leads to vast size and price of the inverter is very high. So in order to overcome this problem the new multilevel inverter is proposed with reduced number of switches. Multi carrier SPWM technique is used for generation of stepped multilevel output voltage from the proposed system.

2. PV SYSTEMS

Although a PV array produces power when exposed to sunlight, a number of other components are required to properly convert, control, distribute, and store the energy produced by the array. Depending on the functional and operational requirements of the system, the specific components required may include major components such as inverter, battery bank, charge controller and an assortment of balance of system (BOS) hardware, including wiring, overcurrent, surge protection, arc fault protection, disconnect devices and other power processing equipment. Back bone of a solar PV system is solar panels which convert sun's energy into DC electricity. A solar panel is made of number of solar cells, these cells are connected series and parallel within a panel to create desired voltage, current and power outputs.

These connected PV cell circuits are then sealed in an environmentally protective laminate, to make a solar PV panels which are the fundamental building blocks of PV systems. Similar to cell connections within a solar PV panels numbers of solar panels are connected in series and parallel to obtain desires power outputs. A group of such connected solar panels are called solar array. The performance of PV modules and arrays are generally rated according to their maximum DC power. Today's photovoltaic modules are extremely safe and reliable products, with minimal failure rates and projected service lifetimes of 25 to 40 years. Most major manufacturers offer warranties of 20 or more years for maintaining a high percentage of initial rated power output. Simulation modal of PV system is shown in Figure 1.

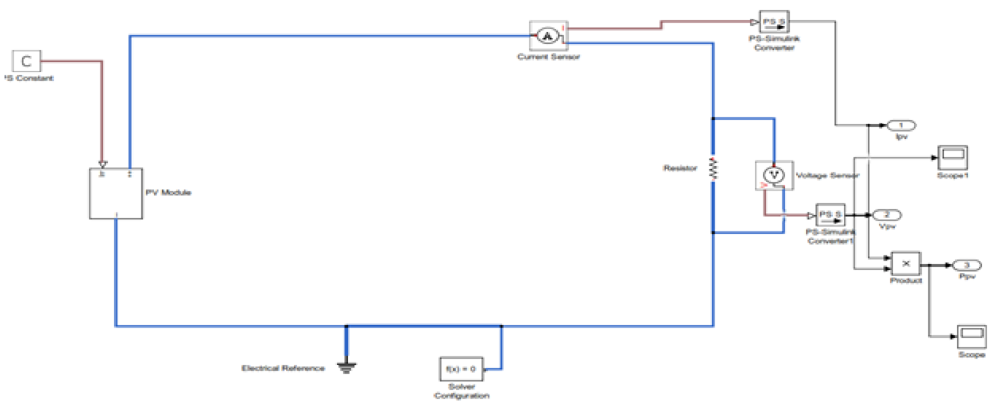


Figure 1. simulink diagram PV system Module

3. PROPOSED REDUCED SWITCH 5-LEVEL INVERTER SYSTEM

The demand for High Voltage (HV) and high power applications is also increasing rapidly. At the same time there are increasing constraints with respect to size, volume, cost and weight of the systems. This restricts the use of low frequency heavy weight transformers in HV and high power applications which would have been a viable solution. Also, the usage of low frequency transformer restricts the variation in input and output voltage. Thus, there is a requirement for power conditioners which not only give extended bandwidth for variations in input and output voltage but also have the advantages of low weight, low cost and controllability. For these reasons, the HV power converters are at the focal point of continuing studies for the researchers. Among the various options, Multilevel Inverters (MLI) are a good solution for HV applications, as they are supported by advantages like high power quality (low THD), reduced switching loss and lower dv/dt stress. The proposed 5-level inverter used 6 controlled power semiconductor switches and 2 clamping diodes, which is shown in Figure 2.

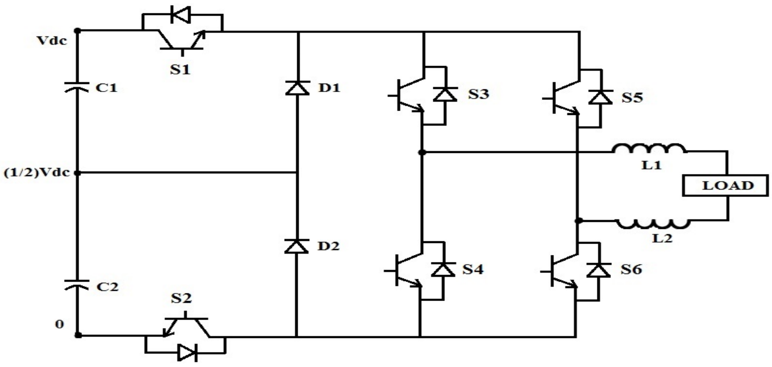
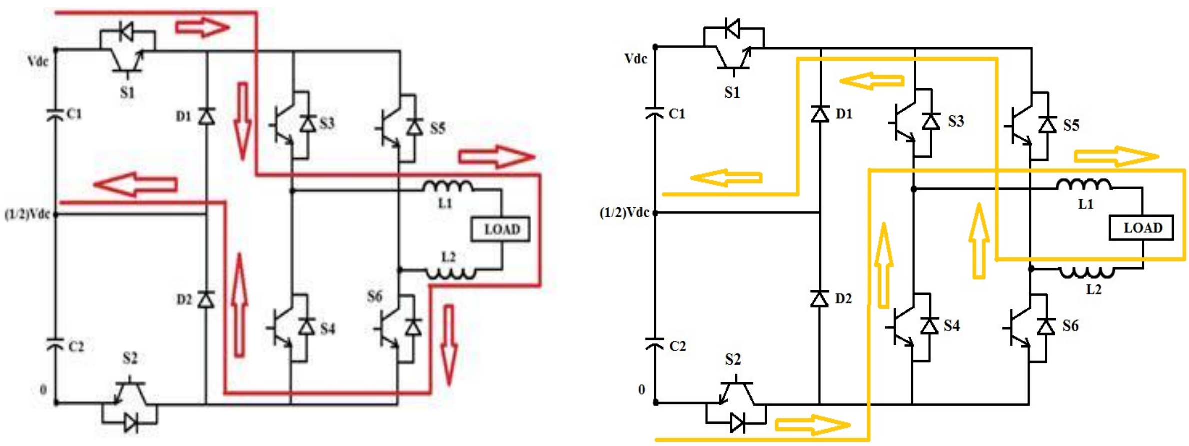


Figure 2. Proposed 5-level inverter circuit

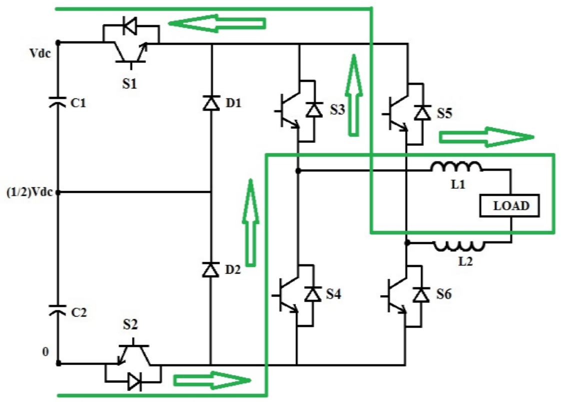
3.1. Modes of Operation

MODE 1: During this mode of operation, voltage generated is equal to +(1/2)Vdc. The current flow is from S1-S3-Load-S6-S4-C1, which is shown in Figure 3a.
MODE 2: During this mode of operation, voltage generated is equal to –(1/2)Vdc. The current flow is from S2-S4-Load-S5-C1, which is shown in Figure 3b.
MODE 3: During this mode of operation, voltage generated is equal to +Vdc. The current flow is from S1-S3-Load-S6-S2-C2, which is shown in Figure 3c.
MODE 4: During this mode of operation, voltage generated is equal to -Vdc. The current flow is from S2-S4-Load-S5-S1-C1, which is shown in Figure 3d.
MODE 5: During this mode of operation, voltage generated is equal to 0 Vdc, switches S4 and S6 are closed, which is shown in Figure 3e and Table 1 shows operating modes with switch conditions.

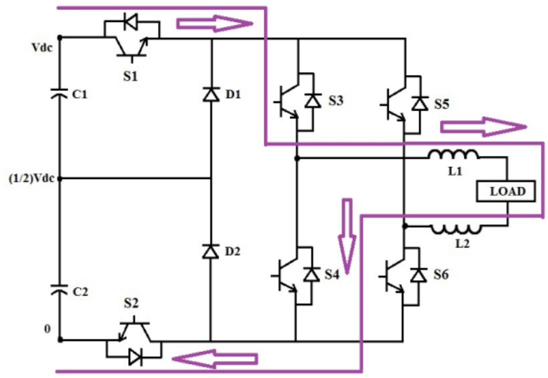


(a) (b)

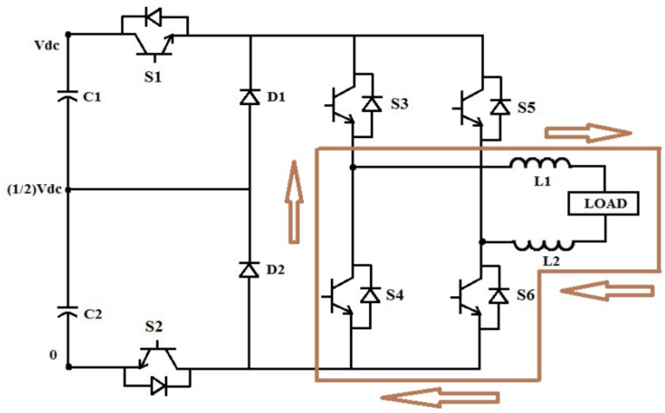
Figure 3. Modes of operation (a) (Vdc/2) V (b) -(Vdc/2) V



(c)



(d)



(e)

Figure 3. Modes of operation (c) Vdc V (d) –Vdc V (e) 0 V

Table 1. Operating Modes with Switch Conditions

MODES	S1	S2	S3	S4	S5	S6	D1	D2
MODE 1	X		X	X		X		X
MODE 2		X		X	X		X	
MODE 3	X	X	X			X		
MODE 4	X	X		X	X			
MODE 5				X		X		

4. MULTICARRIER SINUSOIDAL PULSE WIDTH MODULATION (MSPWM)

In order to preserve or reduce system cost or structure, imperative to maintain the shoot through ratio as constant. At the same to reduce the voltage stress across the power switches, the boosted voltage with proper variation of modulation index. Based on the MSPWM scheme control, the novel 5-level inverter operated either positive or zero gating pulse sequence, which is shown in Figure 4.
Constant boost ratio of the proposed system defined as,

$$B = \frac{\pi}{[3sqrt(3)M]-\pi} \tag{5}$$

Where the B is boost ratio & M is modulation index. And the ripple content in the inductor is,

$$\epsilon L_1 = \frac{V*K}{2*\pi*6f*L} \tag{6}$$

Here V is applied voltage, K-constant, f-frequency, L- design value inductance. A triangle carrier wave is evaluated with a three phase reference sine wave, each phase for a positive side switch shoot through state occurs every time the triangle peak value overshoots the sinusoidal peak amplitude, so twice for each phase in one cycle of operation

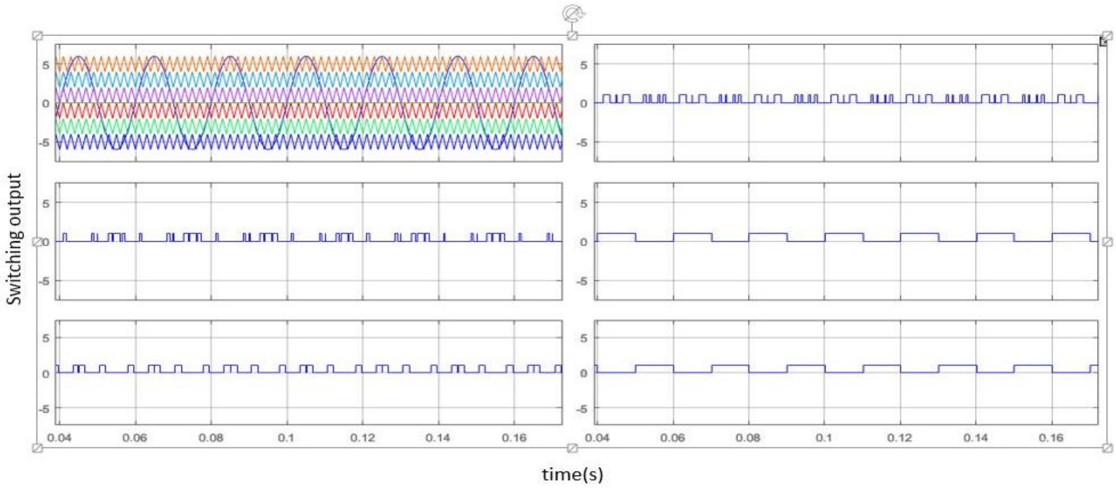


Figure 4. switching pulse generation using MSPWM

5. SIMULATION RESULTS AND DISCUSSION

The Simulation results were verified in Matlab R2016a. Figure 5 shows the matlab simulation model of the proposed novel inverter system. Fig.6 shows the output power generated from PV systems. Proposed 5-level output voltage with direct dc supply and with PV system is shown in Figure 7 and Figure 8 respectively.

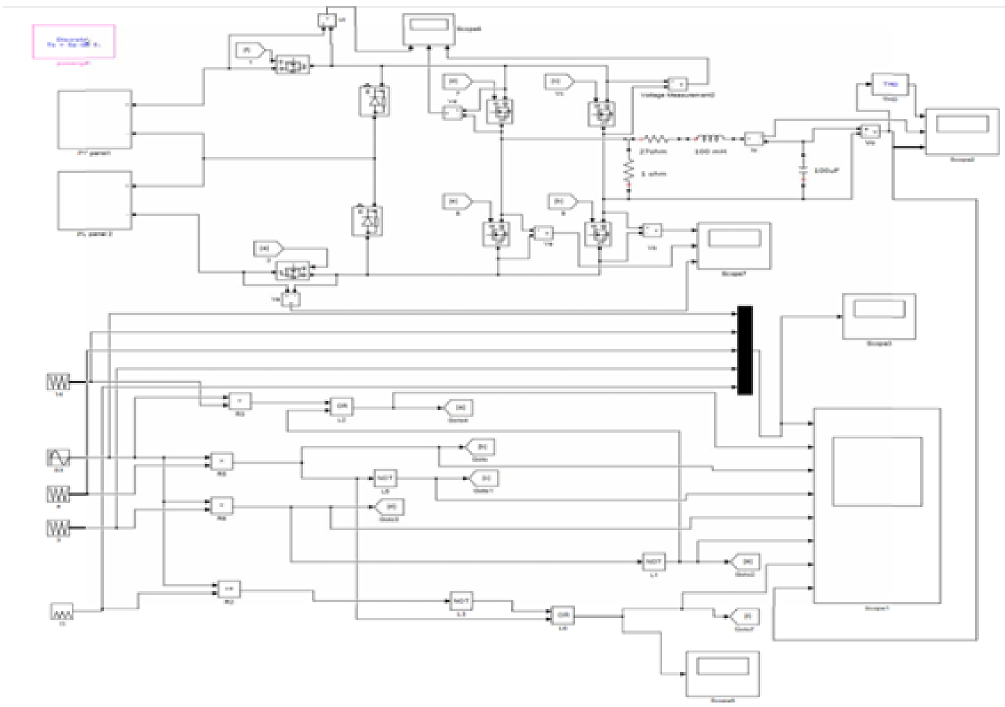


Figure 5. Simulink diagram of proposed 5-level inverter system

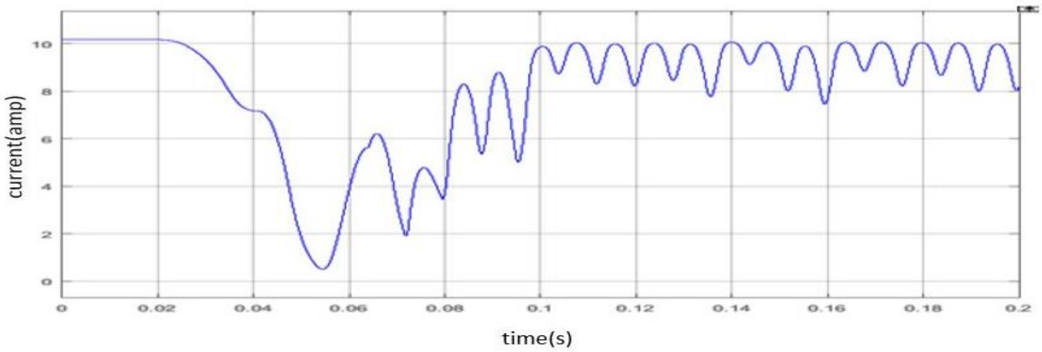


Figure 6. Output power from PV system

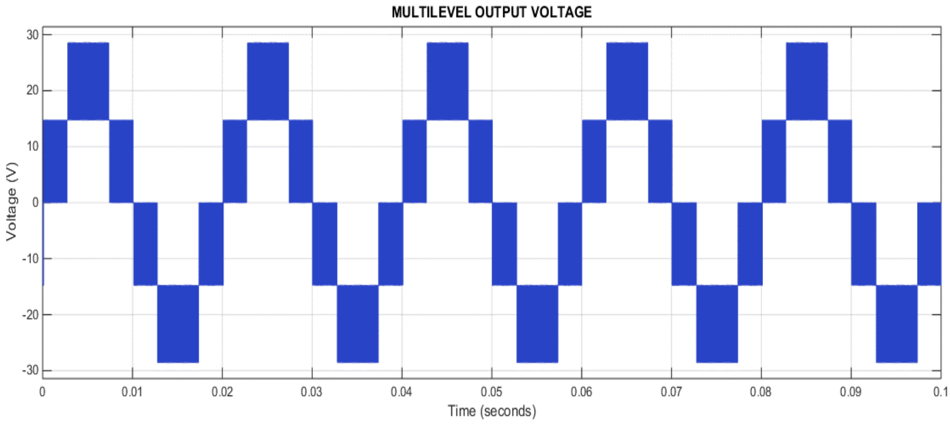


Figure 7. Proposed 5-level output voltage with direct dc supply

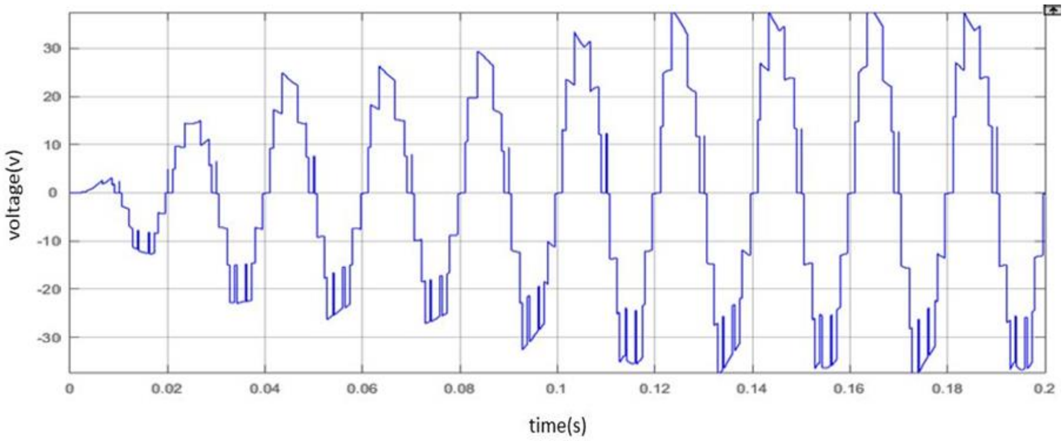


Figure 8. Proposed 5-level output voltage with PV system

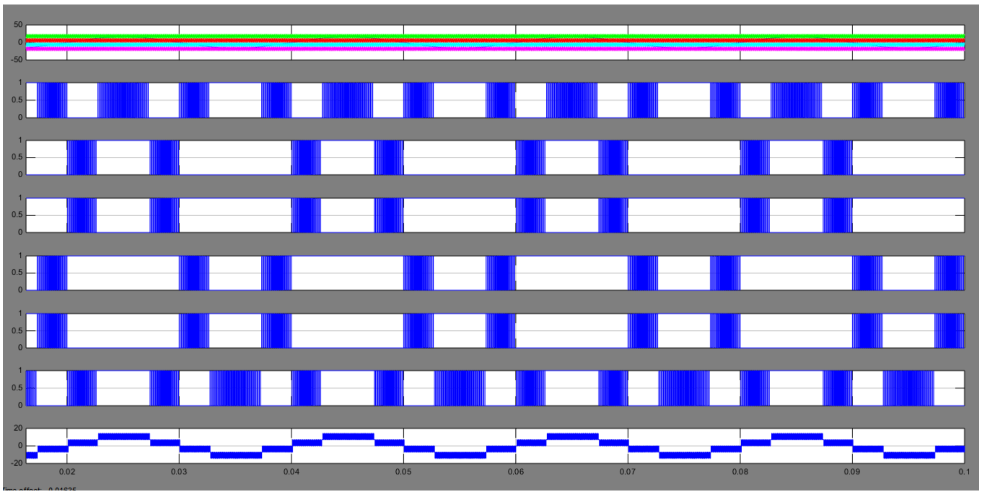


Figure 9.Gating pulse generation using MSPWM scheme

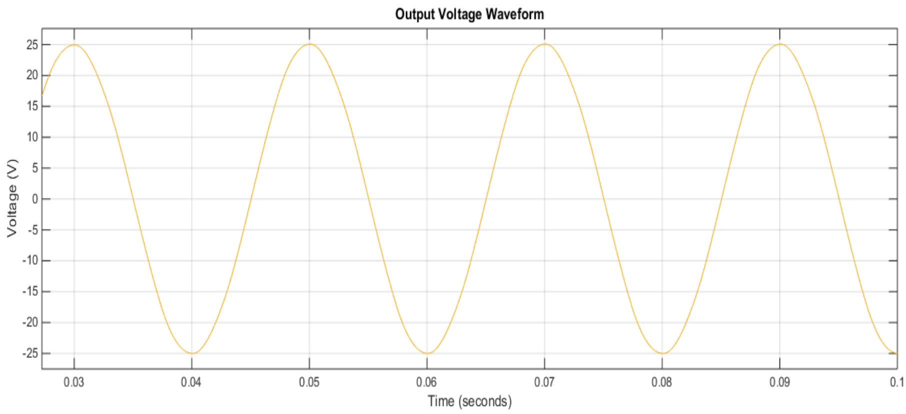


Figure 10. output voltage with filter circuit

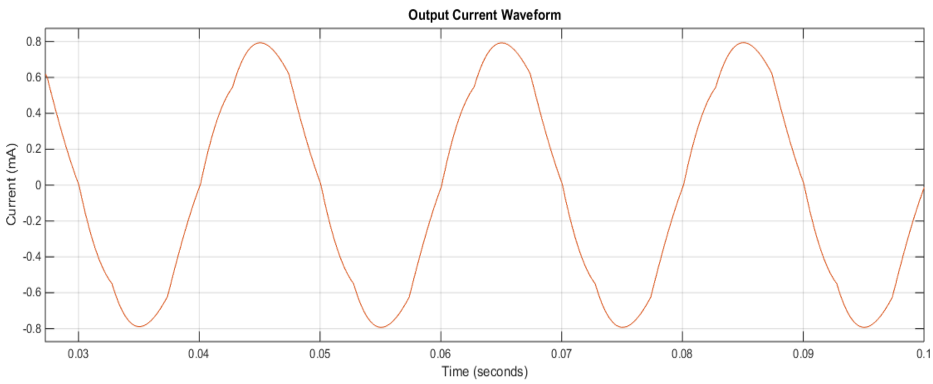


Figure 11. output current without filter circuit

In Figure 9 shows gating pulse generation for 5-level inverter using MSPWM scheme and Figure 10 and 11 shows the output voltage generation with filter circuit and without filter circuit respectively.

6. EXPERIMENTAL RESULTS AND DISCUSSION

This experimental board consists of the latest floating point DSP processor which is TI's TMS320C6713 is the highest performance floating point DSP, has 28K x 16 bit RAM for Program memory. Figure 12 shows hardware implementation of proposed novel 5-level inverter system. And in table-2 shows hardware specifications. The output of 5 level stepped voltage generated, which is shown in Figure 13 and Figure 14 shows the output current of the system.

Table 2. Hardware specifications

S. No.	Components	Specifications	Range	Quantity
1.	DSP	dsPIC30F2010	2.5-5.5 V	1
2.	TLP 250		10-35 V	1
3.	IRF 840		0-500 V	6
4.	LM 7805		3.3-5 V	2
5.	Capacitors			
6.	Coupled Inductor			1
7.	Diode	IN4007		
8.	Transformers		230-12V	2

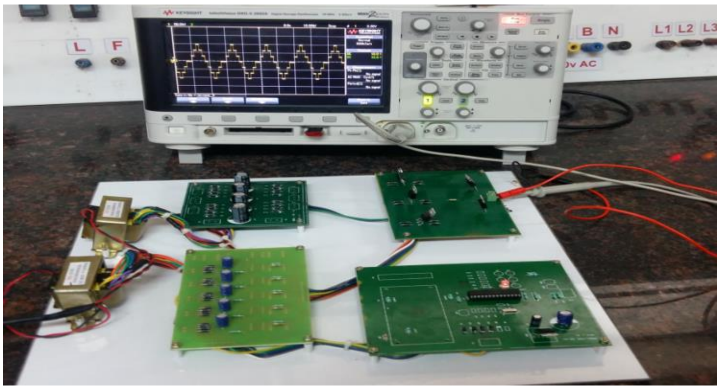


Figure 12. Experimental setup for proposed system

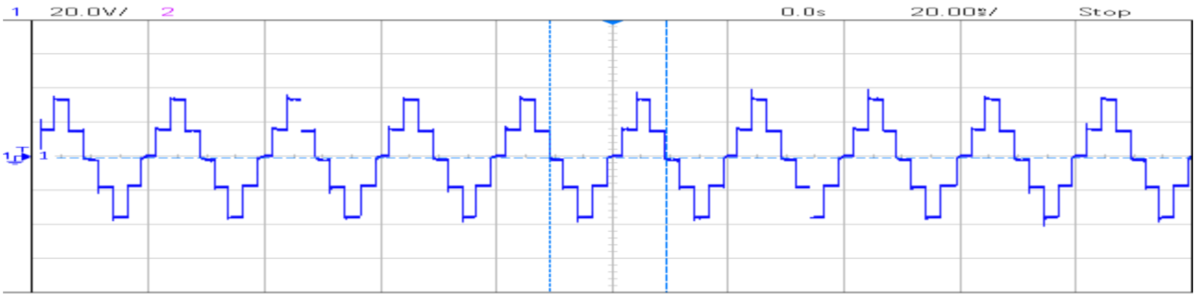


Figure 13. proposed 5-level stepped output voltage

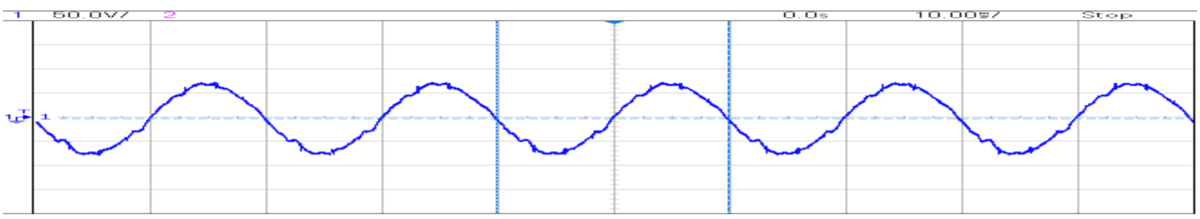


Figure 14. output current of proposed inverter system

7. CONCLUSION

Thus the proposed five-level novel inverter circuit was designed and tested. The simulation of the new inverter with reduced number of switches is carried out in MATLAB. The observed output waveforms which were obtained from MATLAB were compared with the waveform observed from the experimental setup. The proposed energised with help of photo voltaic system and which is controlled using multicarrier sinusoidal PWM scheme. The proposed multilevel circuit was cost-effective owing to the lack of capacitors and was observed to be free from the problems of voltage balancing. The PV cell working was also discussed along with its modeling. The working of the circuit and its modes of operation were also explained in detail. Finally, the results of the simulation were verified using hardware prototype.

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