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Design and Implementation of a Five Level Cascaded Inverter for Variable Drives Applications

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***Abstract*— In this paper, design and implementation of single phase five level Cascaded H-Bridge multilevel inverter with reduced number of switches is done. The existing Cascaded H-Bridge multilevel inverter has two sources and eight switches thus reducing the total harmonic distortion. The two sources being DC is replaced by Photovoltaic modules and are connected to inverter through a closed loop Boost converter. Implementation of five level Cascaded H-Bridge inverter reduces the total harmonic distortion to a least possible and an LC filter at the AC output side of the inverter further reduces it. The analysis has been done for both R and RL loads.**

***Keywords*- Cascaded H-bridge multilevel inverter, Micro-controller.**

I. INTRODUCTION

An inverter is utilized to transform a direct current (DC) source into an alternating current (AC) source using electronic component like switch. While converting DC to AC, it is conceivable to acquire the preferred output voltage and frequency by two types of inverters, one is two level and another one is multi-level inverter (MLI). Cascaded H-Bridge type of Multi-level inverter is more efficient compare to the other topologies of Multi-level inverter. The conventional inverters yield an output voltage with levels ± Vdc, which are termed as the two level inverter. But this output is not a sinusoidal wave. To obtain nearly sinusoidal wave, multi-level inverters are used. Conventional inverters cannot be called as multilevel inverters. If the output of inverter consists of more than 2 levels then only that type of inverter can be called as multilevel inverter. Three level inverter is the initiation of multilevel concept. However, the fundamental perception of a multilevel inverter is to attain higher power with the use of sequence of H-Bridges with numerous low voltage Direct current sources to accomplish the power transformation by generating a set of steps or stepped voltage waveform. Input Direct current sources to the multilevel inverter may be either Batteries or Capacitors or any renewable energy voltage sources. The goal of the inverter is to produce an AC waveform from DC supply. In typical application, the input voltage for the inverter is the same as the DC supply voltage. Also, power is the product of voltage and current. So, larger applications require more power from the DC supply. The power may be maintained by increasing the voltage and decreasing the current by the same proportion or decreasing the voltage and increasing the current in same proportion. If the DC supply voltages increase (adding more batteries in series to maintain or decrease the current) for large power requirement, the components must be able to withstand the maximum DC supply voltage.

The features of a multilevel H-bridge inverter are listed below,

1. The series structure allows a scalable, modularized, circuit layout and packaging since each bridge has the same structure.
2. Requires the least number of components considering there are no extra clamping diodes or voltage balancing capacitors.
3. Output voltages with very low distortion are generated by multilevel inverters.
4. Potential for electrical shock is reduced due to separate DC sources. Limited to certain applications where separate DC sources are available.

II. PRINCIPLE OPERATION OF H-BRIDGE INVERTER

An H-bridge is an electronic circuit that enables a voltage to be applied across the load in either direction. Fig.1. shows the structure of the H-bridge.

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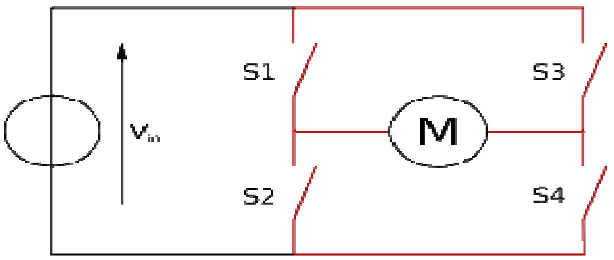

Fig.1.Structure of H-bridge.

An H-bridge is built with four switches. When the switches S1 and S4 are closed and S2, S3 are open a positive voltage will be applied across the load. By opening S1 and S4 switches and closing S2 and S3 switches, this voltage is reversed.

III. CASCADED H-BRIDGE INVERTER STRUCTURE

The quantity of distinct levels in the output voltage of cascaded multilevel inverter is well-defined by m = 2N +1.When the number of DC sources is 2 (i.e. N=2), then the number of levels would be, m=2N+1=2 (2) +1=5. Hence when the quantity of DC sources is two, a five level output is obtained. A five level inverter consists of two H-bridges shown in Fig.2, which are fed by Separate DC sources. There are four switches namely and S1, S2, S3, S4 in the first H-Bridge and there are four more switches namely S5, S6, S7, S8 in the second H-bridge. The load is associated between the terminals A and B.

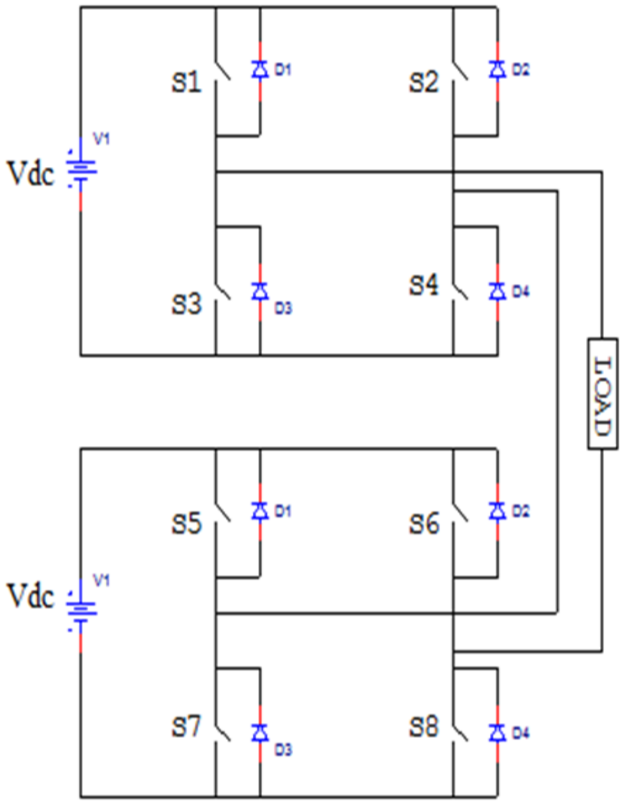

Fig.2. Five level H-bridge inverter circuit.

The multilevel output voltage can be obtained by closing the appropriate switches mentioned in the switching sequence Table 1. Example: by opening all the switches, we get zero output voltage across the load. To get Vdc across the load, close the switches S1, S4, S7, S8. Similarly, to get 2Vdc across the load the switches S1, S4, S5, S8 are closed. And for -Vdc and -2Vdc, the switches S2, S3, S7, S8 and S2, S3, S6, S7 are closed respectively. Fig.3. shows the ideal output waveform of a five level inverter.

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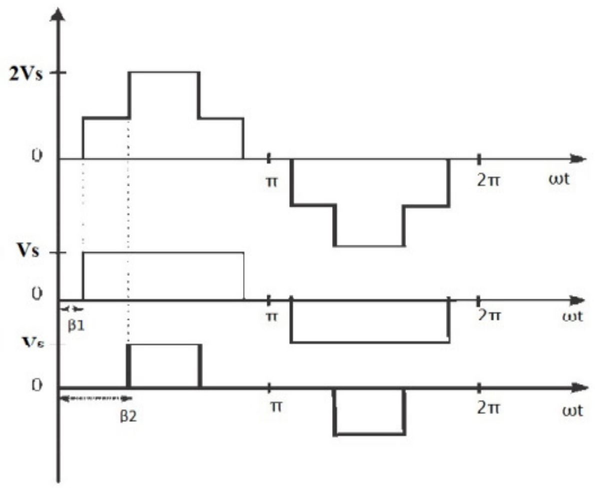

Fig.3. Output waveform of five level inverter

Table 1: Switching states of a five level inverter.

IV. BOOST CONVERTER AND ITS OPERATION

The boost converter in Fig.4 is a DC-DC power converter that steps up the voltage from its input (supply) to its output (load). It is a class of SMPS containing at least two semiconductors (a diode and a transistor) and at least one energy storage element (a capacitor, inductor or the combination of both. To reduce the voltage ripple, filters made of capacitors are normally added. The key principle that drives the boost converter is the tendency of an inductor to resist changes in the current by creating and destroying a magnetic field. In a boost converter, the output voltage is always higher than the input voltage.

1) When the switch is closed, current flows through the inductor in clockwise direction and the inductor stores some energy by generating a magnetic field. Polarity of the left side of the inductor is positive.

2) When the switch is opened, current will be reduced as the impedance is higher. The magnetic field previously created will be destroyed to maintain the current towards the load. Thus the polarity will be reversed. As a result, two sources will be in series causing a higher voltage.

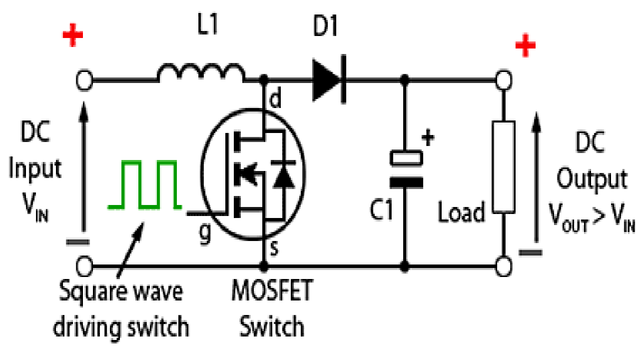

Fig.4. Boost Converter.

OUTPUT VOLTAGE	S1	S2	S3	S4	S5	S6	S7	S8
0	0	0	1	1	0	0	1	1
Vs	1	0	0	1	0	0	1	1
2Vs	1	0	0	1	1	0	0	1
-Vs	0	1	1	0	0	0	1	1
-2Vs	0	1	1	0	0	1	1	0

V. SIMULATION ANALYSIS

The Simulink model for Five level H-bridge inverter is developed using MATLAB is as shown in Fig.5. The 12 pulse generators are used in order to generate the gate pulses for each MOSFET's. The delays and pulse widths in each pulse generator are calculated according to the switching pulses.

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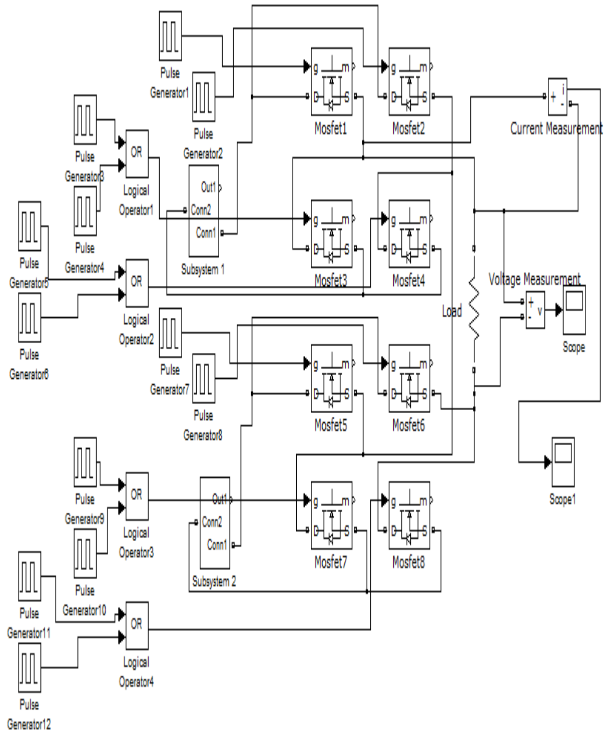

Fig.5.Simulink model of five level inverter.

Subsystem 1 and 2 consist of photovoltaic module in which the solar cells are connected to get a required voltage. Fig.6 shows the Simulink model of subsystem.

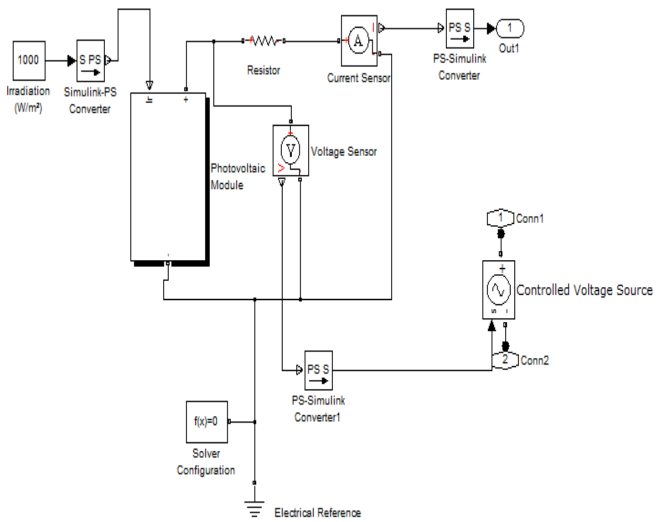

Fig.6. Simulink model of subsystem.

VI. SIMULATION RESULTS

With inverter specifications, simulation has been carried out and the output voltage obtained from the Simulink model for R load and RL load was observed from Fig.7 and Fig 8.,

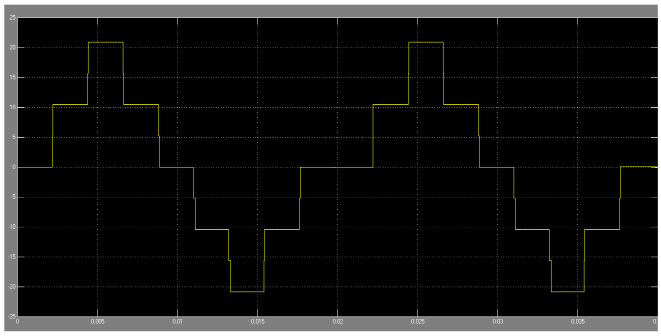

Fig.7.Output voltage waveform of five level inverter for R load.

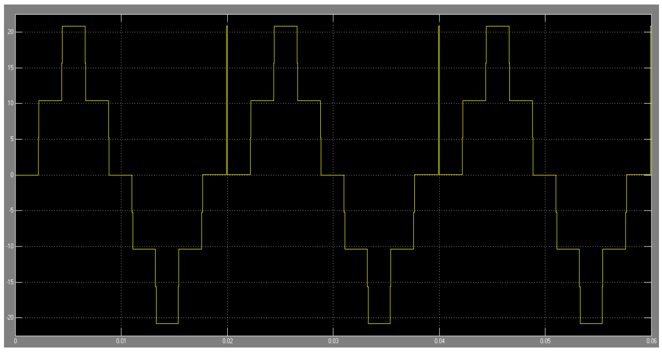

Fig.8.Output voltage waveform of five level inverter for RL load.

VII. HARDWARE IMPLEMENTATION

In the hardware prototype, a supply voltage of 230V is stepped down to 12V using a step-down transformer, which is then transformed to Direct Current using a diode bridge rectifier. The rectified voltage is then fed to the voltage regulator IC, which regulates the voltage to 12V and it is fed to H-bridge as supply.

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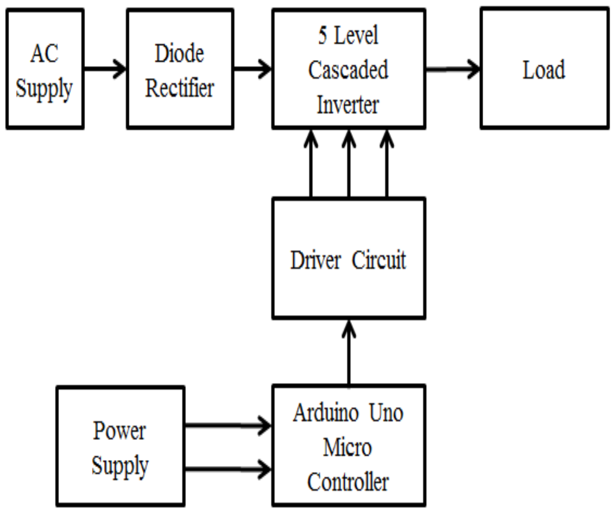

Fig.9.Block diagram of experimental setup of five level inverter.

Using ATmega328 micro-controller the gate pulses are provided to each MOSFET's. The pulses generated by the controller are of 5V magnitude. These pulses are given to the driver circuit as input. Driver circuit Fig.10, is used to for the purpose of isolation of negative current to the microcontroller, amplification of voltage and to create constant voltage source. Isolation refers to the separation of the power circuit from micro-controller. The output voltage from micro-controller is given to IR2110 driver IC.

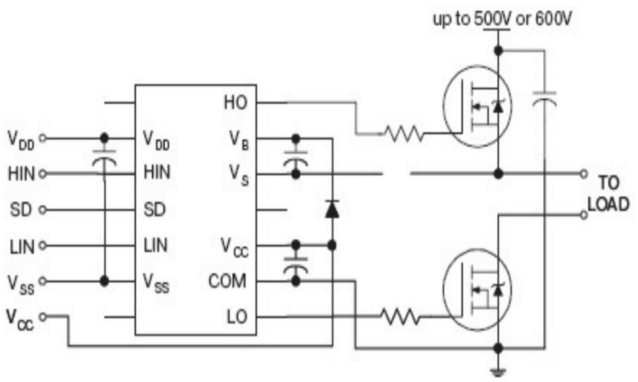

Fig.10. Typical connection diagram of driver circuit.

The square pulse should have a constant voltage of 5V. The output voltage of driver circuit will have an increased magnitude of 12V that will be sufficient for driving the MOSFET P55NF06. It is also used to improve the switching voltage for the MOSFET. Fig.11. shows the hardware prototype of five level inverter for R load. In this analysis the R, RL loads are used.

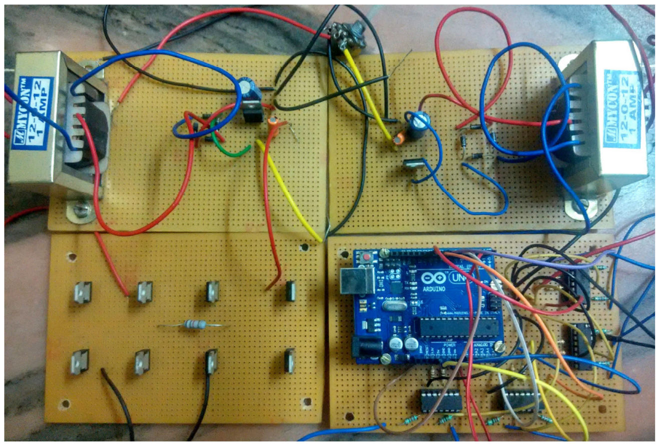

Fig.11.Hardware Prototype of the five level inverter for R load.

VIII. CONCLUSION

In this paper, simulation of five level inverter with R and RL load has been proposed and the hardware prototype of five level inverter with R load using micro-controller ATmega328 is implemented. Future work will be towards the implementation of 7, 9 and 11 level inverters. As the levels of output increases, nearly sinusoidal waveform will be obtained, this results in reduced THD. So the benefits of multilevel inverter include, due to low-frequency switching, less THD, reduced ac filters, and possibility to replace MOSFETs with IGBTs, and thereby providing compact power conversion. It can be concluded that, in order to maintain the good quality of power, it is necessary to replace the conventional drives with 2 level inverters by multilevel inverters.

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