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Seven Level Inverter

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***Abstract*:** *In this paper we proposed better solution for designing seven level inverter by injecting small amount of power from solar cell or battery source into grid to reduce switching power loss, reduce harmonic distortion in it and EMI in power electronic devices caused by switching operation. A new power generation system, which is composed with DC power source, seven level inverter, filter and step-up transformer. The DC power is obtained from either solar cell or battery source. This paper represents the proposed technology of seven level inverter which consist only eight power MOSFETs as a switches. The switching of this MOSFET is done as per the PWM technique which is generated by using AVR microcontroller. By selecting the exact on-off switching of MOSFETs we can generate seven level AC output. There are various techniques in the PWM generation out of these multiple pulse width modulation is most efficient technique which is accepted. The small amount of harmonics produced in this inverter system is removed by the filter. Due to increasing number of levels the filter design is very simple and size of filter reduces.*

Keywords—AVR Microcontroller, MOSFET, Optocoupler

1. Introduction

The multilevel inverter was first introduced in 1975. The first multilevel inverter introduced was three level inverter. A multilevel converter is a power electronic device that gets desired output voltage from several levels of dc voltages as inputs. If we increase the number of DC voltage sources, then the output waveform is nearly sinusoidal. The advantages of the multilevel inverter are the quality of output voltage is high while the small output voltage, the switching losses are less as compared to conventional two level inverters.

There are different topologies of the multilevel inverter out of them Diode-Clamped inverter and H-Bridge inverter are most commonly used. Due to both of this topologies the rating of the switching devices is highly reduces to the rating of each cell. The drawback of multilevel inverter is required more number of switching devices. The number of switching devices required for multilevel inverter is depends on the number of levels. The formula for calculating number of switching devices is,

Number of levels=2(k-1)

where k is the number of levels. If the number of switching devices is high, then circuit becomes more complex, its reliability and efficiency will be reducing.

In cascaded H-bridge inverter the problem of the dc link voltage unbalancing does not occur, thus we can easily increase the number of levels. Because of above advantages the cascaded H-bridge inverter is widely used in HVDC, SVC, stabilizers, and high power motor drives.

Diode-clamped inverter required one dc bus and the voltage level are produced by number of capacitors in series. The capacitor divides the number of DC bus voltage equal to number of capacitors in series. For large number of levels, the balancing of the capacitors is very complicated. The diode clamped topology is difficult for three phase because the neutral point balancing problems.

In the square wave inverter, the harmonics are more than multilevel inverter because in case of multilevel inverter the output waveforms are in stepped form. Due to stepped form, the small amounts of harmonics are present which can be reduced by use of PWM methods. This paper presents how reduced harmonic distortion is achieved for a new topology of multilevel inverters. In this topology the numbers of switching devices required are less compared to Diode clamped multilevel inverter and conventional H-Bridge inverter for same number of levels.

2. Literature Review

In the existing system for constructing the seven level inverter the use of the more number of switching devices is must. In the design of seven level inerter there are three topologies used, these topologies are as,

- Diode clamped multilevel inverter
- Flying capacitor multilevel inverter
- H-bridge multilevel inverter

The Diode clamped and flying capacitor multilevel inverter use capacitor to develop several voltage levels. But it is difficult to regulate the voltage of these capacitor. Since it is difficult to create an asymmetric voltage technology in both the diode clamped and flying capacitor topologies, the power circuit is complicated by the increase in the voltage levels that is necessary for a multilevel inverter. The number of capacitors in series is

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depends on the output voltage levels, and as a level increases balancing of the capacitors is difficult. The diode clamped topology is difficult for three phases because the neutral point balancing problems.

For a single-phase seven-level inverter, 12 power electronic switches are required in the conventional H-bridge topologies. Asymmetric voltage technology is used in the cascade H-bridge multilevel inverter to allow more levels of output voltage, so the cascade H-bridge multilevel inverter is suitable for applications with increased voltage levels.

3. Block Diagram Representation

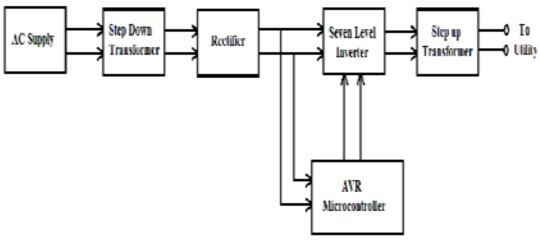

Figure 1. Block Diagram of 7 Level Inverter for power generation system

The above fig shows the block diagram of 7 level inverter in which AC supply, step down transformer, rectifier, AVR microcontroller, 7 level inverter and step up transformer are used. the 230V, 50 Hz AC supply is given to the step-down transformer which step it down to the 15V, 50Hz output voltage. The 15V AC supply is converted into 12V DC supply by using rectifier circuit. The 3 set of the 12V supply is given to the inverter circuit that is total 12V supply is given to inverter. The seven level inverter converts it into 7 stages. The supply till is 36V ac and for the domestic applications we required 230V AC. So by using the step up transformer the 36V ac supply is stepped to230V AC. The microcontroller required 5V DC supply which obtained by using rectifier. The switching sequence required for the MOSFET is given by microcontroller.

AC Supply

Normally the supply used for the residential applications is 230 volts, 50 Hz, AC supply. In this inverter we use AC supply and then it converted into DC by using rectifier instead of use solar panel for DC supply. Because the solar panel does not give constant output.

Step Down Transformer

Step down transformer is one whose secondary voltage is less than its primary voltage. This kind of transformer "step down the voltage applied to it. The step down unit the transformer converts high voltage, low current power into low voltage, high current power.

We use here 230V / 15V step down transformer to convert it into DC supply, is shown in following figure,

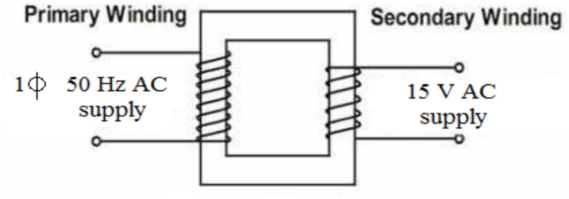

Figure 2. Step down transformer

Rectifier

The rectifier is an electrical device which converts an alternating current into a direct current one by allowing a current to flow through it in one direction only. Only positive cycles of the AC supply are passes the negative cycle is blocked and we give only positive that is DC output.

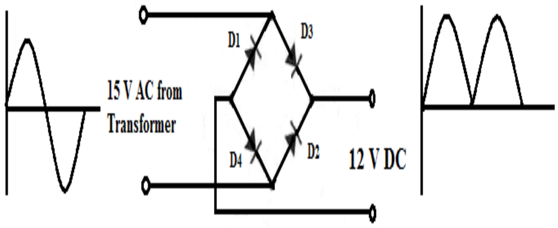

Figure 3. Rectifier Circuit

The rectifier used in this project of seven level inverter power supply is full wave rectifier. From the output of this rectifier circuit the purely rectified and filtered DC supply is given to the seven level inverter and microcontroller circuit. The supply given to the inverter is 36 volts which is divided into 3 sources each consisting 12 volts supply. The circuit for each 12 volts is equipped with separate transformer and rectifier circuit. The supply given to the microcontroller circuit is of 5-volt dc.

Microcontroller

In the seven level inverter we use microcontroller for exact switching of MOSFET according to level as given in circuit configuration. The time delay required for each level is 1.66 milliseconds. The time required for each level is calculated from time period of total cycle that is 20 milliseconds means at fundamental power frequency. The time delay for on and off of MOSFET is set in program. The microcontroller program is set according to the level of output waveform.

The microcontroller used for the seven level inverter is low power AVR Atmel Atmega 328P 8-bit microcontroller.

H-Bridge Inverter

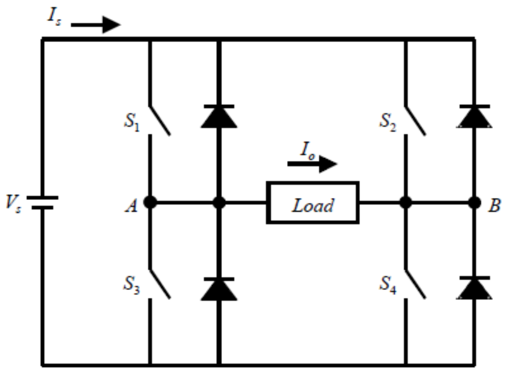

Figure 4. H-Bridge inverter

The inverter circuit consists of four main switches and four freewheeling diodes. According to four-switch combination, three output voltage levels, +V, -V, and 0, can be synthesized for the voltage across A and B. During inverter operation shown in Fig.3.switch of S1 and S4 are closed at the same time to provide VAB a positive value and a current path for Io. Switch S2 and S4 are turned on to provide VAB a negative value with a path for Io. Depending on the load current angle, the current may flow through the main switch or the freewheeling diodes.

When all switches are turned off, the current will flow through the freewheeling diodes. In case of zero level, there are two possible switching patterns to synthesize zero level, for example, 1) S1 and S2 on, S3 and S4 off, and 2) S1 and S2 off and S3 and S4 on. A simple gate signal, repeated zero-level patterns, is shown in Fig.3 all zero levels are generated by turning on S1 and S2.

Step Up Transformer

The step up transformer used to step up the low filtered voltage into 230V required for the domestic applications.

4. MOSFET Switching Sequence

As shown in the above table for switching angle 0^o to 15^o the MOSFETs Q7 and Q8 are on for 0.833 milliseconds. The inverter is designed for 50 Hz switching frequency that is time period of 20 milliseconds, at 0^o to 15^o voltage applied across the load is zero. For 15^o to 165^o MOSFETs Q1 and Q4 are on, at that time the voltage Vdc is applied across the load. After 45^o the MOSFET Q5 is on upto 135^o, at that time +2Vdc voltage is applied across the load. After 75^o the MOSFET Q6 is on upto 105^o. At that time +3Vdc voltage is applied across the load. Between 165^o to 195^o MOSFETs Q7 and Q8 are on at that time zero voltage is applied across the load.

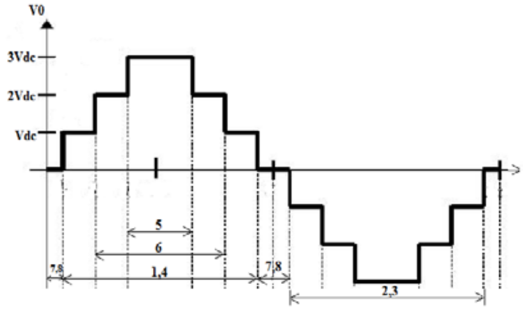

Fig.5: MOSFET switching sequence

Sr. No.	Devices	Associated voltage level	Switching angle	Switching time (Ideally)
1	Q7 & Q8	Zero	0^o to 15^o	0.833 ms
			165^o to 195^o	1.66 ms
			345^o to 360^o	0.833 ms
2	Q1 & Q4	+ Vdc	15^o to 165^o	8.33 ms
3	Q6	+/- 3Vdc	75^o to 105^o	1.66 ms
			255^o to 285^o	1.66 ms
4	Q5	+/- 2Vdc	45^o to 135^o	5 ms
			225^o to 315^o	5 ms
5	Q2 & Q3	-Vdc	195^o to 345^o	8.33 ms

Table 1. switching sequence with time

As shown in the above table for switching angle 0^o to 15^o the MOSFETs Q7 and Q8 are on for 0.833 milliseconds. The inverter is designed for 50 Hz switching frequency that is time period of 20 milliseconds, at 0^o to 15^o voltage applied across the load is zero. For 15^o to 165^o MOSFETs Q1 and Q4 are on, at that time the voltage Vdc is applied across the load. After 45^o the MOSFET Q5 is on upto 135^o, at that time +2Vdc voltage is applied across the load. After 75^o the MOSFET Q6 is on upto 105^o. At that time +3Vdc voltage is applied across the load. Between 165^o to 195^o MOSFETs Q7 and Q8 are on at that time zero voltage is applied across the load.

For generating negative steps, at angle 195^o to 345^o MOSFETs Q2 and Q3 are on, for that period –Vdc is applied across the load. At angle 225^o MOSFET Q5 is on, in that period -2Vdc voltage is applied across the load. The MOSFET Q5 is on upto 315^o. At an angle of 255^o MOSFET Q6 is on and this is on upto 285^o at that period -3Vdc voltage is applied across the load. Between the angles 345^o to 360^o again MOSFETs Q7 and Q8 are on, at that period again zero voltage is applied across the load.

5. Hardware

The following figure shows the complete hardware of the seven level inverter which includes power supply, rectifier circuit, inverter circuit. Three transformers are connected to give supply to inverter circuit and one is used to power supply for MOSFET.

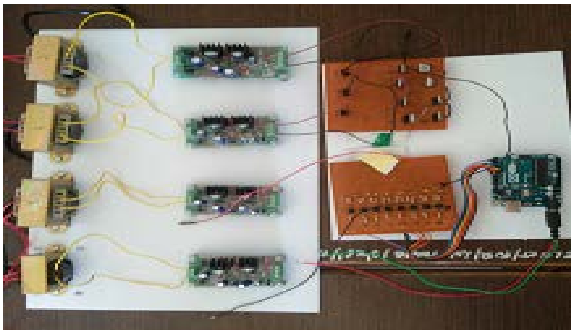

Figure 6. Actual hardware circuit of seven level inverter

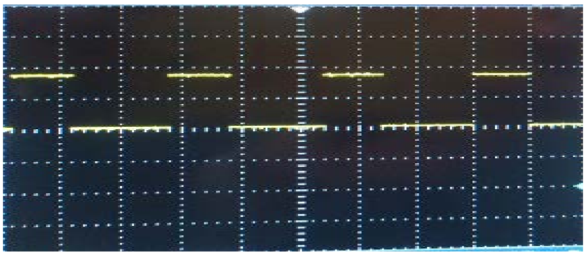

Fig.7: Gate pulse of the single MOSFET

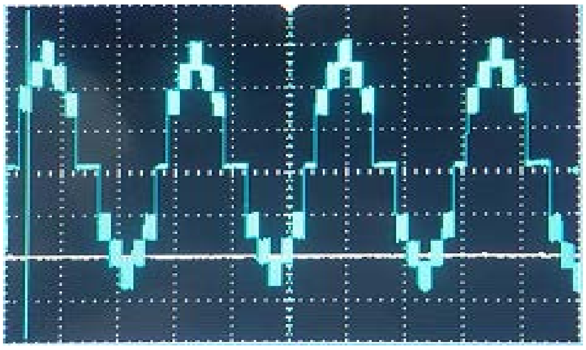

Fig.8: Output levels of the seven level inverter

6. Conclusion

This paper proposes to convert the dc energy from battery or solar cell array into ac energy that is fed into the utility. The proposed solar power generation system is composed of a seven level inverter. The seven level inverter contains only eight power electronic switches, which simplifies the circuit configuration. Out of this one power electronic switch is switched at any time to generate the seven level output voltage. This reduces the switching harmonics and also switching losses therefor increases the efficiency. The output harmonics in the load is reduced by using a filter circuit. The experimental results show that seven level output voltage and it is in sinusoidal voltage.

7. Acknowledgement

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