A DUAL AXIS SOLAR TRACKER WITH A HYBRID CASCADED MULTILEVEL INVERTER

1. Muraleedharan MT
Department of Electrical and Electronics EngineeringGovernment Polytechnic College ,Kalamassery
muraleedharan5149@gmail.com

2.Unnikrishnan P
Department of Electrical and Electronics Engineering
Kerala Government Polytechnic College ,West Hill
unnisrishylam@gmail.com

3.Ajay Kumar EP
Department of Electrical and Electronics EngineeringSreerama Government Polytechnic College,Thriprayar
epajay2010@gmail.com

4. Basheer K
Department of Electrical and Electronics Engineering
SSM Polytechnic College Tirur
hodelectrical@ssmpoly.ac.in

5.Kamal VV
Department of Electrical and Electronics EngineeringKerala Government Polytechnic College ,West Hill
vvkamalvv@gmail.com

6.Akhil Ahammed KE
Department of Electrical and Electronics Engineering
kerala Government Polytechnic College ,West Hill
akhilahmedsav@gmail.com

Abstract— **Energy crisis is one of the biggest problems in developing countries. There is a big gap between generation and demand of Electric energy. Solar energy which is present in abundance can play a vital role to overcome the energy deficiency. The potential of solar voltaic energy can also be exploited for averting environmental pollution and managing atmospheric emission. This project work provides a proposal for design of an inverter using dual axis solar tracker installed on rooftop with a single phase hybrid cascaded multilevel inverter.**

The output of a photovoltaic panel depends on its position with respect to the sun at any instant of time. To extract the maximum power from the panel, tracking systems are generally used for positioning it at an optimal angle. .

This project focuses on presenting the structure and application of a microcontroller based dual axis solar tracker which tracks the direction of the solar radiation thereby adjusting the movement of solar panel accordingly. This facilitates the sun to remain perpendicular to the PV panel throughout the day which makes the total energy received to be increased by 30-40%. The energy hence received gets stored in a chargeable battery. This battery has an inverter attached to it so that whenever there is a power-cut, the stored energy may be used to light up the appliances.

This project also provides single phase hybrid cascaded modular multilevel inverter topology which is derived from a proposed modified H-bridge (MHB) module. This topology results in the reduction of number of power switches, losses, installation area, voltage stress and converter cost. For renewable energy environment such as Photovoltaic (PV) connected to the micro-grid system, it enables the transformer less operation and enhances the power quality. This multilevel inverter is an effective and efficient power electronic interface strategy for renewable energy systems.

The verification of the applicability and performance of the proposed structure in PV renewable energy environment,

simulation results were carried out by MATLAB/SIMULINK under both steady state and dynamic conditions was completed.

I.Introduction

The present scenario of the variation in the climatic changes has reached the critical level. The main reasons for climatic changes are due to natural causes and man-made destructions like global warming and green house gases are affecting the climatic conditions around the world.

The resources of most of the energy consumption are the fossil fuel, which are oil, coal or gas. The other source of energy is the nuclear energy. Each one of these types has its own drawbacks. The increasing consumption of fossil fuel and especially oil has caused the continuing depletion of the world reserve of oil and the lack of new explorations of new reserves. Another negative impact of fossil fuel in the environmental considerations is the carbon dioxide emission that is causes the global warming and climate change which is raising horrible concerns about the future of our planet. For the nuclear energy, although it does not involve carbon dioxide emission but it is still considered a dangerous source of energy because of the risk of nuclear radiation and on the other hand the nuclear waste that needs to be looked after 10'000 years according to United States Environmental Protection Agency standards. Also, nuclear energy is highly controversial and politics plays a big role for the developing countries. For the reasons summarized above, the world has turned to other form of energy sources namely the green energy sources. Green energy is clean in the sense that it does not have a bad impact on the environment, and also it is renewable. Types of green energy sources are:

- Hydropower
- Wind power
- Solar power
- Bio fuel
- Wave power
- Geothermal power

This project describes in detail about the design, development and fabrication of Prototype Solar Tracking Systems mounted with a dual-axis solar tracking controllers. The solar tracking system-Tilted Azimuth-Altitude Dual Axis Tracker are designed in this project. LDR had been used as sensing unit for the projects. The control circuit for the systems was based on Atmega328 Microcontroller which was programmed to detect the sunlight through the LDR sensors and then actuate the DC geared motor using L293D motor driver to position the solar panel where it can receive the maximum sunlight. After studying and analyzing a number of research papers, it is found that most of the tracking systems done are single axis tracking. Many of them are costly according to their framing design and use of components. Their tracking system can track daily change of sun position but not seasonally. Commercially tracking system can be made more efficient discarding the economic issue.

Analytical calculations for both sun tracking and MPPT were presented in this project and the results are compared to fixed system. Hardware implementations were presented in this project using Arduino controller

Ac loads require constant or adjustable voltages at their input terminals. When such loads are fed by inverters, it's essential that output voltage of the inverters is so controlled as to fulfill the requirements of AC loads. This involves coping with the variation of DC input voltage, for voltage regulation of inverters and for the constant volts/frequency control requirement. There are various techniques to vary the inverter gain. The most efficient method of controlling the gain (and output voltage) is to incorporate pulse-width modulation (PWM) control within the inverters. The carrier based PWM schemes used for multilevel inverters is one of the most straight forward methods of describing voltage source modulation realized by the intersection of a modulating signal (Duty Cycle) with triangular carrier wave forms. Multilevel inverters are commonly used for DC to AC conversion in renewable energy conversion.

1.1 Multilevel inverter

Present trends in the market, inverters are in the multilevel mode of inversion comes with many function and advantages. These advantages are focused on improvement in the output signal quality and a nominal power increase in the inverters. This also true if a comparison done to well known two levels with three levels and nine level inverter. The term multilevel inverter was first introduced back in 1981 by Nabae.

By increasing the numbers of levels inverter, the output voltages have more steps generating a staircase waveform, which has reduced harmonics distortion.

Figure 1.1 shows the comparison of the quality between a single-phase two-level inverter is compared to three and nine level voltage multilevel waveform.

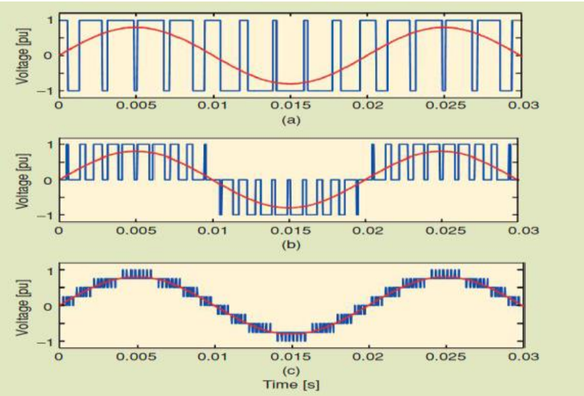

Figure 1.1 **Comparison between a single-phase two-level inverter is compared to three and nine level voltage multilevel waveform.**

Multilevel inverters has gained much attention in the application areas of medium voltage and high power owing to their various advantages such as a lower common mode voltage, lower voltage stress on power switch, lower dv/dt ratio to supply lower harmonics content in output voltage and current.

Three major multilevel inverter structures which have been mostly applied in industrial application have been emphasized as the diode clamp, the flying capacitor and cascade H-bridge inverter with separated DC sources. Based on these three basic types, a hybrid and an asymmetric hybrid has been developed.

This project also focuses a single phase hybrid cascaded modular multilevel inverter topology which is derived from a proposed modified H-bridge (MHB) module. This topology results in the reduction of number of power switches, losses, installation area, voltage stress and converter cost. For renewable energy environment such as Photovoltaic (PV) connected to the micro-grid system, it enables the transformer less operation and enhances the power quality. This multilevel inverter is an effective and efficient power electronic interface strategy for renewable energy systems.

II. Proposed Solar Tracker system

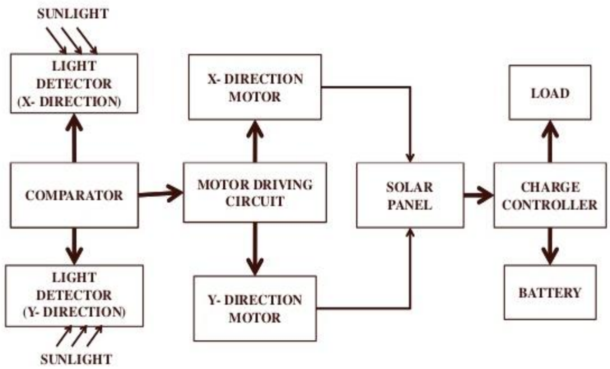

Fig 2.1 Block diagram of solar tracker

Light-dependent resistors are connected at the four side of the solar panel to capture maximum light energy. LDR is a resistor which works on photoconductivity. The resistance of an LDR is extremely high. When illuminated the light resistances will drop dramatically and the main controller receives an analog input from the LDR The internal analog to-digital converter (ADC) compares the solar panel sensor voltage. The analog input from the light sensor goes into the ADC port of the microcontroller and the digital signal is then fed to motor drivers which drive the horizontal and vertical motor.

Dual axis solar tracker consists of four LEDs which are sensed the variation of the incident solar radiation in North, South, East , West and validating the both movements , azimuthally (by checking the response of stepper motor) and zenithal (checking the response of linear actuator). Feedback controller is based on the Arduino platform and the block of sensors is based on the photodiode and operational amplifier. The input to the comparator is the intensity of output received from the sensor block, which is amplified and generates error voltage of feedback between the sensors North-South and West –East imbalance.

This moment the comparator sensitive to these variations the linear actuator being the rod extended or moved back to obtain maximum performance in elevation movement. It also activates the driver that allows turning by means of stepper motor improving the effectiveness in azimuthally movement. Each pair of data is captured and stored by the Arduino platform regularly and it activates the movement of motors.

The solar panel tracks the radiation and fed to battery. The 12V battery goes to 7805 voltage regulator from where the output 5V is spreads to all logic circuitry. The charge controller and auto load change over is connected between solar panel-battery and battery-load respectively to safe guard the battery, The charge controller avoids the battery to get bulged with over charging and auto load change over avoids the over draining of charges from the battery due to excess usage from load. Figure 2 shows the circuit diagram of dual axis solar tracker. LDR'S are placed across the four sides of panel which are connected to analog inputs of Arduino UNO, this compares the voltage set. The analog signals are converted into digital and passed to pin L293D which takes the input from Arduino UNO and controls the horizontal and vertical motor connected across pin 3, 6 and 11, 14 respectively. The motion of motor whether to rotate clockwise or anti-clock wise is controlled by driver as shown in figure 2.2.

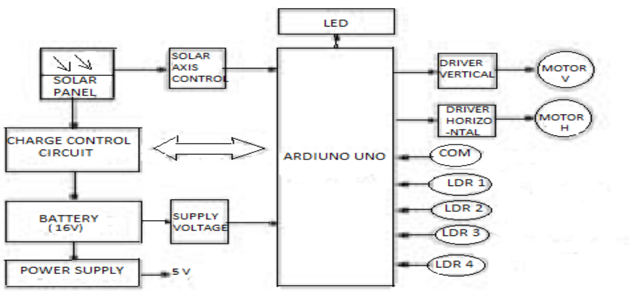

Figure 2.2.**Tracker connection arrangement.**

DC gear motor with speed of 10rpm is used to rotate the panel weighing 0.650Kg. The supply voltage from battery is regulated to 5Vusing voltage regulator 7805. The horizontal and vertical movements of motors are controlled by microcontroller as per the program fed to the Arduino.

The programming cycle on Arduino is basically as follows:

Plug the board into a USB port on your computer.

Write a sketch language that will bring the board to life.

Upload this sketch language to the board through the USB connection and wait for few seconds for the board to restart. The board executes the sketch that you wrote.

2.2 INVERTER SYSTEM

This project focus a cascaded H- bridge nine level inverter connected with a roof top solar tracker and feed to residence building and a utility grid. It consists of a multilevel DC-link voltage source and single phase full bridge inverter. Multilevel DC-link voltage source is formed by connecting a number of half bridge cells in series with each cell having a voltage source controlled by two MOSFET switches. The two MOSFET switches will operate in toggle manner. The MOSFET switches are triggered by proper switching signals by the program fed to the Arduino program.

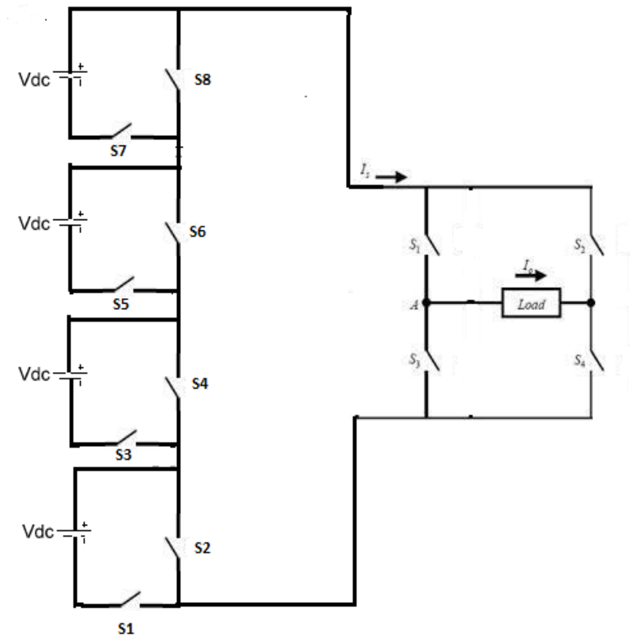

***Figure 2.3.* The nine level cascade H – Bridge inverter**

The nine level cascade H –Bridge inverter is illustrated in figure 3.3. Each separate dc source (SDCS) is connected to a single-phase full-bridge, or H-bridge, inverter through a DC link. Each DC level can generate three voltage outputs, +Vdc, 0, and – Vdc by connecting the dc source to the ac output by different combinations of the four switches, S1 , S2 , S3 , and S4 . To obtain +Vdc, switches S1 and S4 are turned on, whereas –Vdc can be obtained by turning on switches S2 and S3. By turning on S1, S2, S3, and S4 the output voltage is 0.

The DC output of each four sources is connected to the inverter by DC link. The DC linking is possible by switching by eight switches as shown in figure 24. This linked DC voltage with nine level is inverted by an H – bridge inverter. The ac outputs of each of the different full-bridge inverter levels are connected in series such that the synthesized voltage waveform is the sum of the inverter outputs as shown in figure 3.4. The number of output phase voltage levels' **m'** in a cascade inverter is defined by **m** = 2**s**+1, where **s** is the number of separate dc sources.

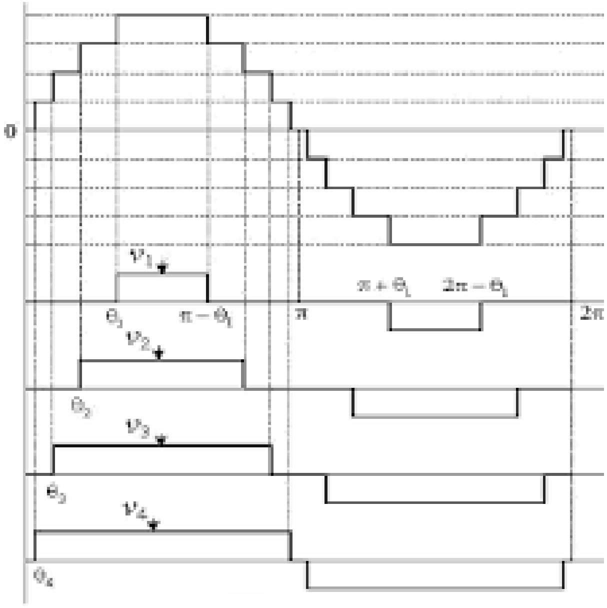

Figure 2.4. **Voltage waveform**

III. Hardware Implementation and Results

5.1 IMPLIMENTATION OF DUAL AXIS SOLAR TRACKER

Figure 5.1 shows the design of dual axis solar tracker. The tracker consists of a solar panel of 22V, 5W moving towards east to west in every day according to the movement of sun. This is possible by a DC motor connected to vertical moving mechanism.

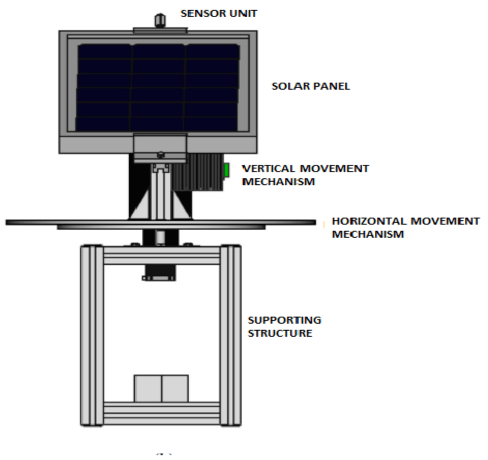

Figure 3.1. **Design of dual axis solar tracker**

The position of sun is tracked by LDR sensors which are fixed on the sensor unit. The sensor unit consists of four LDRs, two of them for vertical movement and two for horizontal movement. The LDRs are positioned at north – south direction and east - west direction. The east – west LDRs are compare with their signal and fed to the microcontroller. The microcontroller controls the vertical movement to the DC servo motor and the panel position perpendicular to sun throughout the day.

Similarly the north – south LDRs also compare their sensor output and fed to the microcontroller and control the horizontal position by tilting the platform by DC servo motor on the horizontal movement mechanism. Thus the tracker keeps the panel in the maximum power tracking point (MPPT).

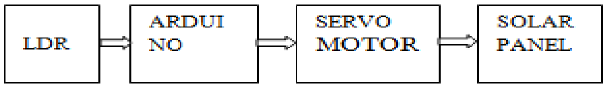

Figure 3.2. **Block diagram of tracker**

The principle of the solar tracking system is done by Light Dependant Resistor (LDR). Four LDR's are connected to Arduino analog pin A0 to A4 that acts as the input for the system. The built-in Analog-to-Digital Converter will convert the analog value of LDR and convert it into digital. The inputs are from analog value of LDR, Arduino as the controller and the DC motor will be the output. LDR1 and LDR2, LDR3 and LDR4 are taken as pair .If one of the LDR in a pair gets more light intensity than the other, a difference will occur on node voltages sent to the respective Arduino channel to take necessary action. The DC motor will move the solar panel to the position of the high intensity LDR that was in the programming.

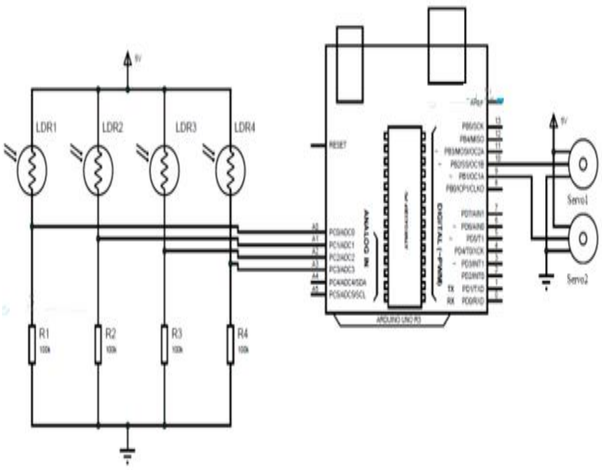

Figure 3.3. **Sensor unit circuit with MC**

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The microcontroller used for this project is ARDIUNO UNO

Figure 3.4. **Prototype model of project**

5.4 COMPARISION BETWEEN FIXED SOLAR TRACKER AND DUAL AXIS SOLAR TRACKER

The voltage drawn by the solar panel with and without tracking and power generated with and without tracking respectively. The maximum generation on power is between 8am to 4pm. Table 5.2& 5.3 shows the voltage and power observation result of tracker system.

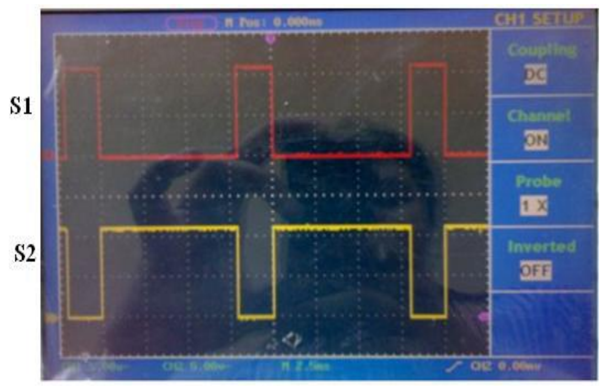
SL NO	*TIME*	*WITH SOLAR TRACKER*	*WITH OUT SOLAR TRACKER*
1	*8 AM*	*18.1 V*	*19.2 V*
2	*9 AM*	*18.2 V*	*19.8 V*
3	*10 AM*	*18.7 V*	*21.5 V*
4	*11 AM*	*18.8 V*	*21.9 V*
5	*12 AM*	*18.9 V*	*21.9 V*
6	*1 AM*	*18.7 V*	*21.9 V*
7	*2 AM*	*18.7 V*	*21.9 V*
8	*3 AM*	*18.6 V*	*21.7 V*
9	*4 AM*	*18.4 V*	*20.8 V*

TABLE 3.1. OBSERVATION RESULT OF VOLTAGE IN PV PANEL

SL NO	*TIME*	*WITH SOLAR TRACKER*	*WITH OUT SOLAR TRACKER*
1	*8 AM*	*2.8W*	*3.6W*
2	*9 AM*	*3.1W*	*3.8W*
3	*10 AM*	*3.1W*	*4.6W*
4	*11 AM*	*3.6W*	*4.8W*
5	*12 AM*	*3.6W*	*4.8W*
6	*1 AM*	*3.7W*	*4.8W*
7	*2 AM*	*3.6W*	*4.8W*
8	*3 AM*	*3.5W*	*4.7W*
9	*4 AM*	*3.0W*	*4.6W*

TABLE 3.2. OBSERVATION RESULT OF POWER IN PV PANEL

3.3 Observation of gate triggering pulses of DC link MOSFET



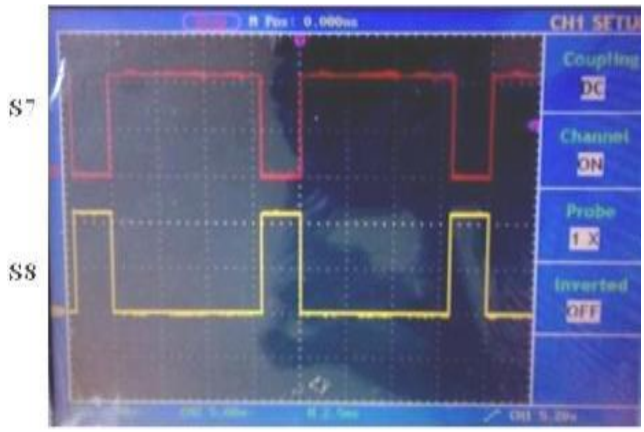


Figure 3.6 Triggering pulses for switches in MLDC voltage source obtained from driver in DSO

5.6 Observation of waveform obtained by DSO from the inverter

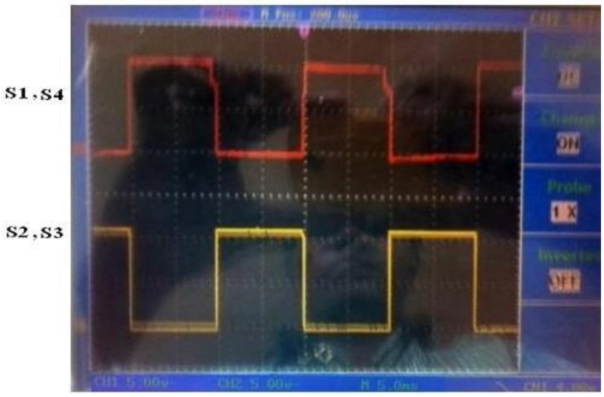


Figure 3.7.Triggering pulses for switches in SPFB inverter obtained from driver in DSO

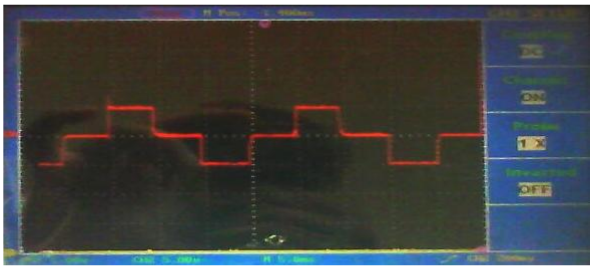


Figure 3.7. **Output of the inverter with single DC voltage source**

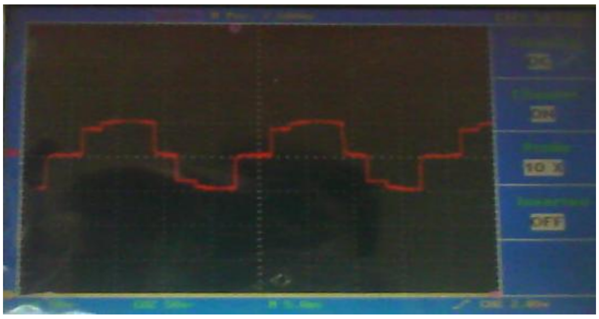


Figure 3.8. **Output of the inverter with single DC voltage source**

IV.Conclusion

The proposed dual axis solar tracker automatically tracks position of sun and maximize the solar power with help of Arduino. As compared to single axis, dual-axis system provides high abundant electrical energy output when compared to the fixed mount system. The Dual axis tracker is having more efficiency. The main aim of this work is to develop two axis solar tracker systems that use four sensors (LDR s) to predict the sun position.

Secondly, program is dumped on to Arduino (ATmega 328 p) so that rotation of servo motor can be controlled by employing the microcontroller. The programming part consists of 5 cases which has been stated and analyzed. Thirdly, to investigate the voltage differences from the sensor (light depending resistor LDR) based on intensity of light received by the sensor. The output has plotted into a graph and compared with static system. And proposed system is eco friendly, and widely used.

The presented nine level cascaded H-bridge MLDCL inverters can eliminate roughly half the number of switches, their gate drivers compared with the existing cascaded MLI counterparts. Despite a higher total VA rating of the switches, the cascaded MLDCL inverters are cost less due to the savings from the eliminated gate drivers and from fewer assembly steps because of the substantially reduced number of components, which also leads to a smaller size and volume.

The principle of operation of nine level cascaded H-bridge MLDCL inverter for supplying RL load is presented. The experimentally generated waveforms of gate pulses from controller and driver for triggering switches of MLDC voltage source and SPFB inverter are presented and the complete hardware of nine level cascaded H-bridge MLDCL inverter with output voltage wave forms of frequency 50HZ of for supplying RL load is implemented with Arduino microcontroller.

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