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PERFORMANCE ANALYSIS OF STATIC AND DUAL AXIS AUTO SUN TRACKING PHOTOVOLTAIC SOLAR PANEL

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Abstract- Photovoltaic solar panel converts photon energy of sunlight into electrical energy and provides a medium of pollution free energy conversion for remote and detachable areas. A photovoltaic panel produces less electricity in static condition than in dual axis auto sun tracking condition due to continuous variability of the sun position around the earth. To tap more power than available sunlight, it is necessary that photovoltaic panels always maintain perpendicular profile relative to the sun during the day. This condition can be acquired by controlling the azimuth angle and elevation angle of photovoltaic panel. Elevation angle and azimuth angle control of photovoltaic panel allow the dual axis auto sun tracking for photovoltaic panel. Dual axis auto sun tracking photovoltaic panel receives the maximum amount of sunlight energy during the daytime and produces more electricity than the stationary photovoltaic panel. Dual axis auto sun tracking photovoltaic panel ensures optimum utilization of installed capacity. In the proposed work, the performance parameters, i.e. Voltage, current, power and energy have been analyzed for both static and dual axis auto sun tracking condition of the photovoltaic solar panel. The setting of azimuth and elevation angle was kept respectively at 270° and 41° for the static condition of photovoltaic solar panel during the data logging of the performance parameter. The investigations reveal that the dual axis auto sun tracking of solar panel produces 39.81 % more electrical energy than the stationary photovoltaic panel. This sun tracking mechanism of photovoltaic solar panel can be easily implemented in remote and detached areas for more electricity production and it also reduces the burden of installing new photovoltaic solar panel for meeting the gradual rise in load demand.

***Keywords:* Microcontroller AT89C51, ADC0809, LDR, JHD162A LCD, DC Energy Meter.**

I. INRODUCTION

Electrical energy plays a staple role in human life and electricity is used for operating electrical appliances, industrial drives, modern transportation system, and electronics equipment. Day to day work like heating, cooling, and lighting requires electricity. Nonrenewable energy sources fulfill more than 67 % of electricity demand and rest electricity demand is fulfilled by renewable energy sources. Nonrenewable energy sources are limited in nature and do create pollution problem in the environment. Solar energy is available everywhere during daytime and doesn't create any pollution problem to our environment. Solar energy is versatile and used for heating, cooking, drying, purification and generation of electrical power. Photovoltaic solar panel directly converts the solar energy into an electrical energy and especially useful for remote area like hills and deserts where electricity is not available through utility. The major challenge with the photovoltaic solar panel is to harness more and more electricity from available sunlight during daytime and auto sun tracking of the photovoltaic panel fulfills this challenge. A closed loop control system that uses sunlight sensor, microcontroller, analog to digital converter and actuators provides a mechanism for auto sun tracking of photovoltaic solar panel. The performance analysis work of the static and sun tracking photovoltaic solar panel provides the necessary information regarding the improvement in the efficiency achieved by the sun tracking photovoltaic solar panel.

II. LITERATURE REVIEW

Navalgund Akkamahadevi, P. P. Revenkar and Sanath Kumar T.P. had investigated the comparison of solar power tracking with fixed power generation. The comparative study was carried out on an open loop sun tracking panel and improvement in efficiency was found to be 31.66 % [1]. Hamid Allamehzadeh had discussed briefly about the three major approaches for maximizing power extraction from a photovoltaic panel. MATLAB software was used to simulate the dual axis sun tracker and designed circuits were implemented on the circuit board. The overall performance of the dual axis sun tracker was evaluated [2]. Pooja K. Chhatwani and Jayashree S. Somani had proposed the method of single axis sun tracking system based on LDR sensor. It was verified that the use of analog to digital converter in the proposed design provides better resolution and stability in sun tracking [3]. Battu Deepa and M. Hemalatha had presented the design and development of single axis sun tracking system by using LDR as a sensor, microcontroller as a controller and geared motor as an actuator and this system provides the basic idea for the development of single axis sun tracking system [4]. Battu Deepa and M. Hemalatha had presented the design and development of single axis sun tracking system by using LDR as a sensor, microcontroller as controller and geared motor as actuator and this system provides the basic idea for the development of single axis sun tracking system [5]. Ashok Kumar Saxena and V. Dutta had developed a microprocessor based sun tracking panel that works on both close loop and open loop modes [6]. Daniel A. Pritchard had given the microcomputer based sun tracking approach in 1983 [7]. Syed Arsalan had implemented the sun tracking by using the microcontroller 8051. Sun tracking system software was used for both auto and manual mode of sun tracking [8]. Soumen Ghosh and Nilotpal Haldar had developed the solar tracking system by using microcontroller and LDR sensors [9]. Meghana Sharma had implemented an efficient, low cost single axis solar Tracker by using microcontroller. The designed system was easy to implement [10]. Huang F., Tien D. and Or. J. had developed a microcontroller based sun tracking system that was combined with MPP detector. MPPT was detected by embedding the software in the microcontroller. The simultaneous use of sun tracking and MPP detector had proven the highly efficient system [11].

III. METHOLODOGY

A performance analysis system for the static and sun tracking photovoltaic panel consists of an ELMEASURE DC energy meter cum data recorder, four light dependent resistance based potential dividers circuit, two DC motors with gear boxes, external spur and worm gears, JHD162A LCD, WAAREE photovoltaic solar panel of 10 watt, L298N dual motor driver module, ADC0809 module, load resistance of 28.5 Ω and AT89C51 microcontroller module. The sunlight intensity sensing system consists of four LDR potential dividers that are arranged on printed circuit board in square shape. These four LDRs are separated by transparent glass. The purpose of separation by transparent glass is to increase the sensitivity of the sun light sensing system. The sunlight intensity sensing arrangement along with a sun tracking mechanism is shown in figure 1. The upper, lower, right and left side located light dependent potential divider senses the sunlight intensity on the upper, lower, right and left side of the rectangular shape photovoltaic solar panel, respectively and provides the sunlight intensity dependent output voltage to ADC0809 module. ADC0809 module converts these voltages into a suitable digital voltage that are compatible with the AT89C51 microcontroller module. The upper and the lower side light dependent potential divider's output voltages are compared continuously by the microcontroller, and any predefined difference in this comparison is corrected by the microcontroller by changing the elevation angle of the photovoltaic panel by running the DC motor through DC motor driver module. DC motor which controls the elevation angle of the photovoltaic panel, runs until both Upper and lower side light dependent potential divider output voltage does not become nearly equal. Similarly, the right and the left side light dependent potential divider's output voltages are compared continuously by the microcontroller, and any predefined difference in comparison is corrected by the microcontroller by changing the azimuth angle of photovoltaic panel by running the DC motor through DC motor driver module. DC motor which controls the azimuth angle of the photovoltaic panel, runs until both Upper and lower side light dependent potential divider output voltage does not become nearly equal. This ensures that photovoltaic solar panel has been tracking the sun during daytime and harnessing the maximum sunlight from available sunlight flux.

Fig.1 Sun Light Sensing System and Sun Tracking Mechanism

The setting of azimuth and elevation angle is respectively kept at 270° and 41° in static condition of photovoltaic solar panel during the measurement of performance analysis parameters. A load resistance of 28.5 Ω is connected across the output terminal of the panel. The performance parameter like voltage, current, power and energy in the static condition of a photovoltaic solar panel are recorded on ELMEASURE DC energy meter cum data logger during morning to evening. A similar process is repeated in the sun tracking position on the same panel and then, the performance analysis parameters on the computer are studied comparatively. The block diagram of setup related to methodology is shown in figure 2.

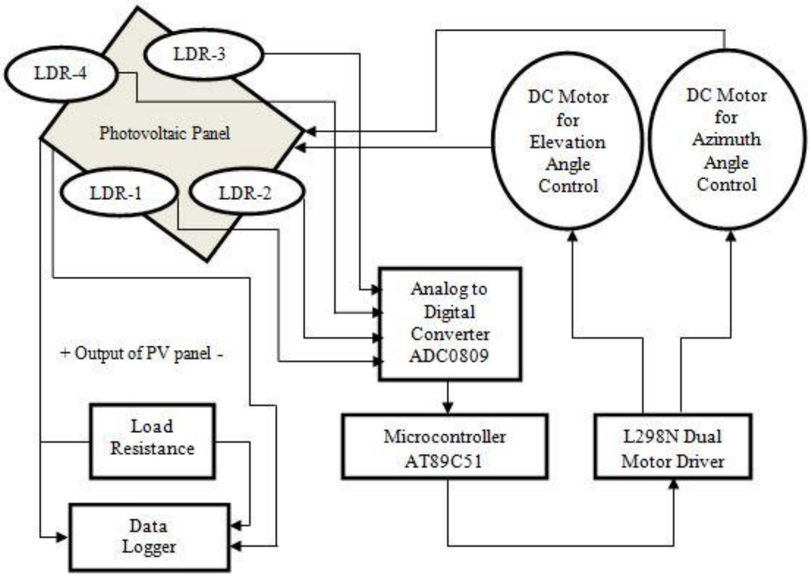

Fig.2 Block Diagram of Proposed Work

IV. PROPOSED WORK

Circuit diagram

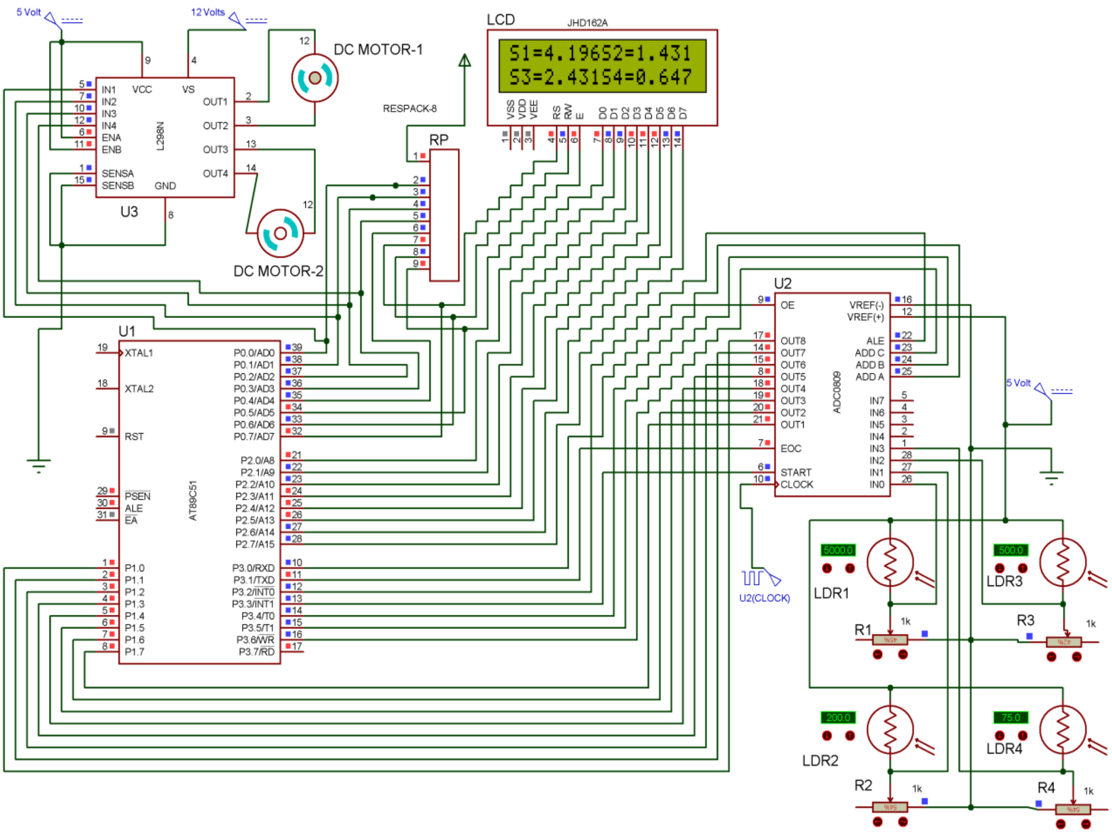

Fig.3 Complete Circuit Diagram

Circuit Description

The designed circuit includes AT89C51 microcontroller module, L298N dual motor driver module, JHD162A liquid crystal display, ADC0809 analog to digital convertor module, LDR-resistance potential divider based sunlight sensing system and two DC motors. L298N dual motor driver module operates on 12 volt DC supply and rest circuit operates on 5volt DC supply. Liquid crystal display JHD162A is used to display the LDR-resistance potential divider voltage and these voltages are used to calibrate an inclination of photovoltaic panel initially. Port 3, port 2 and port 0 of microcontroller work as an output port and provide the suitable control and data signals to ADC0809 analog to digital convertor module, JHD162A liquid crystal display and L298N dual motor driver module. Port 1 of microcontroller works as an input port and receives the digitally converted voltage signals from LDR-potential divider assembly through ADC0809 analog to digital convertor module. L298N dual motor driver module drives the DC motors as per weak signal received from the microcontroller.

V. HARDWARE DESCRIPTION

The figure of complete hardware is shown in figure 4.

Fig.4 Complete Hardware

DC Energy Meter cum Data Logger

ELMEASURE EDC 4100 displays the performance parameters of static and dual axis auto sun tracking photovoltaic solar panel. It works as a data logger and, the value of current, voltage, power and energy is recorded with time stamps in its memory. These parameters are analyzed by computer. All values of parameter are recorded for every one second interval on logger memory. Figure 5 shows the DC energy meter cum data logger.

Fig.5 DC Energy Meter cum Data Logger

Analog to Digital Convertor Module

ADC0809 module converts the LDR-resistance potential divider voltages into digital form that are compatible feedback signals for a microcontroller. It has 8-channel input and provides 8-bit output digital signals on channel selection and control signals. Conversion rate and selection of channels are controlled by instructions of microcontroller programming. This module has a timer 555 based clock circuit for synchronization of ADC0809.

Microcontroller

The AT89C51 microcontroller has used for close loop control of sun tracking system. Microcontroller plays a role of the brain in the design of embedded system. It operates on 5 volt regulated DC power supply. It has 4 bi-directional ports and 32 programmable input/output lines with 4 KB of flash memory. Microcontroller AT89C51 has 40 pins and out of 40 pins only 32 pins are reserved for 8 bit four parallel ports P3, P2, P1 and P0. The rest eight pins are named as EA, PSEN, RST, ALE, GND, V_{cc}, XTAL1 and XTAL2. Pin 40 provides 5V to the microcontroller from LM7805 based 5V regulator circuit. Ground pin is pin 20.

Light Dependent resistance

A light dependent resistance is a light intensity controlled variable resistance. The conductance of a light dependent resistance increases with increasing the light flux intensity falling on it. Four numbers of light dependent resistance-resistance potential dividers are used in the sunlight sensing system. Four Variable resistances of 0-1000 Ω are used in light dependent resistor-resistance potential divider circuit. These variable resistances are used to calibrate the inclination of photovoltaic solar panel initially. A series connection of light dependent resistor and 0-1000 Ω resistance with 5 volts DC supply forms the potential divider circuit and provides light intensity dependent output voltage falling on LDR. This output voltage varies from 0 to 5 volts and its magnitude is indicative of light intensity falling on LDR. The sun light intensity sensing system circuit diagram is shown in figure 6.

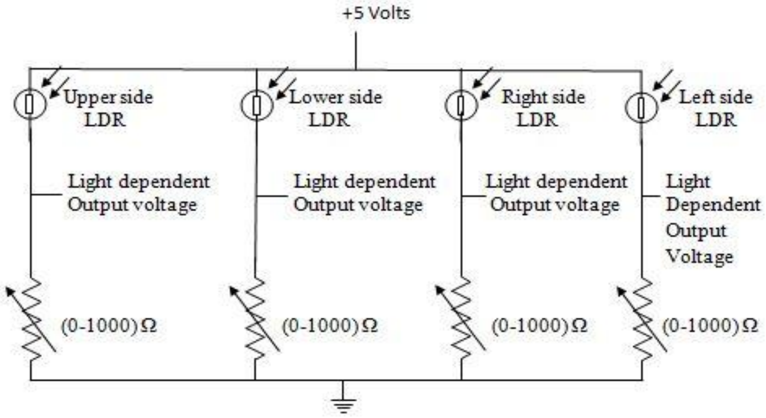

Fig.6 Circuit Diagram of Light Dependent Resistance-Resistance Potential Divider

Liquid Crystal Display

The LCD is used to display information in the form of characters, images, numbers and running pictures. The JHD162A liquid crystal display is cheap and compact in design and can display information in two rows with 16 characters per row. The JHD162A liquid crystal display can be easily interfaced with AT89C51 microcontroller and it displays the sunlight dependent output voltage of LDR-resistance potential dividers in suggested work. The figure 7 shows the JHD 162A LCD.

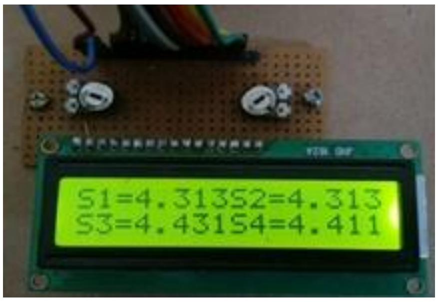

Fig.7 Liquid Crystal Display

Dual Motor Driver module

The output current capacity of AT89C51 microcontroller is below the 50mA and DC motor requires more than 300mA current at full load. Microcontroller cannot run the DC motor directly so current amplifier is required between microcontroller and a DC motor. L298N is H-bridge dual driver module that can be bi-directionally run two DC motors in accordance with microcontroller weak signals. It is designed to provide bi-directional 2A current at a voltage from 4.50V to 35.0V.

Gears

Gears transfer the mechanical power between two shafts by changing the torque and angular velocity. They provide the mechanical coupling between two shafts. Gears are of several types. Worm and spur gears have been used in proposed work for changing the azimuth and elevation angle of photovoltaic solar panel and they provide high resolution in azimuth and elevation angle of photovoltaic solar panel.

Photovoltaic Solar Panel

The primordial element of a photovoltaic panel is the photovoltaic cell that can directly convert the photon energy of sunlight into electricity at the atomic level. A photovoltaic cell consists of a typical p-n junction diode formed on a semiconductor material. This technique uses photovoltaic effect, i.e. voltage is produced when sunlight incidents on semiconductor material. Photovoltaic cells rely on a quantum mechanics process to produce electricity. Because silicon photovoltaic cells typically produce only about 0.5 volt and 0.015 watt of power so a several number of photovoltaic cells are electrically connected in series on a PV module for producing more than 12 volt and increasing the required power output. A solar panel consists of several solar modules that are electrically and physically grouped together in a supporting structure. WAAREE brand photovoltaic solar panel of 10 Watt capacity has been used in the proposed work.

VI. RESULTS AND DISCUSSIONS

The setting of azimuth and elevation angle was kept respectively at 270° and 41° for the static condition of photovoltaic solar panel and DC supply of microcontroller circuit was turned off so that photovoltaic solar panel remains in a static position. A resistive load of 28.5 Ω was connected across the output terminal of photovoltaic solar panel. Performance parameters like voltage, current, power and energy in static condition of a photovoltaic solar panel was recorded on ELMEASURE DC energy meter cum data logger during the time period of 7:05:00 to 17:05:00. Next day, a similar process was repeated on the same panel in the dual axis auto sun tracking condition, i.e. DC power supply of microcontroller circuit had turned on and a photovoltaic solar panel had been tracking the sun. A comparative analysis of performance parameters of both cases was performed on the computer.

The comparison of performance parameters like voltage, current, power and total energy delivered to a load of 28.5 Ω by static and dual axis auto sun tracking photovoltaic solar panel have delineated on the graphs.

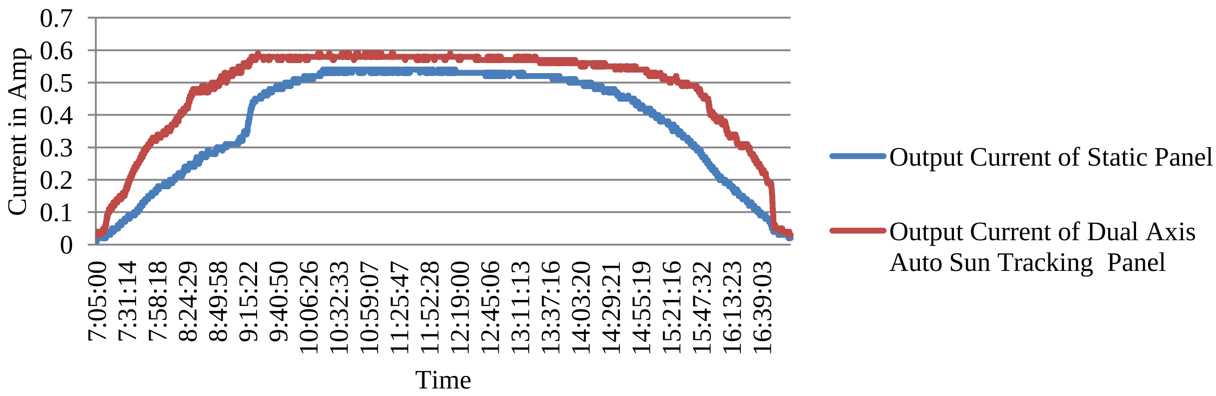

Fig.8 Comparison Graphs of Output Current on Time Scale for Static and Dual Axis Auto Sun Tracking Photovoltaic Panel

It can be observed from the figure 8 and 9 that as compared to the sun tracking photovoltaic panel, the voltage and current of the static photovoltaic panel during the time period of 07:05:00 to 10:10:00 remains low. That happens even after 13:40:00. This happens due to the large inclination angle of the static photovoltaic panel with respect to current position of the sun while dual axis auto sun tracking photovoltaic solar panel maintains the low value of the inclination angle and removes shading effect on panel.

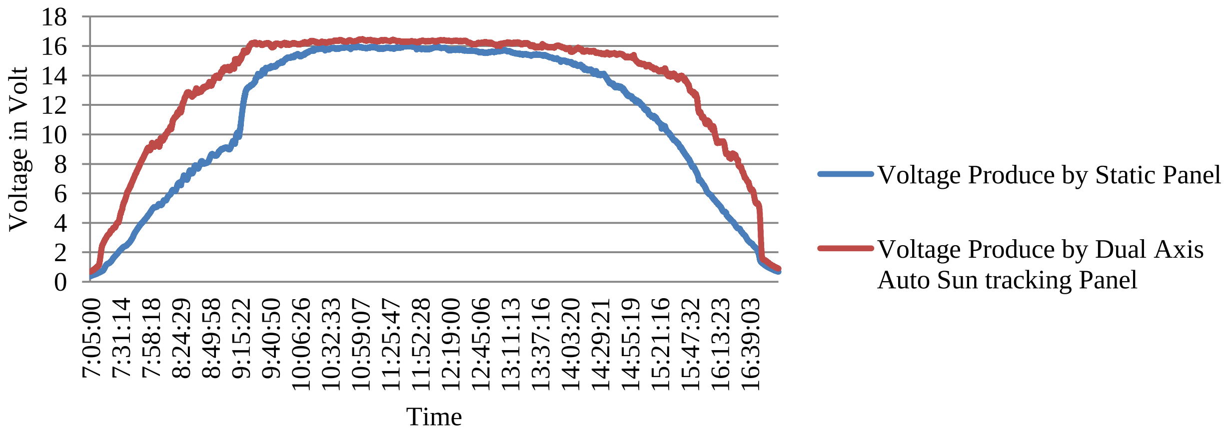

Fig.9 Comparison Graphs of Output Voltage with Time for Static and Dual Axis Auto Sun Tracking Photovoltaic Panel

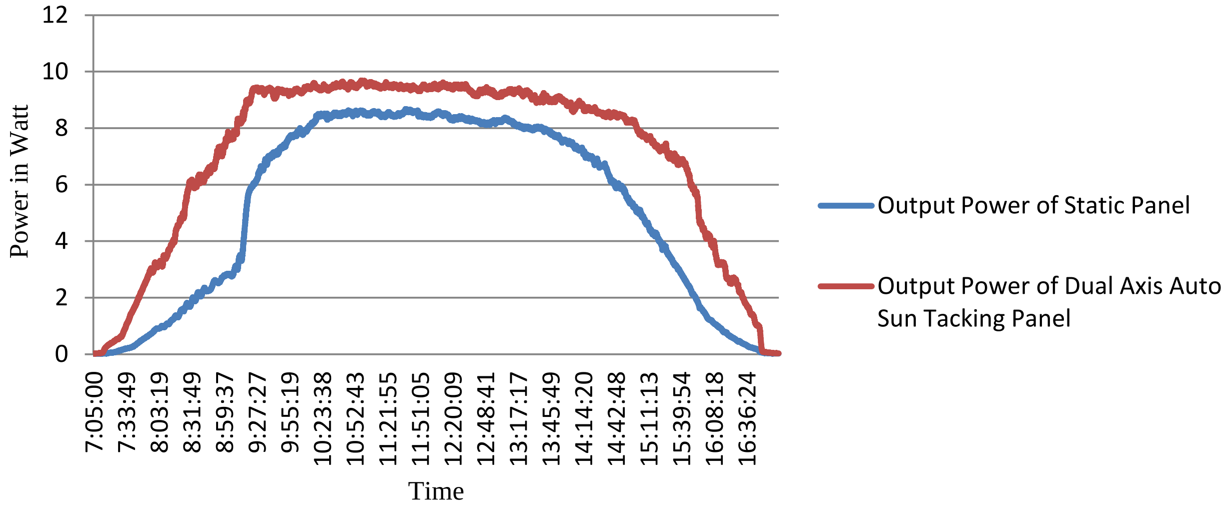

Fig.10 Comparisons Graphs of Output Power of Static and Dual Axis Auto Sun Tracking Photovoltaic Solar Panel

The graphs of performance parameter reveal that the stationary panel maintains the flat profile of the voltage, current and power during the time period between 10:10:00 to 13:40:00. Dual axis auto Sun Tracking Photovoltaic Solar Panel maintains similar flat profiles during the time period from 09:00:00 to 15:30:00. Flat profile for long periods of time for performance parameters indicates that the double axis solar tracking solar panel produces more power than the fixed photovoltaic solar panel. This happens because dual axis auto sun tracking solar panel continuously tracks the sun and retains a perpendicular profile relative to the sun during the daytime.

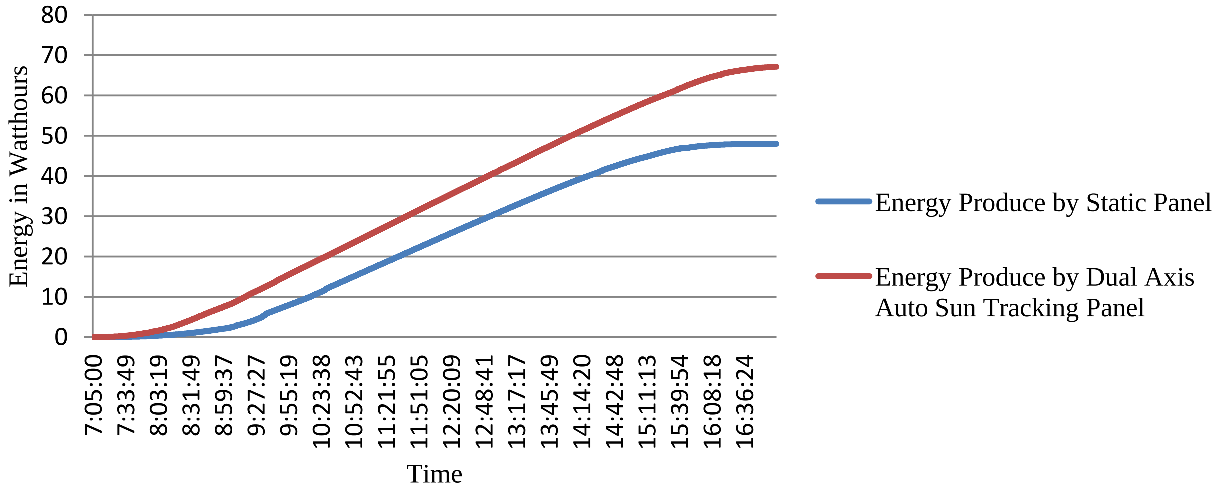

Fig.11 Comparison Graphs of Energy with Time Scale for Static and Dual Axis Auto Sun Tracking Photovoltaic Panel

The maximum value of voltage, current, power and energy produced by the static photovoltaic solar panel is 16.02 Volt, 0.54 Amp, 8.62 Watt and 48.03 Watt-hours, respectively. While these values for dual axis auto sun tracking solar panel is 16.29 Volt, 0.58 Amp, 9.42 Watt and 67.15 Watt-hours, respectively. It can be seen from the performance graphs that dual axis auto sun tracking photovoltaic solar panel consistently harness maximum photon energy from available sunlight during the daytime as compared to static photovoltaic solar panel. The dual axis auto sun tracking solar panel produces 67.15 Watt-hours of electrical energy and consumes 4.05 Watt-hours of electricity for tracking the sun while same panel in specified static conditions produces only 48.03 Watt-hours of electrical energy. The net gain in electrical energy for these two cases is 15.07 Watt-hours.

VII. CONCLUSIONS

The following outcomes have been obtained from the performance analysis of static and dual axis auto sun tracking photovoltaic solar panel.

(1) It has been noticed from the performance analysis work that if energy consumption of sun tracking is not considered then the dual axis auto sun tracking of photovoltaic solar panel can produce 39.81 % more electrical energy than the same type of static photovoltaic panel.

(2) Electrical energy consumption for sun tracking is considered then the dual axis auto sun tracking of photovoltaic solar panel produces 31.37 % more electrical energy than the same type of static photovoltaic panel.

(3) The output power of a photovoltaic solar panel is badly affected by the inclination angle of the panel relative to the sun.
(4) A cost effective dual axis auto sun tracking controller can be realized with few cheap electronic components.
(5) The dual axis auto sun tracking of the photovoltaic solar panel increases the overall efficiency and reduces the requirement of installing the new photovoltaic solar panel for meeting the gradual rise in load demand.
(6) The designed two axis sun tracking mechanism for photovoltaic solar panel can be easily implemented for more electricity production in remote and detached area.

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