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A Study on Dual Axis Solar Sun Seeker using Microcontroller

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Abstract: Solar energy is one of the most important renewable energy sources on the earth which must be collected and should be utilized to its maximum efficiency. It is the major eco-friendly & pollution less method of producing the electricity today. In India most part receives 4 to 7 kWh of solar radiation per square meter per day and solar energy equivalent to more than 5000 trillion kWh per year which is far more than its total annual consumption. According to U.S. solar research centre. "If we convert the Total Solar energy reaches to earth in one time into electricity, then it will be more enough than whole power used by all the nations per year". Considering the maximum utilization of solar power we have tried to develop a dual axis model of a solar panel using a microcontroller that can provide maximum solar power output. Also, we compare the power output of solar sun seeker, for fixed solar sun seeker, single and dual axis sun seeker.

Keywords: Solar cell, solar panel, solar tracker, photocell, microcontroller, sensor, stepper motor.

I. INTRODUCTION

Energy is the basic parameter required for the sustenance of life. The economic, social and industrial development of a country is measured by the utilization of energy by the human beings for their needs. But with the increasing population, industrialization and transport the energy demands are increasing day by day leading to energy crisis. Finding the energy resources to satisfy the world's growing demand is one the society's foremost challenges. Renewable energy resources are preferred not only because they are abundant in nature and low in cost but they also provide low carbon emissions, helps in stimulating the economy and providing job facilities. In the recent times, solar energy has proved an efficient, safe and more secure way of providing energy.

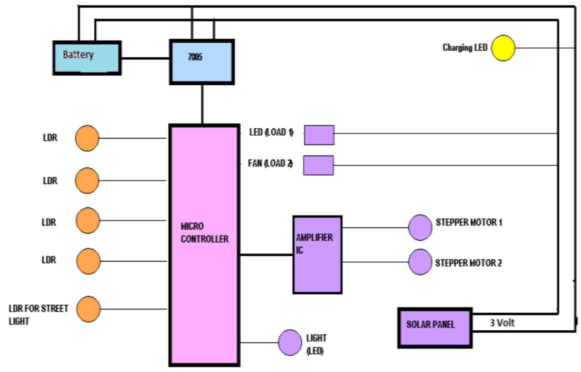
Solar Energy is thus an important source of renewable energy and its technologies are broadly characterized as either passive solar or active solar depending on the way they capture and distribute solar energy or convert it into solar power. Active solar techniques include the use of photovoltaic systems, concentrated solar power and solar water heating to harness the energy. Passive solar techniques include orienting a building to the Sun, selecting materials with favourable thermal mass or light dispersing properties, and designing spaces that naturally circulate air.

This document explicitly describes the controlling of solar panel with the help of microcontroller to track maximum solar energy.

II. PROBLEM IDENTIFICATION & PROPOSED METHODOLOGY

Presently about one-third population of the world does not have access to electricity and are not connected to the national grid. A solution to this problem has been dealt by the use of Photovoltaic Systems to capture the solar radiations received from the sun more efficiently. The solar panels usually employed are either static or rotate on a single axis. But the sun keeps on changing its position continuously due to the rotation and revolution of the Earth. As a result the intensity of the direct radiation falling on these panels is greatly reduced thereby decreasing the amount of solar power generated. A solution to these problems is what we have found in a Dual Axis Model of Sun Tracker. It uses the solar panels that track the location of the sun. Maximum capture of the solar energy occurs when the angle of incidence of the sun's rays is perpendicular to the panel. This purpose is served by tracking. It has been estimated that the use of a tracking system, over a fixed system, can increase the power output by 30% - 60%. The designing of the system should be done in such a manner that it may follow the position of the sun in the daytime and it should be totally automatic and simple to operate.

A. Block Diagram



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III. Components Used

A. *Solar Panel*

It is a packaged, connected assembly of solar cells. A solar cell, or photovoltaic cell, is an electrical device that converts the energy of light directly into electricity by the photovoltaic. It is a form of photoelectric cell, defined as a device whose electrical characteristics, such as current, voltage, or resistance, vary when exposed to light. Solar cells are described as being photovoltaic irrespective of whether the source is sunlight or an artificial light. They are used as a photodetector (for example infrared detectors), detecting light or other electromagnetic radiation near the visible range, or measuring light intensity. Multiple solar cells in an integrated group, all oriented in one plane, constitute a solar photovoltaic panel or solar photovoltaic module. The solar cell works in several steps. Initially the photons in the sunlight strike the solar cells in the solar panel. These photons collide with the valence electrons and imparts them sufficient energy to leave their parent atom. This results in the generation of free electrons and holes. This phenomenon will occur on both side of the junction. Thus, current flows through the material and produces electricity. The wavelength of the incident light will affect the response of the p-n junction to the incident photon. An array of solar cells converts solar energy into a usable amount of direct current (DC) electricity. An inverter can convert the power to alternating current (AC). At the current of about 1.05A, the output voltage is about 3.1V, resulting in an output power of 3.25Watts.

The solar cell is fabricated from a wide variety of semiconductor materials, using numerous device configurations and structures. The most commonly used semiconductor material for fabrication of solar cells is silicon because of its higher conversion efficiency, greater stability and is less subject to fatigue. Non-silicon material is too expensive and has a low efficiency.

Crystalline, or single-crystal, silicon is one of the best materials for solar cells. It has very high solar cell efficiency (approx. 23 %) under unconcentrated sunlight and a workable band-gap of 1.1. However, single-crystal silicon cells are expensive and have low absorptivity. A cheaper version of crystalline silicon is polycrystalline silicon.

Polycrystalline silicon has the same band-gap, is cheaper, but has a lower efficiency. The last variation of silicon used in solar cells is amorphous silicon. It is relatively cheap and has a much higher absorptivity than its silicon counterparts. Its main drawbacks are that it has a low efficiency rate (approx. 13%), and its band-gap energy (1.7) is not ideal. Solar panels can be used as a component of a larger photovoltaic system to generate and supply electricity in commercial and residential applications. Each module is rated by its DC output power under standard test conditions (STC), and typically ranges from 100 to 320 watts. The efficiencyof a module determines the area of a module given the same rated output – an 8% efficient 230 watt module will have twice the area of a 16% efficient 230 watt module. The solar panel used here is of 3 Volts, 1Ampere.

The efficiency of operation of a solar cell is determined by the electrical power output divided by the power provided by the light source, i.e.

$$n = \frac{P_0(Electrical)}{P_i(lightenergy)} * 100\ \%$$

Typical levels of efficiency range from 10% to 40%. This level improves with the usage of a Dual Axis Solar Sun Seeker.

B. *MicrocontrollerPIC16F877*

It is the heart of the system. It controls all the operations. The solar panel is aligned according to the position of the sun under the control of the microcontroller. The microcontroller used here is PIC16F877. It has 40 pins and its features are:

i) *Microcontroller Core Features:*

- High performance RISC CPU
- Only 35 single word instructions to learn
- All single cycle instructions except for program
- branches which are two cycle
- Operating speed: DC - 20 MHz clock input
- DC - 200 ns instruction cycle
- Up to 8K x 14 words of FLASH Program Memory,
- Up to 368 x 8 bytes of Data Memory (RAM)
- Up to 256 x 8 bytes of EEPROM Data Memory
- Pinout compatible to the PIC16C73B/74B/76/77
- Interrupt capability (up to 14 sources)
- Eight level deep hardware stack
- Direct, indirect and relative addressing modes
- Power-on Reset (POR)
- Power-up Timer (PWRT) and
- Oscillator Start-up Timer (OST)
- Watchdog Timer (WDT) with its own on-chip RC
- oscillator for reliable operation
- Programmable code protection
- Power saving SLEEP mode
- Selectable oscillator options
- Low power, high speed CMOS FLASH/EEPROM
- technology
- Fully static design
- In-Circuit Serial Programming (ICSP) via twopins
- Single 5V In-Circuit Serial Programming capability
- In-Circuit Debugging via two pins
- Processor read/write access to program memory
- Wide operating voltage range: 2.0V to 5.5V
- High Sink/Source Current: 25 mA
- Commercial, Industrial and Extended temperature

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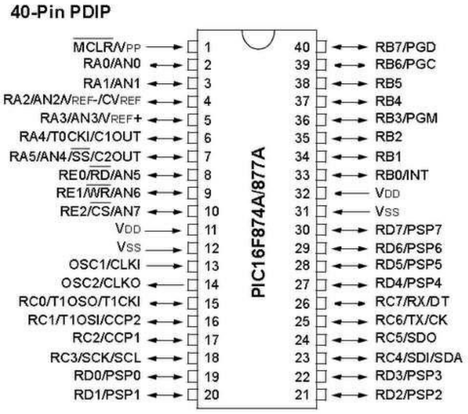
- ranges
- Low-power consumption:
  - < 0.6 mA typical @ 3V, 4 MHz
  - 20 µA typical @ 3V, 32 kHz
  - < 1 µA typical standby current

ii) Peripheral Features

- Timer0: 8-bit timer/counter with 8-bit prescaler
- Timer1: 16-bit timer/counter with prescaler,
- can be incremented during SLEEP via external crystal/clock
- Timer2: 8-bit timer/counter with 8-bit period
- register, prescaler and postscaler
- Two Capture, Compare, PWM modules
- Capture is 16-bit, max. resolution is 12.5 ns
- Compare is 16-bit, max. resolution is 200 ns
- PWM max. resolution is 10-bit
- 10-bit multi-channel Analog-to-Digital converter
- Synchronous Serial Port (SSP) with SPI (Master
- mode) and I2C (Master/Slave)
- Universal Synchronous Asynchronous Receiver
- Transmitter (USART/SCI) with 9-bit address
- detection
- Parallel Slave Port (PSP) 8-bits wide, with
- external RD, WR and CS controls (40/44-pin only)
- Brown-out detection circuitry for
- Brown-out Reset (BOR)

The pin configuration is as shown

40-Pin PDIP



It takes the analog input from LDR and provides digital output.

The ports of microcontroller define the specific functions of the design, such as port1 defines the input signal from the sensor which is received by the microcontroller as a bit pattern, port2 rotates the stepper motor in a specified direction according to the sensor bit pattern, port3 defines the excited solar cells and the converted power is defined by port4. Environmental conditions are also sensed by the microcontroller such as cloudy conditions, etc.

C. LDR Sensor

LDR is the Light Dependent Resistor. Tracking of the sun should be done in a closed loop system. For this the microcontroller must sense the light through a light sensor. This purpose is served by a light dependent resistor (LDR). It is a light sensitive resistor. It is made of two types-Cadmium Sulphide (CdS) and Gallium Arsenide (GaAs). The LDR sensor consists of a disc of semiconductor material with two electrodes on its surface. Here we are using LDR sensor made up of two Cadmium Sulphide (CdS) photoconductive cells with spectral responses similar to that of the human eye.

The material used in CdS photocell is of high resistance semiconductor. Therefore, once light falls on its surface, photons absorbed by the semiconductor will give bound electrons enough energy to jump into the conduction band. As a result a large number of free electrons are available which conduct electricity and thus lowers the resistance. In case of high light intensity, the photocell will produce lowest resistance, the opposite will occur in the case of complete darkness.

Absolute maximum ratings

Voltage, ac or dc peak ________ 320V
Current ________ 75mA
Power dissipation at 30°C ________ 250mW
Operating temperature range ________ -60°C to +75°C

Electrical characteristics

T_A = 25°C. 2854°K tungsten light source

Parameter	Conditions	Min.	Typ.	Max.	Units
Cell resistance	1000 lux 10 lux	-	400 9	- -	Ω kΩ
Dark resistance	-	1.0	-		MΩ
Dark capacitance	-	-	3.5	-	pF
Rise time 1	1000 lux 10 lux	- -	2.8 18	- -	ms ms
Fall time 2	1000 lux 10 lux	- -	48 120	- -	ms ms

Its applications include smoke detection, automatic lighting control, batch counting and burglar alarm systems. Some other applications are as listed below:

i) Analog Applications

- Camera Exposure Control
- Auto Slide Focus - dual cell
- Photocopy Machines - density of toner
- Colorimetric Test Equipment
- Electronic Scales - dual cell
- Automatic Gain Control – modulated light source
-

ii) Digital Applications

- Automatic Headlight Dimmer
- Night Light Control
- Street Light Control
- Absence / Presence (beam breaker)
- Position Sensor

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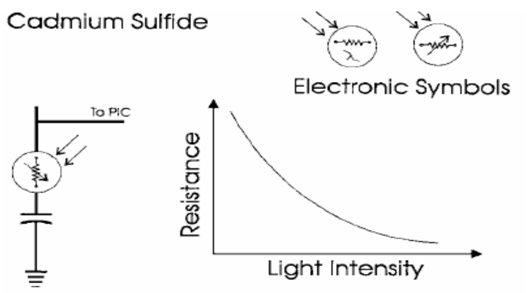
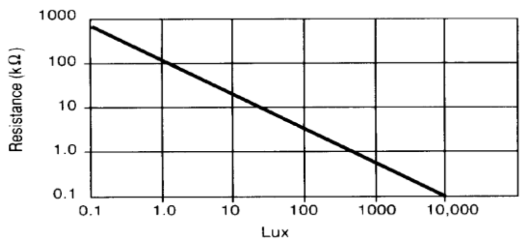
Its various other characteristics can be as shown:

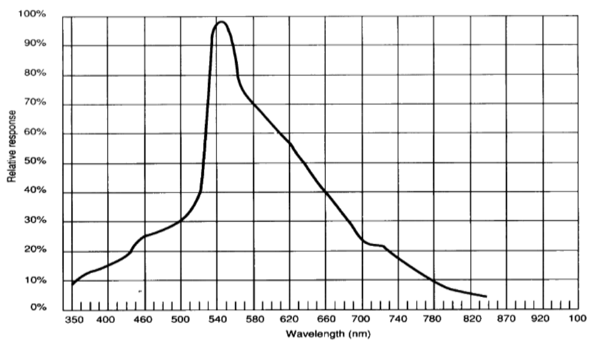


iii) Resistance as a function of Illumination

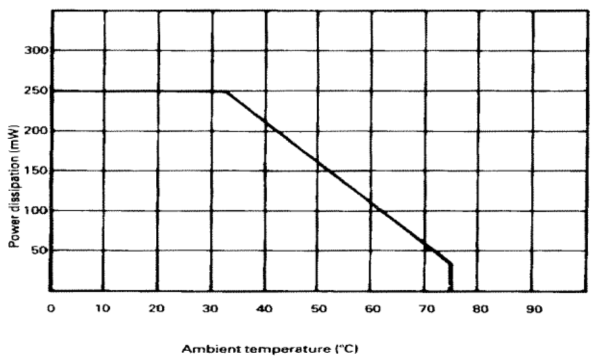


iv)Spectral Response

Like the human eye, the relative sensitivity of photoconductive cell is dependent on the wavelength (colour) of the incident light.

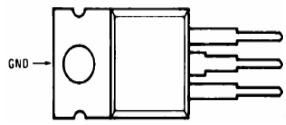


v) Power dissipation Derating



D. Voltage Regulator 7805

It is used to convert any voltage level into 5V. The solar energy is stored inside a battery because the sun is not available at all times of the day. This energy stored in the battery is connected to the Vcc pin of the microcontroller. As the battery is of 9V and the microcontroller requires 5V, 7805 is used. Its circuit diagram is as shown:-



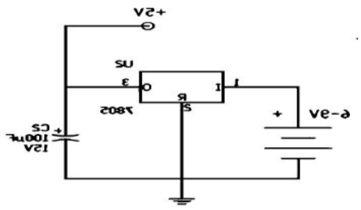


Fig. 1 Block DiagramFig. 2 Circuit diagram

E. Motor

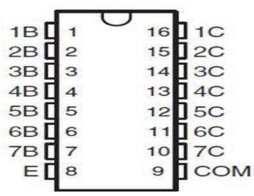
When it comes to specifying electric motors for solar photovoltaic tracking applications, environmental protection is a prime consideration due to their exposure to the elements.

AC induction motors used in earlier solar tracking systems drew power directly from the grid but it is difficult to control at slow speeds which is necessary in tracking applications. It does not permit most efficient tracking and collection of solar energy.

Here, Stepper motors are commonly used for precision positioning control applications because of their following characteristics-- they are brushless, load independent, have open loop positioning capability, good holding torque, and excellent response characteristics. There are three types of stepper motors: permanent magnet, variable reluctance, and hybrid. The arrangement of windings on the stator is the main distinguishing factor between the three types. Permanent magnet motors may be wound either with unipolar or bipolar windings. We use a bipolar stepper motor because of the simple drive circuitry. The motor specifically used in the project was a 5 Volt, 7.5 degree step angle, and 4phase bipolar motor.

F. Motor Driver Circuit (ULN2003)

It is a high voltage, high current Darlington transistor array. A Darlington transistor array is a compound structure consisting of two bipolar transistors connected in such a way that the current amplified by the first transistor is further amplified the second one. It provides very high current gain. It is interfaced with the stepper motor to provide it high ratings which is generally not provided by the microcontroller. The Darlington transistor array in fig. 3 and pin diagram of ULN in fig. 4 are as shown:-



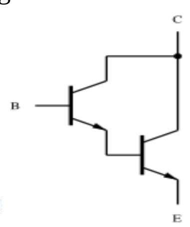


Fig. 3 ULN2003Fig. 4 Darlington transistor

The microcontroller PIC 16F877 controls the rotation of the base platform, in both directions, clockwise (CW) and counter clockwise (CCW). To reverse the rotation direction of the PM DC motor, the polarity of the applied voltage must be reversed. This may be achieved by motor-driver amplifier capable of outputting a positive and negative voltage. When the drive voltage is positive with respect to ground, the motor turns CW. When the drive voltage is negative with respect to ground, the voltage polarity at the motor terminals reverses and the motor rotates CCW.

The output transistors are capable of sinking 500mA and will sustain at least 50V in the off state. Under normal operating conditions, these devices will sustain 350mAper output with voltage $V_{ce(STA)}$=1.6V at +70^{0}C with a pulse width of 20ms and a duty cycle of 34%. It is designed to drive relays, lamps, LED displays and stepper motors. There are three ways to drive unipolar stepper motors (one phase on full step, two phases on full step, or half step), each one has some advantages and disadvantages. In this project full step mode is used.

In two phase mode, successive pairs of adjacent coils are energized in turn, motion is not as smooth as in one phase mode. Power consumption is more but it produces greater torque. The diagram of two phases is shown below.

A. Step Angle Step angle of the stepper motor is defined as the angle traversed by the motor in one step. To calculate step angle, we divide 360 by number of steps a motor takes to complete one revolution. The step angle of the motor PM42S-048 is 7.5^0.

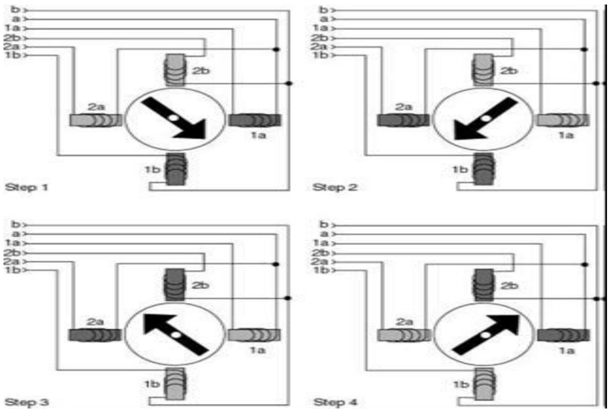
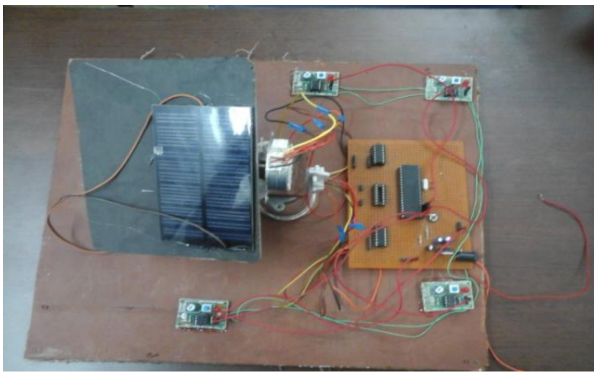


Fig. 5 Stepper Motor Operation



The microcontroller is very sensitive to electrical spikes (which may cause a reset or lockup), to solve this problem Darlington transistor arrays are used in the ULN2003. It also stops any electrical spikes caused by switching the motor's winding on and off.

G. Software Part

The program is stored in the flash memory of the microcontroller chip PIC16F877and the microcontroller operates accordingly. Program is written in ASM notepad and compiled and debugged for errors. After getting the program successfully compiled the HEX-code is generated. Then the program is simulated in 8052 simulator to check for the result of the code. If the code gives desired result then the USB based superpro is used to load the program or to burn the chip. USB based superpro is basically a universal programmer. After downloading the HEX code in the chip, it is again connected to the main circuit.

IV.OPERATION OF THE CIRCUIT

A set of four LDR sensors is used to provide output to the microcontroller. Depending upon the combinational output produced by microcontroller, the stepper motor is operated through ULN. Accordingly the stepper motor then rotates the panel in a position perpendicular to the position of the sun's rays. Another application demonstrated in the project is the Automatic Street Lightning System.

V.ADVANTAGE OF DUAL AXIS OVER SINGLE AXIS

A. Single Axis Solar Tracker

A single axis solar seeker consists of two LDR sensors that sense the position of the sun and accordingly the solar panel is rotated on around a tilted shaft by a bidirectional DC Motor. It is as shown below:

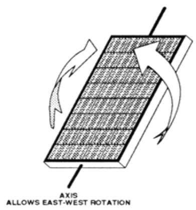


Fig. 6 Solar panel rotating in single axis

Out of the two LDRs, the LDR which receives higher intensity of the sun rays will generate a stronger signal and the other will generate a weaker signal. The difference in their output voltage moves the PV panel in the direction in which the intensity of the sun rays is maximum.

The efficiency for the single-axis and fixed mount panel may be calculated for one day. The average power values prove that the single-axis panel produces more power than that of the fixed mount. The power efficiency calculated for the singe-axis solar tracker is 13% more than that of the fixed mount. The tabulated values are simulated and the graph is obtained.This kind of tracker is most effective at equatorial latitudes where the sun is more or less

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Hours	Power for Fixed Mount in W	Power for Single Axis in W	Power for dual axis in W
07:00	0.09	0.35	0.68
08:00	0.25	0.47	0.87
09:00	0.75	1.02	1.55
10:00	0.98	1.23	1.78
11:00	1.58	2.24	2.86
12:00	3.1	3.1	3.15
13:00	2.22	2.54	2.98
14:00	1.88	2.11	2.44
15:00	1.56	1.86	2.3
16:00	1.58	1.34	2.01
17:00	0 .78	0.98	1.56
18:00	0.44	0.65	0.78
Sum= 12 hrs.	Sum= 15.21W	Sum= 17.89W	Sum= 22.96W
Solar Energy in Whr.(Day Time)	1.2675W/hr	1.4908W/hr	1.913W/hr
All Day Solar Energy Output	**0.6337W/hr**	**0.7441W/hr**	**0.9566W/hr**

overhead at noon. Due to the annual motion of the earth the sun also moves in the north and south direction

depending on the season and due to this the efficiency of single-axis is reduced since the single-axis tracker only tracks the movement of sun from east to west. During cloudy days the efficiency of the single axis tracker is almost close to the fixed panel.

B. Dual Axis Solar Tracker

The Dual Axis Solar Tracker designed by us, on the other hand, tracker follows the angular height position of the sun in the sky in addition to following the sun's east-west movement i.e. it measures the horizontal as well as the vertical axis. It is as shown in figure:

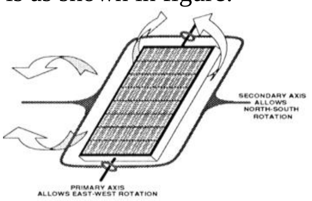

Fig. 7 Solar panel rotating in double axis

The power efficiency calculated for the dual-axis solar tracker is said to be 25-45% more than that of the fixed mount. The tabulated values are simulated in the table and the graph of power w.r.t time with different mounting of solar sun seeker are represent in figures. In the graph the lowest curve shows the power output of fixed mount, middle curve represents the power output of single axis solar seeker and the uppermost curve shows the power output of dual axis solar sun seeker.

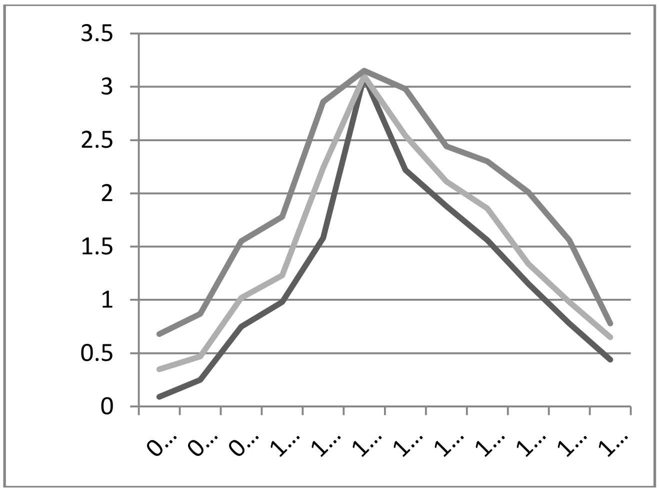

Fig. 8 Output power Vs time graph

Thus in the Dual Axis Solar Sun Seeker, we can delivered to a load of 1.913Whr for Daytime (12hrs). If we connect a battery to solar sun seeker to store the surplus solar energy during day time, we can connect approx. 1 Watt load for 24 hr.

VI.CONCLUSION

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Thus we see the advantages that the Dual Axis Solar Sun Seeker holds of all the methods employed of storing solar energy. It holds great no. of advantages when it comes to the efficient use of solar energy.

VII.FUTURE PROSPECTS AND SCOPES

The use of solar energy offers huge potential for natural resource and climate protection and for the expansion of renewable energies on the road to a future-oriented energy supply. The Government of India takes a major decision towards the renewable energy sources. The Jawaharlal Nehru solar mission (JNNSM) target to produce 20 giga-watts up to 2022 and should 100 % Renewable up to 2050.It can be possible by two ways. First is to install large number of plant as much as you can and second way is to provide the best dual tracking mechanism to solar panel by which we can increase the panel efficiency upto 80%. By using dual tracking mechanism we will increase some amount of power generation in every plant so we need install less power unit as compare to the other.

Apart from this, Government of India also shows the interest towards the hybrid system like Small Wind Energy and Hybrid Systems (SWES) programme. The main objective of SWES is to develop technology and promote applications of Wind-Solar hybrid systems, so we can use tracking mechanism with solar panel in hybrid system by which we can store the more electricity into battery in a small duration by providing the continuous energy supply and also increase the efficiency of the hybrid system. Clearly, we need more incentives to quickly increase the use of wind and solar power; they will cut costs, increase our energy independence and our national security and reduce the consequences of global warming.

Apart from all the above uses of solar energy, it can be increasingly used in solar vehicles and in Building Integrated Photovoltaics Systems (BiPV).

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