Supported by tetfund

DESIGN AND CONSTRUCTION OF A TWO AXIS SOLAR MAXIMUM POWER POINT TRACKING USING PIC16F877A MICRCONTROLLER BASED SYSTEM

A.Z. Loko[1*], A.I. Bugaje[2], I. I. Ewa[1], U. Ibrahim[1] and B.J. Kwaha[3]
[1]Department of Physics & Electronics, Nasarawa State University, PMB 1022, Keffi, Nigeria
[2]National Space Research and Development Agency, Abuja, Nigeria
[3]Department of Physics, University of Jos, Nigeria
*Corresponding author: azubairuloko@yahoo.com

Abstract: Today, most of the streetlights in Nigeria use solar energy to operate; however, streets and road within cities of Nigeria experience street black out as night goes by due to minimum power tracking of sunlight during the day time thereby resulting to low or slow charging of backup systems (battery). Consequently, this research focus on the design and implementation of a maximum power tracking using the PIC16F877A microcontroller and dc motors for two dimensional sun tracking under different temperature, humidity and irradiation and extract maximum available power from photovoltaic (PV) panel that would serve as an alternative solution towards solving the issue of street blackout. This paper also covers the designing and construction of the Solar Tracking mechanical structure together with the associated electronic circuits and two DC motors. One DC motors is mounted to control the rotation part, while the second one is to control the tilting part. Four pairs of Light sensors Cadmium sulphide (CdS) were installed for detecting the light source position. The PIC16F877A is programmed using C language in microC PRO for PIC. The sensor values, temperature of the day are transmitted to the PC for monitoring purpose. A working system was finally demonstrated to validate the design.

Keywords: C-Language, DC motor, LDR sensor, photovoltaic, PIC 16F877A microcontroller.

Introduction

As the world's population is growing, the demand on electricity is also increasing and unfortunately the world mostly depends on non-renewable energy (i.e. coal, petroleum, natural gas) for electricity production which emits tons of carbon dioxide and other pollutions contributing to environmental problems. Some of the environmental problems include climate change, chemical pollution, nuclear fuel disposal, energy infrastructural impact and poor air quality that put the health and prosperity of people around the world, but especially developing nations at serious risk. Furthermore, non-renewable energy sources will eventually run out in years to come.

Solar power is one of the most abundant clean, renewable energy and is gaining acceptance due to advances in solar panel manufacturing and efficiency as well as increasingly rising fuel costs. Photovoltaic (PV) solar cells are the most readily available solar technology, and they operate best on bright days with little or no obstruction to incident sunlight (Bingol *et al*., 2005). However, temperature, humidity, irradiation and partial obstructions such as tree or dust reduce the performance of solar power in Nigeria. Furthermore, with conventional solar panel, fixed within a certain angle, limits their area of exposure from the sun during the course of the day (Steven *et al*., 2010). Thus, the average solar energy is not always maximized.

Materials and Methods

Photovoltaic system

Photovoltaic (PV) meaning literally "Light-Electricity" is the field of technology and research related to the application of solar energy by converting sunlight directly into electricity. Derived from the Greek word "phos", meaning "light" and from volt which was named in honor of the Italian physicist Alessandro Volta, photovoltaic describes materials with the property of producing electricity when exposed to sunlight. They are generally known as a method for generating solar power by using solar cells packaged in photovoltaic modules, often electrically connected in multiples as solar photovoltaic arrays to convert energy from the sun into electricity. The most common and most efficient photovoltaic products are made from crystalline silicon, representing over 95% of the market (EPIA, 2011).

Photovoltaic (PV) technology has developed rapidly over the last two decades from a small scale, specialist industry supplying the United States space program to a broadly based global activity. Virtually, all photovoltaic devices are some type of photodiode. Solar cells produce direct current electricity from light, which can be used to power equipment or to recharge a battery lead acid. Therefore, solar panel is the fundamental energy conversion component of PV systems. Its conversion efficiency depends on many extrinsic factors, such as insolation (incident solar radiation) levels, temperature, and load condition. There are three major approaches for maximizing power extraction in medium- and large-scale systems. These are; sun tracking, maximum power point tracking (MPPT) or both. Therefore, this project is about the maximum power point tracking MPPT.

Cadmium sulphide

Cadmium sulphide is a chemical compound with the formula CdS. Cadmium sulphide is yellow in colour and is a semiconductor. Cadmium sulphide is a direct band gap semiconductor and has many applications for example in light detectors. Cadmium sulphide (Cds) cell is a resistor whose resistance decreases with increasing incident light intensity. It can also be referenced as a photoconductor. If light falling on the device is of high enough frequency, photons absorbed by the semiconductor give bound electrons enough energy to jump into the conduction band. The resultingfree electron (and its hole partner) conduct electricity, thereby lowering resistance.

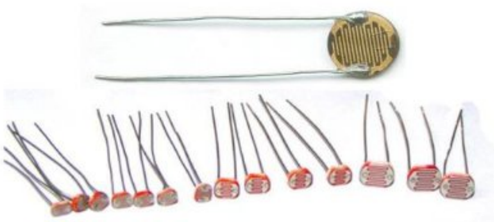


Fig. 1: Cadmium Sulphide

Principle of operation of a direct-current motor

Based on the research it was understood that a motor is a device that converts an electrical energy to mechanical energy. According to Faraday's law, "whenever a current carrying conductor is placed in a magnetic field; it experiences a mechanical force". Hence, when a supply is given, the interaction between the flux produced by the current carrying conductor and the flux produced by the permanent magnet called the main flux, magnetic repulsion and attraction takes place, this exerts a magnetic force on the conductor which causes the rotation on the system.

System design

A proposed block diagram is designed to evaluate the hardware description. The project will function as described in the block diagram given below

Overview of the design

The block below gives an overview of the microcontroller based dual axis solar tracker.

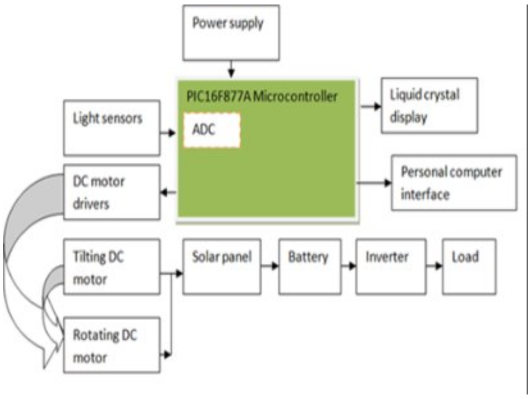


Fig. 2: overview of system design shown as block

As had been seen in the above block diagram, the input of the whole system is the light source which usually comes from the sun in practical real time cases. The light sensors are situated in the top either ends of the solar panel and they acts as feed back to the system. The microcontroller and is programmed using computer programming language (Mikro C language), to send signal to the two servo motors which all lies below the solar panel. The micro controller is programmed in such a way to ensure the movement of the panel to the point of maximum light intensity so as to ensure the maximum tracking of the solar energy. Therefore, the above block diagram can be further sub-divided as electrical, mechanical and computer sub-divisions and these are the PID controller all serves as the input to the microcontroller, while the output of the controller is the servo motor and by extension the solar panel which is controlled by the motor.

Microcontroller

The micro controller is needed to serve the purpose of receiving and processing signal accordingly from the LDR circuit and sending it out to the motor as output, so as to enhance the tracking action of the system. In order to fulfill the task of sending and receiving signal in the cause of this project, a PIC micro controller was used because of its flexibility and suitability to serve us the purpose of the tracking of the maximum sunlight through the motor control. Similarly, the PIC16F877A has the capability of sending the sensor values to a personal computer for monitoring purposes.

Light dependence resistors

For maximum tracking of the sun to be achieved, the use of a light sensor is required, and the light dependence resistors can act as our sensor in the cause of this project. Four of this light dependence resistors were used for the project. The light dependence resistor uses a cadmium sulphide (cds) for light sensing. The cds component is a passive component, whose resistance is found to be inversely proportional to the amount of light intensity that is directed towards it. To utilize the LDR in a photocell, it is placed in series along with a resistor. A voltage divider is thus formed, and the output at the junction is determined by the two resistors. Below shows a voltage divider formed by the four LDRs used for the project.

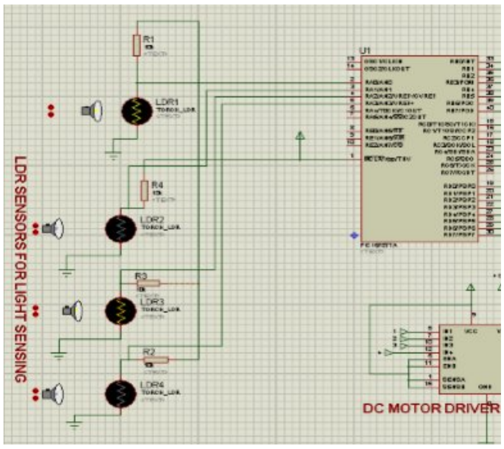


Fig. 3: Light sensor circuit as used in the microcontroller

For us to implement the four light dependence sensors in this project, two were placed on the west and east part of the panel to take care of the rotational movement of the panel via the pin number 2 and 3 of the micro controller input, the other two were placed in the north and south position and slotted into pins number 4 and 5 of the microcontroller to take care of the system azimuthally. Considering the East-West movement which is encountered daily, the panel has to be perfectly normal, 90 degrees to the sun, for maximum energy to be tracked. As the sun begins to move, there will definitely be difference in the resistances detected by those two sensors whose input are connected to pins number 2 and 3, this change in resistance will be communicated promptly to the servo motor via the output of the microcontroller, in this case output pin number 40,and based on the signal received by the micro controller, the motor will automatically acts to tilt the solar system to the direction of lower resistance of the LDR which corresponds to the position of the maximum sun light. The same technique happens as regard the north -south movement of the system.

Therefore conclusively, from the explanations above on light dependence resistor, a kind of direct proportionality exists between the LDR resistor and the light intensity. Based on an experiment which was conducted, the below readings were obtained respectively for LDR resistances when the panel is placed in a dark area, an average area and a bright area (EPIA, 2011).

Software design

This is usually the brain of the whole system without which the system will not operate. The programming language employed for the purpose of the project is the C language program. Through the language, the system will be able to communicate with the motor as to where the position of the maximum energy is. In order to highlight the implementation of our system software, flow chart of the system might be a good starting point.

Flow chart of the solar tracking system

This is use to represent a flow of sequential events which when implemented through the controller via the C programming language, will bring about the rotation of the panel towards the point of maximum sun intensity. From the below flow chart diagram, the program starts by initializing the ports, ADC and serial ports and checks the LDR sensor for any voltage difference between them. Normally two LDRs are used for tilting the solar panel to and fro while the other two were used to rotate the solar panel back and front. Whenever one sensor between the two is greater than the other, the microcontroller commands the DC motor to tilt or rotate towards the direction of the sun, thereby leading to maximum capturing of solar radiation.

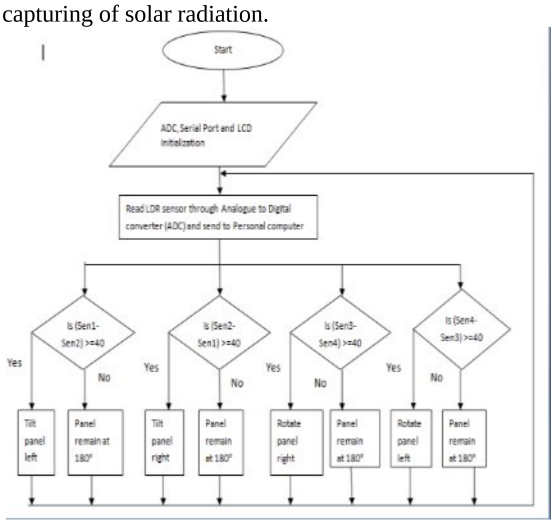


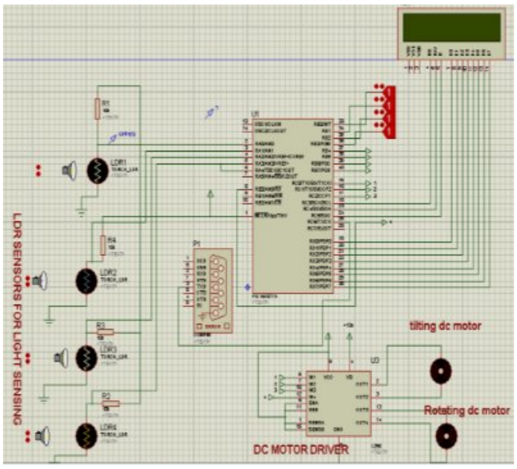
Fig. 4: System flowchart

The flowchart above shows the initial description of the system program code. The first thing the program does is to initialize the ports, ADC and serial ports. The sensors value are read through the ADC and the USART pins then sends the sensor values to the personal computer system for monitoring and the LCD display is used to display the sensor values on a screen. The microcontroller ADC will capture the sensor values continuously and as soon as the difference between two sensors is greater than 40, the solar panel tends to rotate or tilt to a certain angle towards the direction of the sun.

Hardware and software design and implementation

Complete schematic diagram

The circuit section consists of PIC16F877A microcontroller; four LDR sensor for sunlight sensing, two DC for the two axis movement i.e. titling and rotating of solar panel, RS232 for communicating between microcontroller and the personal computer.



Visual basic 6.0 with Proteus ISIS 7 professional results

Fig. 5: Complete schematic

The outputs obtained from the microcontroller and transmitted to the PC via VB GUI interface are given below. Therefore, using the virtual serial port Emulator, the entire project was simulated perfectly. This gives us a clear idea of the hardware implementation. The aims and objectives of this task are well achieved.

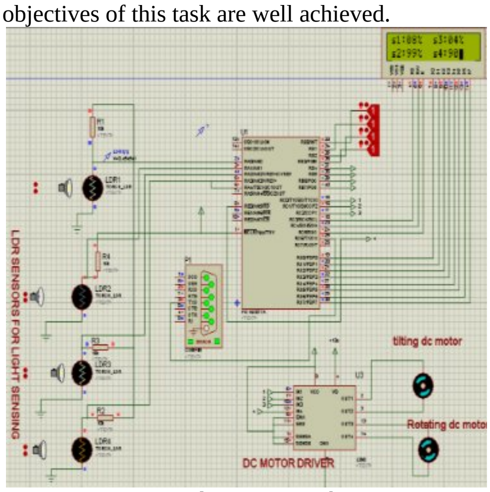


Fig. 6: Monitoring and transmitting the sensor parameters using microcontroller with Protues software

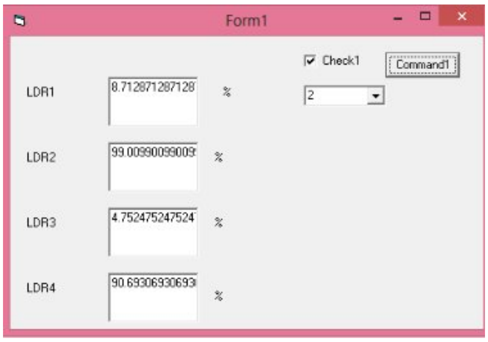


Fig. 7: Receiving and monitoring sensor parameters via PC using the VB GUI interface

Prototype

As seen in Fig 8, the system prototype has been developed with all the features of a microcontroller based solar tracking as named to be the project title. The solar panel tends to move towards the sun radiation using the four LDR sensors, where the microcontroller compares the sensor values in such a way that if the difference between two sensors is greater than 40%, the microcontroller then decides the most suitable direction the solar panel should rotate or tilt at. However, for the purpose of this paper, the microcontroller is set to operate at 40% changes in the difference of the value of irradiation of the sun reflected in the LDR, even though the 40% difference can be changed based on the design requirements and application. The LCD was used for displaying the sensor vales and finally the MAX 232 and RS232 were used for transmitting the transformer parameters to PC.

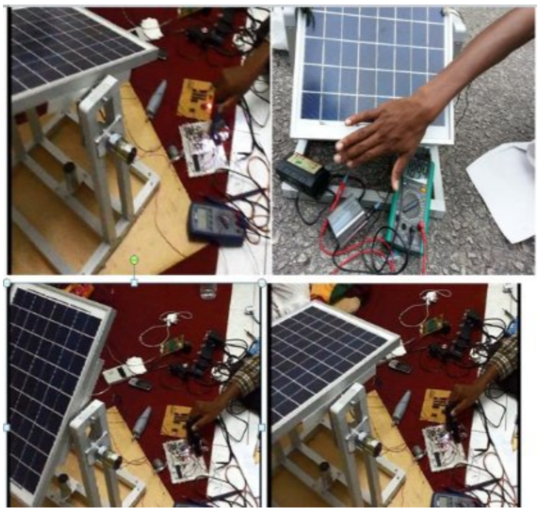
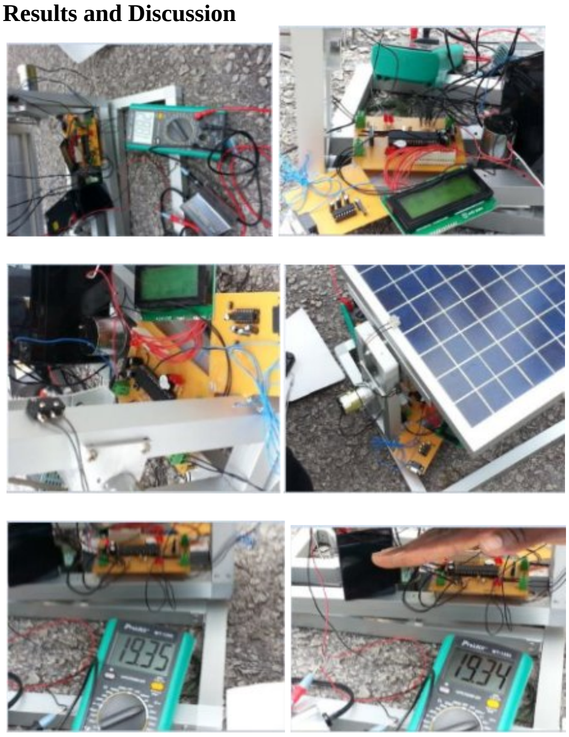


Fig. 8: Project prototype

Results and Discussion



PV module performance testing

The PV module serves as the input power source of the whole system in this project. The power delivered by the PV module is greatly determined by its electrical characteristic such as the one shown in Fig. 9. With such characteristic, the circuit parameters necessary for maximum power point operation can be obtained. In order to obtain the electrical characteristic of the given PV module, a laboratory performance test was carried out. The lab setup is shown in the figure below:

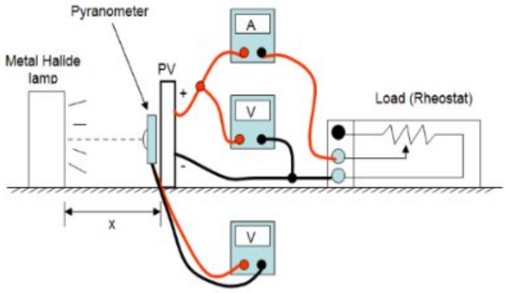


Fig. 9: PV module lab testing setup

All the lab equipment were setup as shown above, the metal halide lamp was used as a stimulate of the sun, the pyrometer measures the level of radiation on the surface of the PV module which depends on the distance X. The distance X was varied to acquire the characteristic curves at different radiation levels. Voltage and current measurements were taken for different resistance value. The table below represents the laboratory test results of the PV module at different radiation levels and resistances.

Table 1: PV module laboratory test results at different irradiance level

Irradiance Level = 300Wm			Irradiance Level = 100Wm			Irradiance Level = 170Wm			Load Resistances (Ohm)
Voltage V	Current A	Power W	Voltage V	Current A	Power W	Voltage V	Current A	Power W	
0	0.249	0	0	0.12	0	0	0.157	0	Short circuit
3.24	0.249	0.80676	1.56	0.12	0.1872	2.04	0.157	0.32028	13.4
4.3	0.249	1.0707	2.01	0.12	0.2412	2.68	0.157	0.42076	17.3
6.32	0.249	1.57368	2.95	0.119	0.35105	3.9	0.157	0.6123	25.7
11.84	0.234	2.77056	5.55	0.118	0.6549	7.35	0.155	1.13925	53.7
14.97	0.206	3.08382	8.4	0.118	0.9912	11.1	0.154	1.7094	79.5
15.25	0.201	3.06525	8.95	0.117	1.04715	11.69	0.154	1.80026	83.7
15.85	0.19	3.0115	9.75	0.118	1.1505	12.49	0.15	1.8735	92.5
17.05	0.163	2.77915	11.95	0.117	1.39815	14.18	0.139	1.97102	117.6
17.8	0.136	2.4208	13.8	0.11	1.518	15.9	0.122	1.9398	175.4
18.1	0.111	2.0091	15.3	0.099	1.5147	16.84	0.106	1.78504	187.2

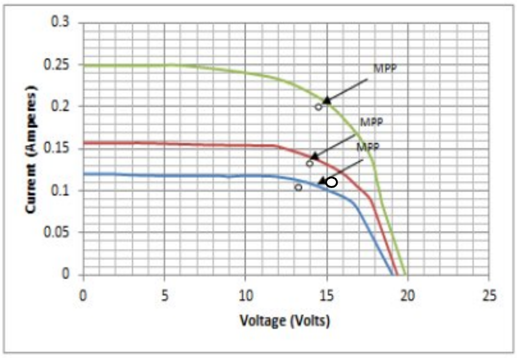


Fig. 10: PV module I-V characteristic

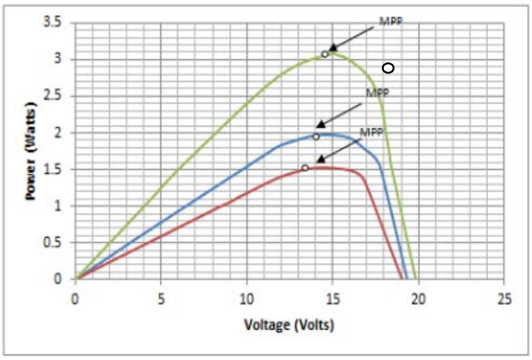


Fig. 11: PV module power curve

In order to effectively track the sun and test the prototype system,several ways were employed. The best way to do the effective testing is to keep the system outside and monitor the output voltage generated through out the day, which was carried and the result are shown below.

Table 2: Output voltage obtain in real time tracking

	Fixed PV Voltage (V)	Tracking PV Voltage (V)
7:00AM	9.9	15.2
8:00AM	13.4	18.6
9:00AM	15.8	19.76
10:00AM	19.5	20.1
11:00AM	18.92	19.3
11:30AM	18.9	19.2
12:00 noon	19.55	19.6
1:00PM	19.62	19.62
2:00PM	19.6	18.95
3:00PM	19.71	20.1
4:00PM	19.5	19.7
5:00PM	19.4	20.2
5:30PM	18.8	19.84
6:00PM	14.7	19.9
7:00PM	9	10.5

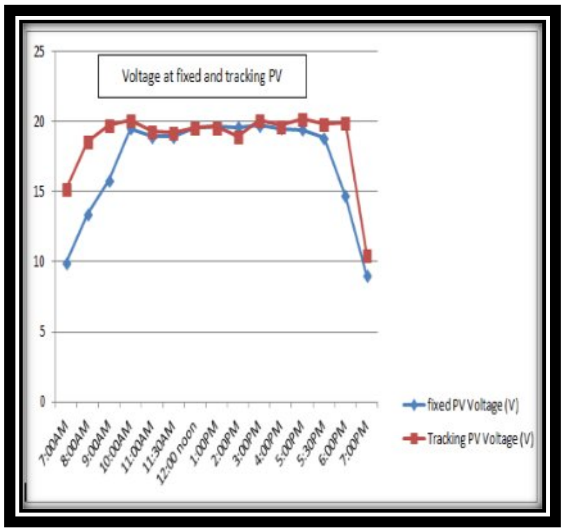


Fig. 12: Represents the voltage data in the Table 2 as a graphical curve using MS_EXEL program.

The system focuses on the controller design. The constructed system has been tested and data from hardware measurement was collected. Typical solar panel was used and the purpose only to prove the designed system is able to operate accordingly. Therefore, the surrounding effects, for instance, weather condition are not seriously considered during hardware testing.
Hardware and software portions of the paper were separated into stages whiledeveloping the overall system. The portions consisted of light detection, motor driving,software tracking, and software enhancements. Building and testing smaller sections ofthe system made the research more manageable and increased efficiency by decreasingdebugging time.The output shows that the system performs the required functions envisioned during the review. However,while satisfied with software operation and simulation, less satisfaction was obtainedfrom two hardware areas. Firstly, there was a potential problem with motor/photocellmovement due to the photocell wires creating binding issues. There are two wiresattached to the photocell mounted on the motor shaft, once the tracker has movedapproximately 30 to 45 degrees, the wires place a counter torque on the motor and themotor slips. This creates positioning error. The present workaround for this is to holdthe photocell wires in a way as to keep them perpendicular to the rear of the photocell.
For every irradiance level; different current, voltage and power exists at maximum power point. The curves of the module are as expected; they correspond with the non-ideal characteristic found in PV cells and modules as shown in Fig. 11.

Conclusion
This research has provided a technical overview into the working and operation of solar tracking for maximum power generation using microcontroller based system for charging our batteries to guarantee energy supply to our streetlights throughout the night at a minimum cost. The system was design and implemented using the PIC16F877A microcontroller that served as the brain of the systems, four light sensors for sensing the sun radiation, a 30W solar panel, two dc motors for tilting and rotating the solar panel to and fro and finally LCD display and computer interface for monitoring of sensor parameters. The system and output of solar panel has been

tested in various time intervals throughout the day and it has been observed that the solar tracking system is more effective than the fixed solar panels. Therefore the system has eliminated the drawbacks of the present system (i.e. fixed solar panels) of powering our streetlights whereby whenever the sun rotates to another direction, the power efficiency of the solar panel reduces thereby leading to low battery charging during the day time and reducing the discharging time of the batteries at night time thus undermining the purpose for which the solar panels were installed on the streetlight poles.

The sun tracking system was implemented meeting its objective to follow the sun's position for maximum power tracking which is based on PIC microcontroller. After examining the information obtained in the data analysis section, it can be said that the proposed sun tracking solar array system is a feasible method of maximizing the energy received from solar radiation.

References

Bingö lO, Altintas A & Öner Y 2005. Microcontroller based solar-tracking system and its implementation. *J. Engin. Sci.*, 12(2): 243-248.

Enslin JHR & Snyman DB 1992. Simplified feed forward control of the maximum power pont in PV installations. *Proceedings of the IEEE International Conference on Power Electronics Motion Control*, 1: 548-553 .

Hua C & Shen C 1998. Comparative study of peak power tracking techniques for solar storage system, pp. 15-19.

Ibrahim HESA & Houssiny FF 1999. Microcomputer controlled buck regulator for maximum power point tracker for DC Pumping system operates from photovoltaic system. *Proceedings of the IEEE International Fuzzy Systems Conference*, August 22-25, 1: 406-411.

IoanVB & Marcel I 2008. Modeling of Maximum Power Point Tracking Algorithm for Photovoltaic Systems Gheorghe Asachi Technical University of Iasi Faculty of Electrical Engineering Iasi, Romania.

Joe-Air J,Tsong-Liang H, Ying-Tung H & Chia-Hong Ch 2005. Maximum power tracking for photovoltaic power systems Department of Bio-Industrial Mechatronics Engin., National Taiwan Univ. Taipei, Taiwan, 106, R.O.C. Department of Electric Engineering, Tamkang University Tamsui, Taiwan 251, R.O.C Tamkang. *J. Sci. & Engin.*, 8, No 2, Pp. 147-153

Midya, P., Kerin, P. T., Turnbull, R. J., Reppa, R. and Kimball, J.(1996) Dynamic maximum power point tracker for photovoltaic applications. *Proceedings of the IEEE Power Electronics Specialists Conference, PESC*, Vol. 2, Pp. 1710-1716

Steven LB, Clarence WR, Sanjeev RK & Charles C 2007. Maximum power point tracking for photovoltaic optimization using ripple-based extremum. *IEEE Transactions on Power Electronics*, 25, no. 10, October 2010.

The European Photovoltaic Industry Association (EPIA). 2011. Solar Photovoltaic Competing in the Energy Sector – On the road to competitiveness available online http://www.iea-pvps.org/index.php?id=9&eID=dam_frontend_push&docID=831