# DESIGN AND CONSTRUCTION OF THE INTENSITY BASED SOLAR TRACKING SYSTEM USING PIC 16F887 MICROCONTROLLER

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## Abstract

Solar energy is abundantly available Renewable Energy Source harnessed in all areas of the world and it is available every day. Energy produced by Photovoltaic system is used in many industrial and domestic applications. The sun position can be tracked based on the intensity of light and the power generating capability of the system can be increased. This paper presents the hardware implementation of the solar tracking system by using PIC microcontroller. An efficient and accurate DC motor control system is used to increase the system efficiency and reduces the solar cell system cost. The proposed automatic DC motor control system based on PIC 16F887A microcontroller is used to control the photovoltaic (PV) modules. This DC motor control system will track the sun rays in order to get maximum power point during the day using direct radiation. A photo cell is used to sense the direct sun radiation and feedback a signal to the PIC 16F887A microcontroller, and then the decisions are made through the microcontroller and send a command to the DC motor control system to achieve maximum power generation. The proposed system is demonstrated through simulation results. Finally, using the proposed system based on PIC microcontroller, the system will be more efficient, minimum cost, and maximum power transfer is obtained.

**Keywords:** DC Gear Motor, LDR, PIC 16F887A Microcontroller, PV cell

## Introduction

One of the most important problems facing the world today is the energy problem. This problem is resulted from the increase of demand for electrical energy and high cost of fuel. The solution was in finding another renewable energy sources such as solar energy, wind energy, potential energy etc. Nowadays, solar energy has been widely used in our life, and it's expected to grow up in the next years. Solar energy has many advantages:

1. Need no fuel
2. Has no moving parts to wear out
3. Non-polluting & quick responding
4. Adaptable for on-site installation
5. Easy maintenance
6. Can be integrated with other renewable energy sources
7. Simple & efficient [Macagnan MH, F Lorenzo and C Jimenez , 1994]

As the range of applications for solar energy increases, so does the need for improved materials and methods used to harness this power source. There are several factors that affect the efficiency of the collection process. Major influences on overall efficiency include solar cell efficiency, intensity of source radiation and storage techniques. The materials used in solar cell manufacturing limit the efficiency of a solar cell. This makes it particularly difficult to make considerable improvements in the performance of the cell, and hence restricts the efficiency of

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the overall collection process. Therefore, the most attainable method of improving the performance of solar power collection is to increase the mean intensity of radiation received from the source. There are three major approaches for maximizing power extraction in medium and large scale systems. They are sun tracking, maximum power point (MPP) tracking or both. A solar tracker is a device that is used to align a single P.V module or an array of modules with the sun. Although trackers are not a necessary part of a PV system, their implementation can dramatically improve a system's power output by keeping the sun in focus throughout the day. Efficiency is particularly improved in the morning and afternoon hours where a fixed panel will be facing well away from the sun rays. PV modules are expensive and in most cases the cost of the modules themselves will outweigh the cost of the tracker system. Additionally a well designed system which utilizes a tracker will need fewer panels due to increased efficiency, resulting in a reduction of initial implementation costs. The dual axis solar tracking system is implemented in this research work. Block diagram of the intensity based solar tracking system is shown in Figure 1.

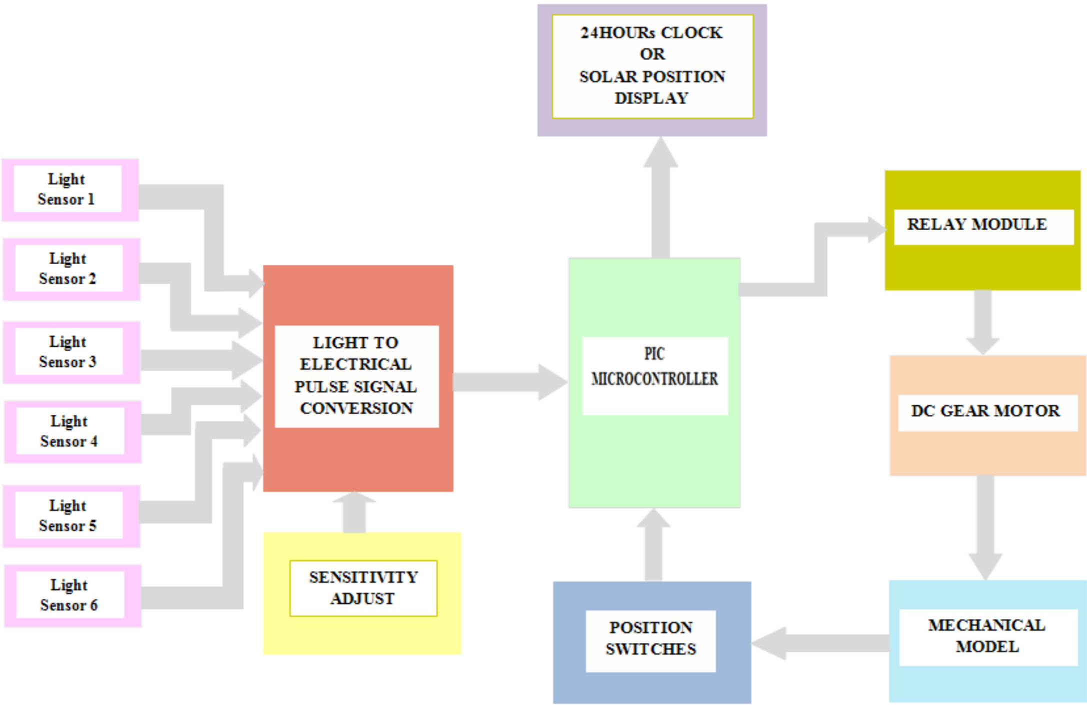



**Figure 1** Block diagram of the intensity based solar tracking system.

## Fundamentals, Materials & Methods

### Solar Tracker Fundamentals

A solar tracker is a device that is used to align a single P.V module or an array of modules with the sun. Although trackers are not a necessary part of a P.V system, their implementation can dramatically improve a system's power output by keeping the sun in focus throughout the day. Efficiency is particularly improved in the morning and afternoon hours where a fixed panel will be facing well away from the suns rays. P.V modules are expensive and in most cases the cost of the modules themselves will outweigh the cost of the tracker system. Additionally a well designed system which utilizes a tracker will need fewer panels due to increased efficiency, resulting in a reduction of initial implementation costs.

**Types of Solar Trackers**

There are many different types of solar tracker which can be grouped into single axis and double axis models.

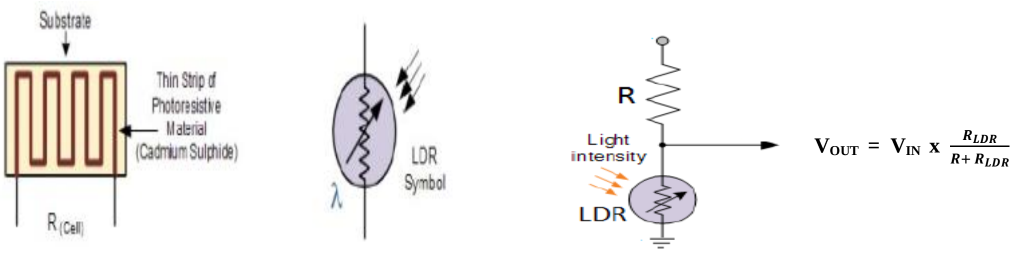
**Single Axis Trackers**: Single axis solar trackers can either have a horizontal or a vertical axle. The horizontal type is used in tropical regions where the sun gets very high at noon, but the days are short. The vertical type is used in high latitudes (such as in UK) where the sun does not get very high, but summer days can be very long. These have a manually adjustable tilt angle of 0 - 45 °and automatic tracking of the sun from East to West. They use the PV modules themselves as light sensor to avoid unnecessary tracking movement and for reliability. At night the trackers take up a horizontal position.

**Dual Axis Trackers**: Double axis solar trackers have both a horizontal and a vertical axle and so can track the Sun's apparent motion exactly anywhere in the world. This type of system is used to control astronomical telescopes, and so there is plenty of software available to automatically predict and track the motion of the sun across the sky. Dual axis trackers track the sun both East to West and North to South for added power output (approx 40% gain) and convenience. [Gay, CF; Wilson, JH & Yerkes, JW, 1982]

**Hardware Components Required For the System**

**PV Panel**: Solar panel absorbs the energy from the sunlight and convert it in to heat or electricity. A 12volts, 10 Watts Solar panel is used for this system. Four LDR's are place on the four sides of the solar panel and another two LDR are placed at the bottom of solar panel to generate output that will be applied to the microcontroller.

**Photosensor (LDR)** : A photo sensor or light-dependent resistor (LDR) or photocell is a light controlled variable resistor. In the dark, a LDR can have a resistance as high as a few megaohms (MΩ), while in the light, a LDR can have a resistance as low as a few hundred ohms. Light dependent resistor OPR12 is used in the System. It is a photoconductive cadmium sulphide cell and its output is connected to the Analog input of the Microcontroller. The change in the resistance in the LDR is converted in to changes in output voltage that can be sensed by analog input of the microcontroller. Schematic symbol and voltage divider circuit of a LDR is shown in Figure 2.[Scherz P]




(a) (b)

**Figure 2 (a)** Schematic symbol of a photo resistor. (b) Voltage divider using LDR.

**Control Unit** : The PIC 16F887A microcontroller with FLASH memory has been used in this system because data are retained even when the power is switched off. Its features are the PIC16F887 incorporates 256 bytes of EEPROM data memory, 368 bytes of RAM, and program memory of 8K. Apart from self-programming capability, it also contains 2 Comparators, 10-bit Analog-to-Digital (A/D) converter with 14 channels, and capture, compare and PWM functions. Pin connection diagram of a PIC 16F887A microcontroller IC is shown in Figure 3. [Bates, Martin P]

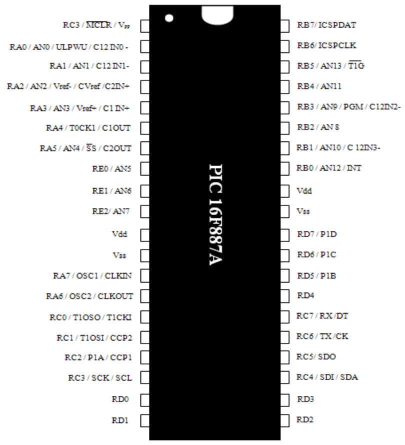



**Figure 3** Pin connection diagram of a PIC 16F887A microcontroller IC.

**DC Gear Motor** : DC Gear Motor is used for the suggested system. This motor will rotate the Solar panel according to the Sun's maximum intensity position. The specifications of DC Gear Motor used in this system are shown in Table 1.

**Table 1 Specifications of DC Gear Motor used in this system**

| **Voltage** | **12 V** |
|---|---|
| Continuous Current | 0.5 A |
| Output Power | 7 W |
| Torque | 100 |
| Speed (RPM) | 3800 RPM |

**Relay circuit using in DC Motor's direction control** : A relay based DC motor controller works with an H-bridge arrangement. With an H-bridge circuit, the polarity across a load can be altered in both directions.

**Power Supply Unit**: The regulated +5V , dc power supply is used for DC motor driver and microcontroller units. The voltage regulator IC 7805 is applied in this power supply unit. The line voltage 220V, ac is transformed to 12V,ac by using 12V ac step-down transformer. Step-down ac voltage is converted to unregulated dc voltage by using full wave rectifier and filter circuit. This dc voltage is applied to DC gear motor.

**Software and System Design**

The program for the intensity based solar tracking system is written in CCS C language. The C program is converted into machine code (HEX code) by using MPASM assembler. After converting the HEX code, MPLAB simulation is essentially needed to execute properly for the source code. The window of simulation on program execution is shown in Figure 4. The HEX code is downloaded into the MCU by the use of the programmer circuit.

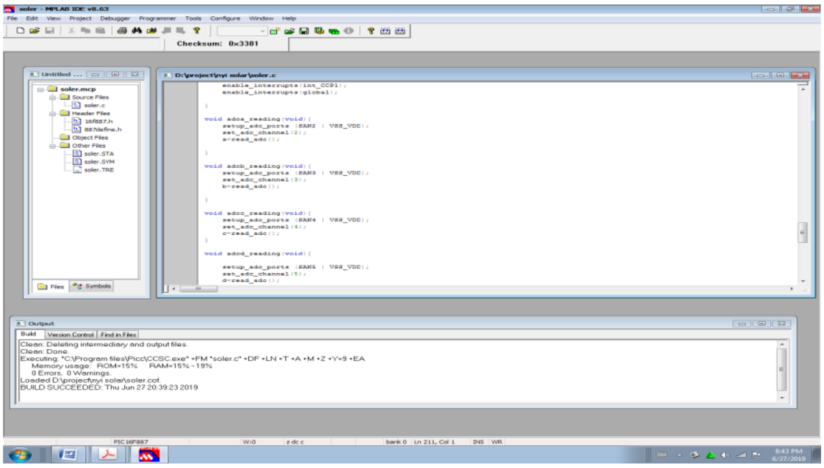


**Figure 4** The window of simulation on program execution

The simulation window of the intensity based solar tracking system is illustrated in Figure 5. The type of microcontroller used in this circuit is PIC16F887A. This type of microcontroller has 14 ADC channel, and four channels (AN2, AN3, AN4, AN5) are used to read the analog signal of the cadmium sulfide (CdS) photocells, the photocell sensors are used to measure light intensity. The two horizontal LDR 1&2 are used for azimuth sensing and the two vertical LDR 3&4 are used for the declination sensing. Remaining two LDRs, LDR 5&6 are parallel with LDR 3&2. Position limit switches (S1 through S2) are connected to Port C (RC4 through RC7) of PIC 16F887A.It is used to limit the solar tracker position. Relay module is connected to Port C (RC0 through RC3). RC0 and RC1are used to control the solar panel azimuth motion and RC2 and RC3 are declination motion. These outputs (RC0 through RC3) are used to control the relay module. The outputs of the relay module control the two DC gear motors. Two DC gear motors are used to achieve maximum power output of the intensity based solar tracking system. The purpose of relay module circuit is to achieve DC gear motor control in two directions. Four seven segment LED display is used to display the 24 hour clock or solar panel position. Microcontroller output PORT B (RB0 through RB7) is connected to four seven segment (LED display segment) and PORT D output (RD4 through RD7) is used for digit control. Three push button switches (S5 through S7) are setting adjust, hour adjust and minute adjust. These three switches are also used to control the solar tracker position.

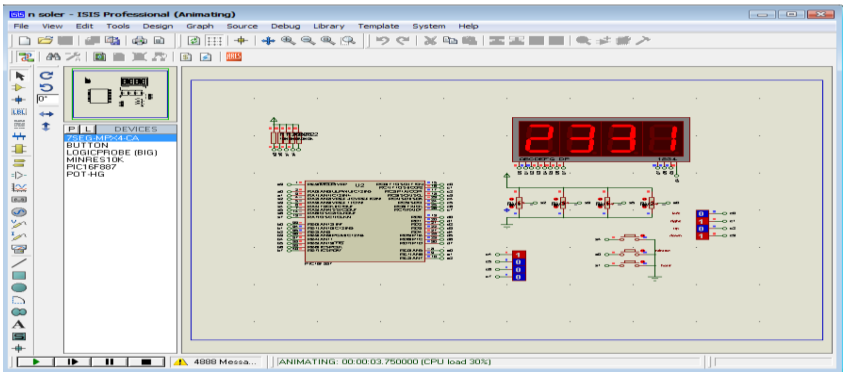


**Figure 5** Simulation window of the intensity based solar tracking system.

The sequence for tracking algorithm main program of the intensity based solar tracking system for this project is illustrate in the flow chart(Figure 6) below.

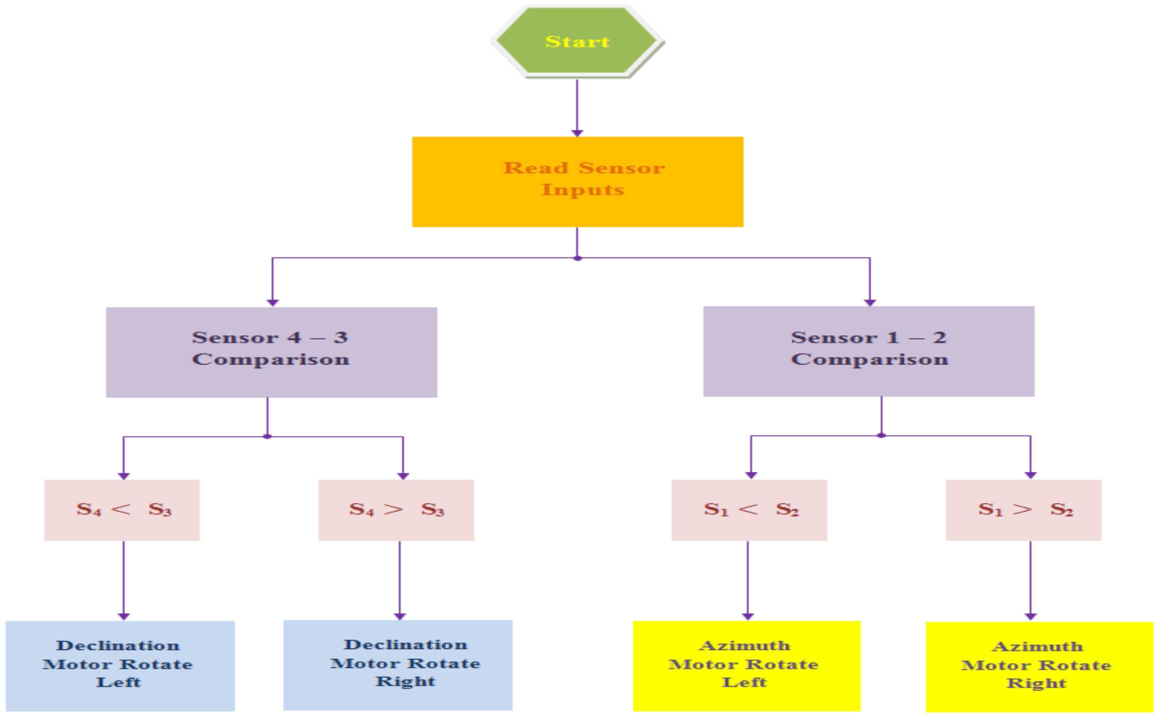



**Figure 6** Flowchart of tracking algorithm for intensity based solar tracking system.

## Results and Discussion

When sun light exposes to the solar panel, the angle at which the sun's rays meet the surface of the solar panel determines how well the panel convert the incoming light into electricity. The narrower the angle, the more energy a PV panel can produce. Solar tracker helps to minimize this angle by working to orient the panel, so that light strikes them perpendicular to this surface. The intensity of the sun light varies with time and location. The sun position can be tracked based on intensity of sun light and the power generating capability can be increased. This research paper describes the solar tracking system with 2 degree of freedom (dual axis solar tracker). This type of solar tracking system is designed to maximize solar energy collection throughout the year. It can track seasonal variations (north-south motion) in the height of the sun in addition to normal daily (east- west) motion of the sun.

### Testing setup

Testing setup for intensity based solar tracking system is shown in Figure 7. LDR's placed at the solar panel detects the light intensity and based on the output, microcontroller will give the pulse to the driver circuit of motor .Based on the intensity, the DC geared motor drive the solar panel towards the maximum intensity position. The complete setup was exposed to the sunlight to check the operation of the system. Quantity of sunlight that reaches the solar panel is detected by LDR placed at the panel. Panel gets activated by the DC gear motor in response to the output of LDR, so that the panel aligned with sun's direction. This operation will be done by completing the three stages. The first stage was conversion of luminous intensity in to electrical signal (Voltage). The second stage that controls the actuation and decision making is made here. Movement of the panel using a DC gear motor was done at the last stage that is driver stage.

LDRs are used as Light sensors because its resistance varies with light. Microcontroller receives the voltage from the LDR and it activated the motor so that panel gets aligned. DC gear motors are used in this system because this motor will provide high torque, high precision and high speed.

**Figure 7** Testing setup for intensity based solar tracking system

**Testing of the System and Results**

The designed solar tracking system was tested from morning 8 AM to 5 PM. The variation of the intensity of sunlight offers the several output voltages and currents throughout a day. The power output and varying intensity of the solar tracking system are listed in the following table 2.

**Table 2 Measured Output of the solar tracking system versus intensity of the light**

| Time | Intensity of light (lx) | Output Voltage (V) | Output Current (A) | Output Power (W) |
|---|---|---|---|---|
| 8:00 AM | 2156 | 12.2 | 0.31 | 3.782 |
| | 1496 | 11.5 | 0.23 | 2.645 |
| | 1250 | 10.7 | 0.19 | 2.033 |
| Average | 1634 | 11.5 | 0.24 | 2.790 |
| 9:00 AM | 2874 | 12.9 | 0.28 | 3.623 |
| | 2324 | 12.6 | 0.25 | 3.140 |
| | 1845 | 11.9 | 0.2 | 2.380 |
| Average | 2348 | 12.5 | 0.24 | 3.034 |
| 10:00 AM | 3865 | 13.6 | 0.34 | 4.621 |
| | 2940 | 13.2 | 0.28 | 3.688 |
| | 2100 | 12.8 | 0.20 | 2.550 |
| Average | 2968 | 13.2 | 0.27 | 3.600 |
| 11:00 AM | 4012 | 14.0 | 0.39 | 5.452 |
| | 3655 | 13.6 | 0.36 | 4.885 |
| | 3565 | 13.5 | 0.33 | 4.439 |
| Average | 3744 | 13.7 | 0.36 | 4.920 |
| 12:00 Noon | 4562 | 14.9 | 0.4 | 5.952 |
| | 4950 | 15 | 0.39 | 5.733 |
| | 4876 | 15 | 0.39 | 5.967 |
| Average | 4796 | 15 | 0.39 | 5.884 |
| 1:00 PM | 3690 | 14 | 0.36 | 4.855 |
| | 3420 | 13 | 0.33 | 4.422 |
| | 3374 | 13 | 0.33 | 4.369 |
| Average | 3495 | 13 | 0.34 | 4.547 |
| 2:00 PM | 3565 | 13.6 | 0.34 | 4.610 |
| | 3542 | 12.5 | 0.3 | 3.750 |
| | 2712 | 12 | 0.26 | 3.120 |
| Average | 3273 | 12.7 | 0.3 | 3.806 |
| 3:00 PM | 2871 | 10.5 | 0.26 | 2.730 |
| | 2341 | 9.2 | 0.25 | 2.308 |
| | 2540 | 9.6 | 0.25 | 2.400 |
| Average | 2584 | 9.8 | 0.25 | 2.790 |
| 4:00 PM | 2421 | 9.5 | 0.23 | 2.185 |
| | 2300 | 9.0 | 0.20 | 1.800 |
| | 2240 | 8.6 | 0.20 | 1.720 |
| Average | 2320 | 9.0 | 0.21 | 1.897 |
| 5:00 PM | 2343 | 8.5 | 0.20 | 1.700 |
| | 2240 | 7.4 | 0.18 | 1.332 |
| | 1548 | 6.1 | 0.17 | 1.037 |
| Average | 2044 | 7.3 | 0.18 | 1.344 |

## Comparative Analysis

Comparative analysis was made between fixed axis solar system and dual axis solar tracking system. The results are given in Table 3. Figure.8 shows the relation between intensity of light and output power of the comparison results of dual and fixed axis solar system..

**Table 3 Comparison results of the dual axis and fixed axis solar system**

| Dual Axis Solar Tracker | | | Fixed Axis Solar System | | |
|---|---|---|---|---|---|
| Time | Intensity of Light (lx) | Output Power (W) | Time | Intensity of Light (lx) | Output Power (W) |
| 8:00 AM | 1634 | 2.79 | 8:00 AM | 550 | 0.45 |
| 9:00 AM | 2348 | 3.034 | 9:00 AM | 1548 | 1.275 |
| 10:00 AM | 2968 | 3.6 | 10:00 AM | 2240 | 1.62 |
| 11:00 AM | 3744 | 4.92 | 11:00 AM | 2324 | 3.12 |
| 12:00 Noon | 4796 | 5.884 | 12:00 Noon | 3365 | 4.05 |
| 1:00 PM | 3495 | 4.547 | 1:00 PM | 3754 | 3.900 |
| 2:00 PM | 3273 | 3.806 | 2:00 PM | 2230 | 2.3 |
| 3:00 PM | 2584 | 2.79 | 3:00 PM | 880 | 0.98 |
| 4:00 PM | 2320 | 1.897 | 4:00 PM | 550 | 0.55 |

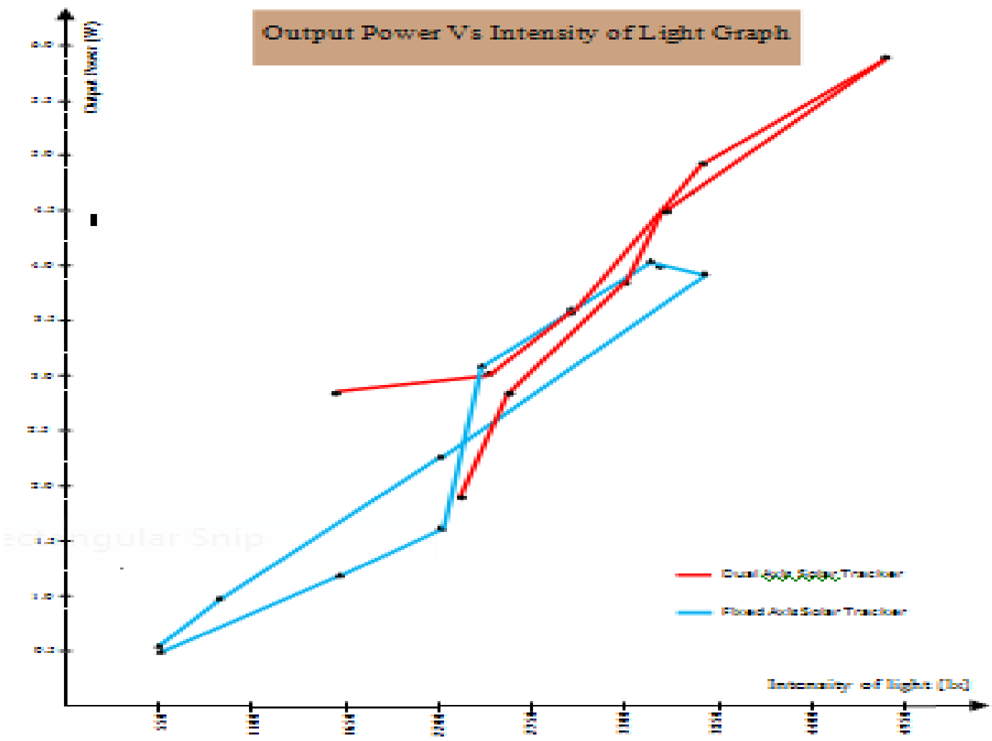



**Figure 8** The relation between intensity of light and output power of the comparison results of dual and fixed axis solar system..

Average power output for the fixed tracking is 1.83 W whereas with tracker, it is 3.45 W. The suggested system produces more power (47%) than the fixed axis solar tracking system.

## Conclusion

Intensity based solar tracking system (dual axis solar tracker) using PIC microcontroller has been proposed in this paper. The performance of the dual axis solar tracking system is better than static and because it saves the losses of the intensity of sun rays due to daily and seasonal variation in the sun's path. No matter where the sun is in the sky, dual axis trackers are able to angle themselves to be in direct contact with the sun. At high latitude locations, where the sun's position in the sky varies dramatically between summer and winter months, this solar system gives benefits to maximize the solar production and collect enough power for proper usage. An efficient and accurate DC gear motor control system is used to increase the efficiency of the system and reduce the cost. The system is completely automatic and maintenance cost is also less. This system can be designed to accommodate more number of panels so that the power output can be increased in future.

## Acknowledgement

I am greatly indebted to Associate Professor Dr. Yee Yee Oo, Head of the Engineering Physics Department, Technological University (Maubin) due to her permission to undertake this piece of research. I am also extremely greatful to Dr. Ni Ni Win, Associate Professor, Physics Department, Magway University for her helpful suggestions during the preparation of this paper. I would like to especially thank to U Nyi Nyi Win for his guidance and kind help throughout this work.

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