Solar Helio-Tracker

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Declaration

We certify that this project titled "*Solar Helio-Tracker"* is our own work. The work has not been presented elsewhere for assessment. The material that has been used from other sources it has been properly acknowledged / referred.

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Language Correctness Certificate

This report has been read by an English expert and is free of typing, syntax, semantic, grammatical and spelling mistakes. Thesis is also according to the format given by the university.

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Copyright Statement

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Abstract

With increasing demands of power and energy crisis, renewable energy is the solution of the future. Out of all the famous renewable energy options, solar power has gained the most fame owing to its long life time and the fact that it is one time investment. However in some places where we have interrupted supply of sun due to cloudy weather solar panels can't be as efficient as they can be. The motivation of this project came from these reasons and the fact that we could employ some sort of improvement method to solve this problem. Hence this project was started to look for solutions to this problem in tracking. As a result we have produced a design that will orient itself in the direction of maximum sunlight at all times. The design is free to rotate on 2 degrees of freedom that covers the maximum workspace. The functioning of a PV panel is such that it grabs the incident light on its cells and converts in to electricity. A study has shown that only 18% of the incident energy is successfully converted in to electricity. Tracking the sun can supposedly achieve an efficiency improvement of about 30-40% [2]. We have incorporated the designed tracking system on to a PV panel so that it tracks the sun all the day for maximum sunlight. The control system assists the assembly holding the panel to orient itself in to the position of maximum intensity so that it can absorb and convert maximum possible energy throughout the day. By using this design it was shown that a good degree of efficiency improvement could be achieved by employing this technique on stationery solar panels (tested on 80W rated power) which not only improves production efficiency but also provides more space efficient system.

1 Introduction

1.1 Background

Increasing gap between energy demands and supply is the debate of the time. The world is facing acute problems on energy crisis which is not only affecting the daily life of people but also hindering the overall development and progress of a country. Increased production of electricity using fossil fuels such has coal, oil and natural gas have only helped to increase the rates of electricity making it unaffordable for common man especially in developing countries like Pakistan. Fossil fuels have provided us power for a long time and it is time to shift our energy resources to renewable because fossil fuels are getting depleted at increasing rates and crude oils will end by 2075 [3]. Moreover the use of fossil fuels has increased the global warming effects in the entire world to concerning levels. Their use has also led an increase in the air pollution due to the emissions of the burning fuels. Besides the fact that fossil fuels are being heavily consumed for electricity production, one third of population of the world has lived without access to electricity (2002) [4]. This crisis has led to closure of industries in developing countries and has led to economic losses. With no electricity every field of life has suffered badly. From industry to offices to schools to homes, every activity has suffered interruption and this in turn has led to losses. Moreover with rising number of technological advances from the developed countries and their improving lifestyles the developing world has seen a rise in energy consumption in all sectors of life. Whether it be office use or industrial consumption there is a great need for larger units of energy production.

The central challenge facing the world at the moment is to find cheaper and more efficient means of generating electricity and to reconfigure the energy mix for continued supply of uninterrupted power at an affordable price [1].

With fossil fuels not left as option the world is digging in to renewable energies. Since the start of the last decade, countries with more potential of renewable energies like Solar, Wind, Biogas and Tidal Wave energy have changed trends and have tried to shift the Power production load to renewable resources. The trend of renewable energy has risen gradually in the last few years. In countries like Pakistan where we have a great source of sunlight in Sindh, Punjab and winds in Sindh and coastal areas of Baluchistan there is a rich scope for introduction of renewable energy technologies on larger scales. By observing the trends of the past one decade and the market availability of PV panels we can easily say that most influential of these renewable technological advances has been Solar Power. The main reason of this is that besides installing larger units of production from solar panels, this technology can also be applied on smaller scales for example in homes, offices etc.

There are multiple ways in which we can extract energy from the Sun i.e. solar thermal systems and direct extraction technologies. Direct extraction means PV panels that extract sunlight and convert it in to electricity. This technology is being practiced all over the world and is gradually increasing owing to its longer lifetime and one time investment. Thus active solar systems like PV panels are one of the best options to be used to produce electricity at smaller as well as large scales in this time of energy crisis.

1.2 Problems and Proposed Solution

Solar power has seen increasing trends in the past few years. Active Solar technique means using a PV (photovoltaic panel) for absorbing solar light and converting it in to electricity. The PV panel is a semiconductor material of silicon and germanium which offers absorption of selected rays of light and convert into electrical energy. A fact states that only 18% of the incident light on the PV panel is efficiently converted in to electrical energy. The rest of the energy is either reflected back or is unable to be absorbed because of its wavelengths. Considering an area where sun is available for an average of 6 hours a day, we can say that the panel absorbs maximum possible intensity for just 1-2 hours. 18% of this figure will further decrease the figure of the converted energy. This means that an investment of a certain amount on PV panel gets only 18% of available energy. There are ways in which we can increase by some percentage, the amount of energy coveted from solar to electrical by the PV panel.

There is a solution to this problem. We can do something to make the panel face the sun at all times, just like a sunflower. If it faces the orientation of maximum light intensity at all times of the day, then it can increase the light falling on it. With this the converted energy per unit time can be automatically increased, hence increasing the output power from the system.

1.3 Present Study

Presently the tracking systems that are available are mainly in 1 axis used for commercial purposes. These have been in use in Northern California [9]. Tracking in 2 axis has been done on experimental basis but commercially neither are they available, nor being practiced on larger scales.

The tracking of the panel had certain objectives to be achieved before completion. Main Objectives of the project have been highlighted as

- Designing a 2 DOF assembly
- Preparing successfully a physical model that allows 2 degrees of freedom.
- Designing a control system that compares and actuates the motors in desired direction.
- Making a stand-alone system that traces the sun and automatically adjusts its orientation in the direction maximum light.
- Testing the model in real time.
- Fine tuning the model for achieving the desired efficiency improvement of PV panel.

2.1 Solar Radiation in Pakistan

Pakistan is estimated to possess a 2.9-TW solar energy potential. Photovoltaic units have been installed in mosques and schools and are being used for solar lanterns, solar home light systems, street and garden lighting and telecommunications.

It is further stated that the maximum amount of solar radiation in Pakistan is around Quetta. The breakdown was as follows:

- Sindh and Baluchistan: > 440 cal/cm^2 day
- Punjab and KPK: 400-440 cal/cm^2 day
- Northern areas and Kashmir: < 400 cal/cm^2 day

Daily average global irradiation in Pakistan is estimated to be about 200-250 W/m^2 which amounts to about 6840–8280 MJ/m^2 in a year. (Bhutto et al., 2012)

2.2 Active Systems

Active Solar system means extracting direct solar energy from incident sunlight using some device and converting it in to other useable forms of energy (electrical energy in our case with the help of photovoltaic panels). Some other uses are using the direct sunlight to warm the water for daily household use or for space heating.

2.2.1 Photo-Voltaic Panel:

Photo-voltaic is a device made on silicon-germanium alloy that absorbs incident sunlight and converts it in to electrical energy. Different modules can be attached in series to make larger and larger units of panels for greater outputs. For a single PV panel the output of the system was found dependent on the following factors.

1. Sunlight Incident area
2. Exposure time to the sunlight
3. Surface reflective index

By incorporating tracking for a specific panel we can improve the factor number 2 mentioned above. Because tracking will let the panel face the sun for the maximum possible time and will improve the output greatly in the morning and evening times as during the peak hours of the day, the intensity of light from sun remains almost same.

2.3 Development Techniques

We can implement two controlling methods to the PV panel for following the sun.

1. Logged Data for Sun’s Position and Orientation throughout the Year

2. Adjusting the panel by light detection sensors and smart Control System

2.3.1 Logged Data for Sun's Position and Orientation throughout the Year:

In this technique data is collected for sun's position in a specific location (city) throughout a year. Then this data is logged in to a control system program to simply follow the pre-set values of sun position. This method however has a serious drawback. This technique is only applicable in specific locations because sun does not follow the same pattern of time in all parts of the world. This method is also affected by the type of weather example. Sunlight's intensity was not the same on 25/6/2013 and 25/6/2010.

2.3.2 Adjusting the panel by light detection sensors and Smart Control System:

In this technique the basic controlling mechanism is designed by involving light intensity sensors. We can employ a set of sensors which measure the intensity of light falling on different sections of the panel. The control system program will analyze these values to evaluate the orientation of the maximum intensity, and then pass this value to the actuator, which is a DC motor. The control circuit then makes the motor to rotate about a certain angle to bring the panel to the new orientation.

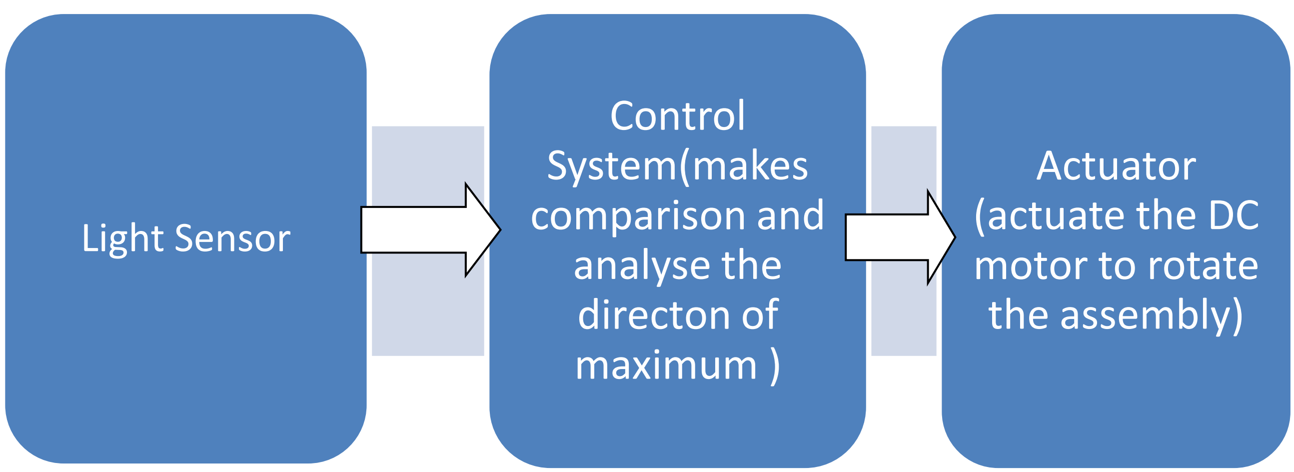


Figure 1.a

3.1 Materials

3.1.1 Physical Assembly

Here is a list of materials that were bought from the market (City Saddar Road, Rawalpindi).

3.1.1.1 Iron plates

Iron plated of following specifications were used in the manufacture of Helio-tracker assembly.

1. 10mm thickness for base
2. 6mm thickness for support plate
3. 8mm thickness for holding plate
4. 25mm thickness for Hubs

Figure 2.a

3.1.1.2 Hubs

The hubs were basically made to hold the bearing i.e. to serve as the bearing housing. First of all the larger plate was cut into four equal pieces. It made at the lathe machine. The housing was 12mm deep with diameter equal to the external diameter of the bearing (34mm). Following this the holes were made in the hub at the hub as shown in the figure below. The holes made were of M10 size. This was followed by tapping the holes. All the four hubs are identical.

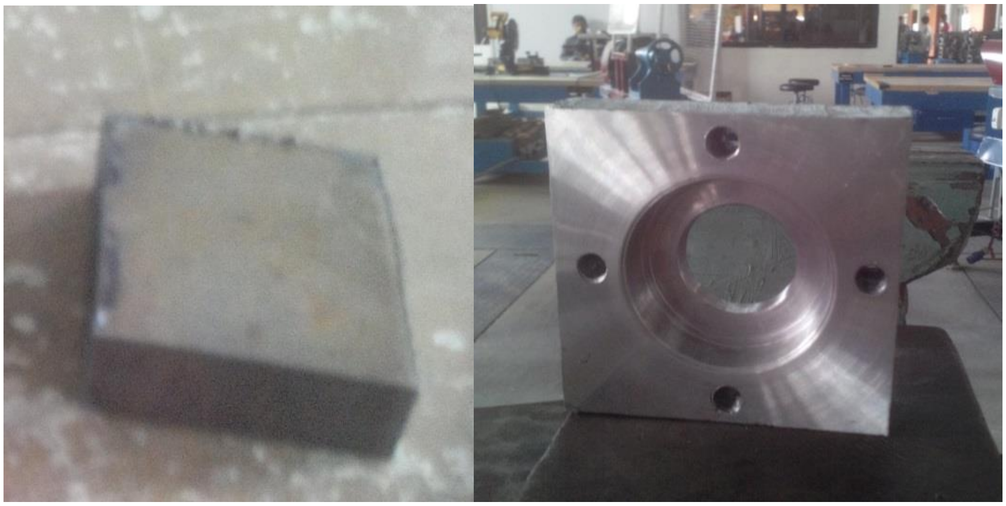


Figure 2.b

3.1.1.3 Iron Shaft Pipes

1. Internal Diameter 29mm and external diameter34mm, length 450mm
2. Internal Diameter 29mm and external diameter 34mm, length 750mm

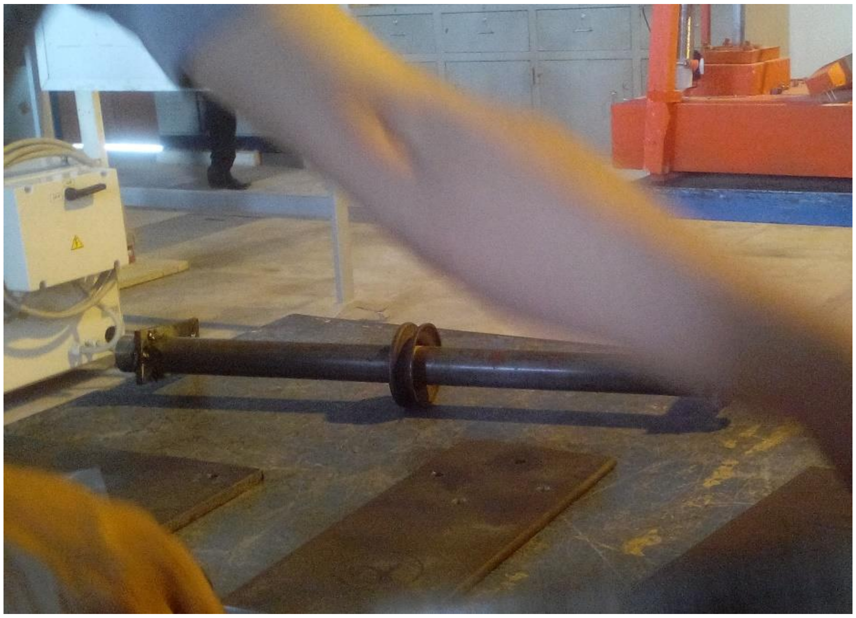


Figure 2.c

Figure 2.d

3.1.1.4 Iron Pulleys

Four blind pulleys were bought. Material of the pulleys was cast iron. Pulleys were used to couple the motors with the shafts so that the rotation can be made possible. Pulleys on the motors are coupled with the pulleys holding shafts using V-Belts. The type of belts used is B-type. One belt is of the size 475mm and the other is of 600mm. Two pulleys are coupled with the both shafts and the other two are coupled with the motors. The holes of the pulleys are equal to the outer diameter of the shafts holding them. Their fixture is shown in the figures 2.e and 2.f.

Pulley 1

Figure 2.e

Pulley 2

Figure 2.f

3.1.1.5 Iron rods caps

The material which was used for this purpose was an iron rod of 50mm diameter and 200mm of length. First of all it was cut into 3 equal pieces. Then the machining was done on the Lathe in such a way that one side of rod can be press fitted into the shaft pipe and the other side into the bearing inner diameter so that both pipe and bearing can be joined together for smooth operation.

3.1.1.6 Screws and Nuts

Three types of nuts and bolts are used in our assembly.

1. M10 type
2. M8 type
3. M4 type

M10 type is used in hubs, M8 type is used for holding the panel using supporting rods while the M4 type is used in connecting the motors with the angle rods.

3.1.1.7 Angle Rods

Angle rods were used to hold motors at the fixed positions so that motion can be controlled. Three angle rods are used for the bigger motor and two are used for the smaller motor.

For motor A (lower), one angle rod is connected with the two supporting rods at the right side of the assembly. The connection is made by electric arc welding. Other two angles of similar size have been welded with the base plate of the assembly parallel to each other. At these two angle rods, a slot of 70mm length and 4mm width was made so that motor can be fixed for belt adjustment. The width is kept 4mm because motor has holes of 4mm size for connection. Finally the motor is connected to these angle rods with the help of M4 screws. Angle rods are shown in figure 2.j.

For smaller motor B (upper), two angel rods are used. These angle rods are welded with the bigger strip of ‘U’ shaped assembly, parallel to each other. At these rods, similar type of holes are made and the motor is connected with them.

3.1.1.8 Small Strip

Two small strips of iron are used. These are mounted over the upper shaft pipe to hold the PV Panel as shown in the figure 2.g.

Figure 2.g

3.1.1.9 Hub Holder Plates

These strips are used to hold the hubs which are connected to the upper shaft pipe. Two pieces of 300mm length were cut from the iron plate. Four holes were made at the upper part of both strips. The dimensions and size of these holes was equivalent to the hub holes so that both may fit properly over each other. Another plate of same thickness but with a length of 450mm was used to hold these hub holder plates. 300mm strips were weld at both the ends of the longer strip thus a ‘U’ shaped assembly was made which holds the PV panel. Figure 2.h shows the hub holder plates.

Figure 2.h

3.1.1.10 Base & Support Plate

Two similar plates of dimensions 1x1 ft. The base plate has a thickness of 10mm and the upper support plate has a thickness of 6mm.They hold all the load of the assembly. Figure 2.i shows the base and support plate.

Figure 2.i

3.1.1.11 Support Rods

4 support rods were used each 1 ft. long and 15mm diameter. Their only purpose was to support the heavy assembly.

3.1.1.12 Motors

Two DC motors are used in our system. One of which rotates the entire assembly along the z-axis and the other rotates the upper panel along the x-axis. The larger motor used is of high torque and low speed while the smaller motor used is of relatively smaller torque and high speed. The speed of larger motor is about 25rpm and that of smaller motor is about 50rpm with the current ratings of about 0.3A and 0.4A respectively.

Figure 2.j

3.1.2 Panel & Wiring

The panel had a rating of 80W output power. The company was MINGLY GERMNAY.

Figure 2.k

Real time outputs were measured outside Controls Lab, SMME-NUST. It was a sunny day with an average temperature of 35 degree Celsius.

1. Voltage 18.4V
2. Ampere 4.3A
3. Power 80W

- Insulation tape was used to bind the joints made in wiring.
- 6 meters long copper wire was used to connect the coil terminals and the Solar panel directly.
- All above readings were taken from multi-meter.

3.1.3 Control System Circuitry

1. **Arduino UNO** is a microcontroller with 6 analog inputs and 6 outputs that can be used as PWM outputs. It serves as a very simple device for controlling automated systems, just like ours. The board can operate on an external supply of 6 to 20 volts. If supplied with less than 7V, however, the 5V pin may supply less than five volts and the board may be unstable.[5]

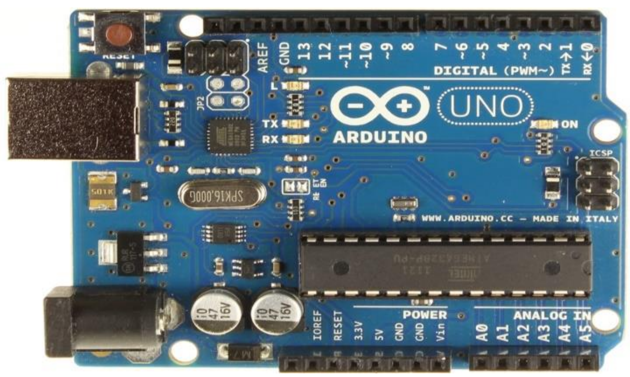


Figure 3.a

2. **Dual H-Bridge (L298 driver module)** is a chip which has two H-bridges built-in one chip. It can control the direction and speed of two motors at one time.

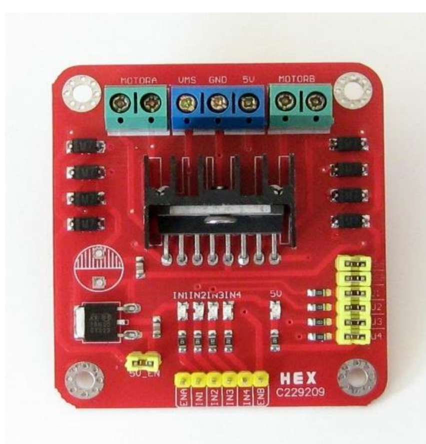


Figure 3.b

3. **2 DC Motors** whose direction and speed is controlled in order to move the PV panel in the desired orientation.

4. **Jumper Wires** for connections on the circuit.

5. **Connector pins** for making strong connections and resist damage when placed in harsh wind and rain conditions.

6. **LDR sensors** were used as light sensors and to take analog voltage values at all times, to be used further in comparison.

.

7. **5V Battery** was used to power the Arduino UNO board.

8. **12V battery** which serves as charging battery as well as power source for the motors.

3.2 Methods

3.2.1 Physical Assembly

Physical assembly of the tracker was prepared after a hectic work of almost one month. All the CAD drawings and fabrications were done here at SMME. The CAD drawings were approved by the MRC and manufacturing was done at MRC, SMME.

3.2.1.1 Assembly

In section we explained all the components that were used for the fabrication of the model. Here is a list of main components that were assembled together to form the tracker assembly.

1. Hubs
2. Base plate
3. Support plate
4. Support rods
5. Shaft Pipes
6. Pulleys
7. Upper Holder Strips
8. Bearings
9. Screws

With all these prepared and fabricated in the MRC, we started to assemble all of them in the manner explained ahead. Assembling of the mechanism is divided into two parts:

1. **Upper Portion** that holds the panel and rotates the panel about x-axis.
2. **Lower Portion** that holds the upper part and rotates the assembly about z-axis.

Upper Portion:

First of all the bearings were press-fit in to the hubs. Then the shaft pipes were press fit in to the bearings. As the panel needs to move, so the rotation of the pipe will be assisted by these bearings in the hubs. Hubs have been used to provide enough support to the assembly for carrying enough load. The process is shown below.

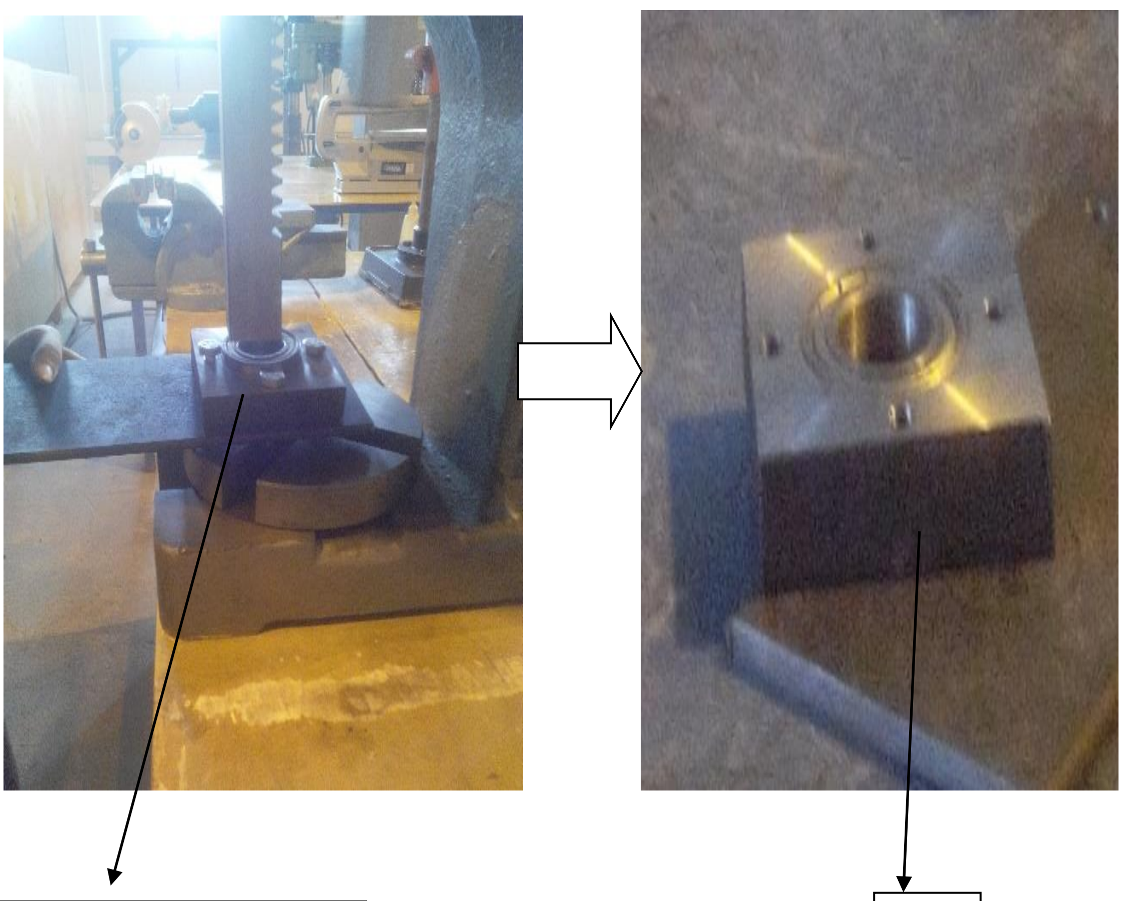


Figure 4.a

The next part of the assembly was welding the pulley to the smaller pipe.

Figure 4.b

This was followed by the attachment of two hubs to the Hub Holder plates to make the U shaped part. This was simply done by putting in the M10 screws in the holes of the hubs and the corresponding holes on the plates.

Figure 4.c

The next step was welding the larger strip to the two hub holder plates to complete the upper part of the assembly.

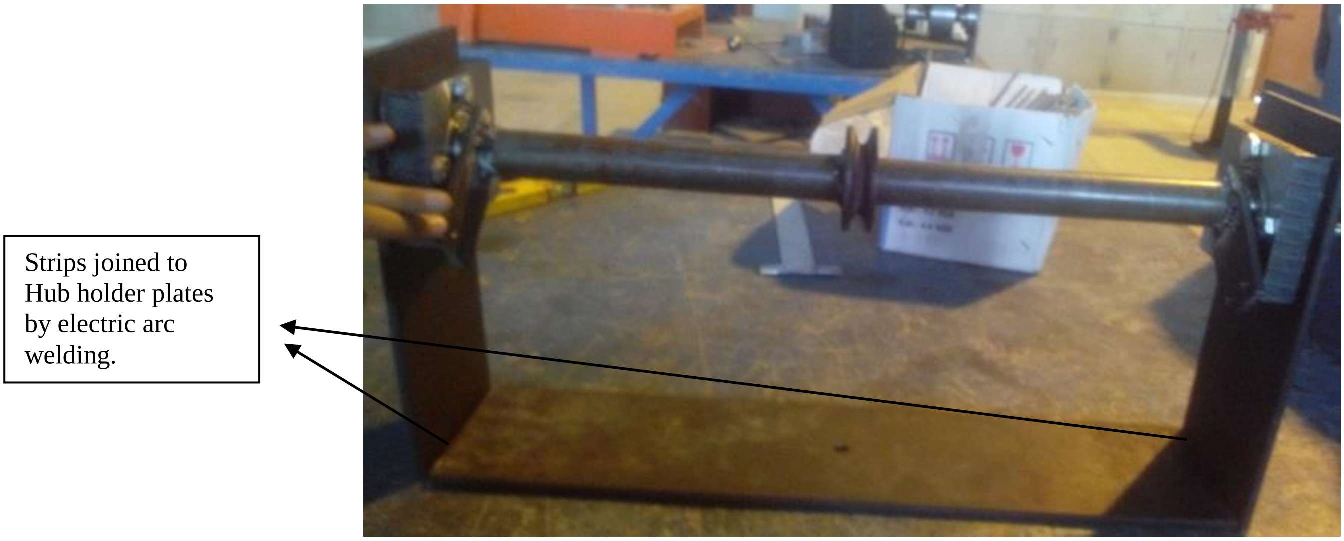


Figure 4.d

The upper part of the assembly is almost complete. The remaining task in to make the motor housing. For this task 2 angle rods were used. The pulley was mounted on the motor shaft by keeping the alignment with the upper pulley. The motor was adjusted using the following process. The angle rods are welded at the base strip of “U” shaped mechanism. Smaller motor is connected with these angle rods with the help of the M4 screws. The motor is then coupled to the pulley over the upper pipe with the help of a belt. The belt used is of type A with the size of 475mm as shown in the figure 4.e.

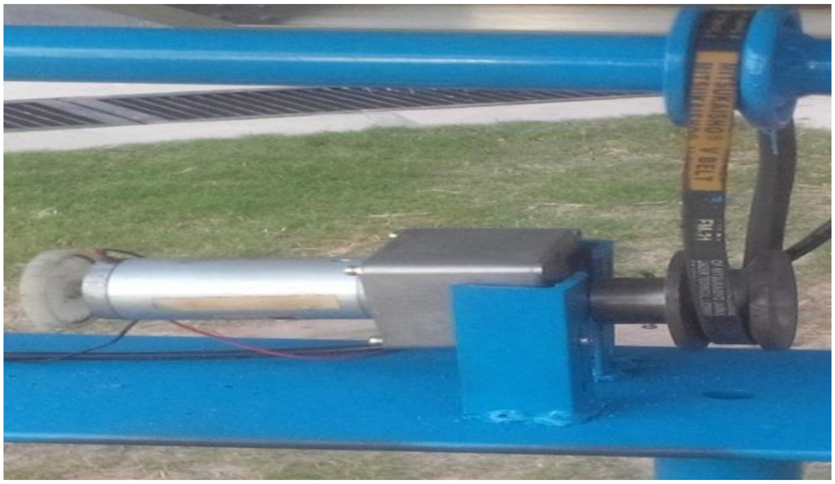


Figure 4.e

The assembly at the upper section was completed at this point. The only thing left was the connection of panel which was done at the last stage of final assembly.

Lower Portion

The bearings were already press-fitted in to the hubs. Now the base hub has to be attached to the base plate. Similarly the fourth hub was attached to the support plate. The attachment was simply using M10 screws.

Figure 5.a

Now this base plate is attached with all the four rods with the help of M8 threads that were made on the rods on lathe machine.

Figure 5.b

After that the support plate with the hub is placed over the rods and tightened with the help of M8 nuts and bolts as shown in the figure 5.c.

Figure 5.c

The pipe is inserted into the assembly through the hole of the supporting plate.

At this stage a hole of size M10 is made into the pulley which will be used to grip pulley with the pipe. This hole has M10 threads made in to it using the tape handle.

Pulley is attached with the pipe as shown in the figure 5.d.

Figure 5.d

B type V-belt of size 600mm is also inserted over the pulley to be coupled to the Motor.

Figure 5.e shows the press fitting of the pipe in the base hub.

Figure 5.e

The other side of the pipe is welded at the center of the base strip of ‘U’ shaped mechanism. The assembly completed up till now looks like

Figure 5.f

The angle rods are welded with the rods.

Last pulley is attached to the shaft of the larger motor with the help of a small screw.

Motor is connected with the angle rods with the help of M4 screws.

Belt is now used to connect the pulley over pipe with the pulley over the shaft of motor.

Figure 5.g

Now two M8 holes are made at the both sides of the PV Panel according to the size and dimensions of holes of smaller strips.

Finally the panel is attached to these strips.

Blue color is sprayed to give the assembly a glorious look.

The final assembly is shown in the following pictures;

Figure 5.h

FINAL ASSEMBLY

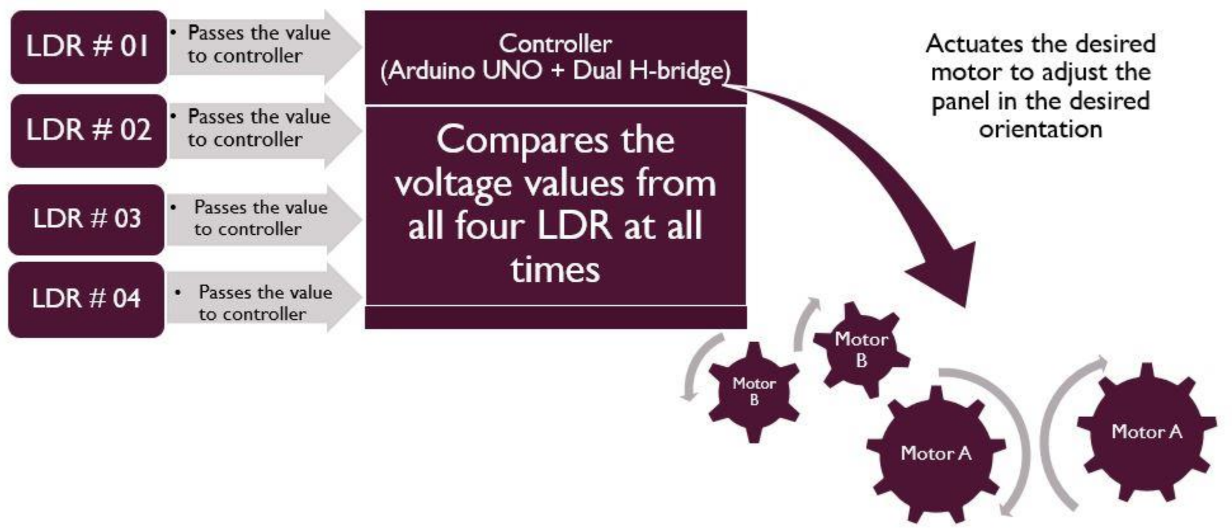
Figure 5.i

3.2.2 Control System

The control system of the tracker was designed simply by the technique of taking real time values and evaluating them to analyze the required motion. Main components used in its design are Arduino UNO, h bridge, sensors and 2 motors.

3.2.2.1 Design of the Circuit

The control circuit has the following sequence of action.



Four LDR sensors have been mounted on 4 corners of the panel. LDR has a characteristic of increasing its resistance in dark. When the light intensity on the LDR increases, resistance decreases. Hence the voltage drop across the sensor decreases. We have another 10kOhm resistor connected in series to each of the LDR. The values being passed to the Arduino UNO controller are voltage across the 10kOhm resistor. Now when a sensor is in dark, the corresponding voltage across the LDR increases and the voltage across the 10kOhm resistor decreases. This voltage value (across the resistor) is being passed on to the controller for simple calculations. Arduino makes comparison of averages of voltages passed to it every 500ms.

The four sensors at the corners have been named as LDR1, LDR2, LDR3 and LDR4. Averages are being calculated for the values of 1 & 2 (one long side) and 3 & 4 (the opposite side), and comparison is made between the two averages. Similarly averages are calculated for 1 & 3 and 2 & 4. Then the enable signal is passed to the desired motor to orient the assembly and the panel in the desired direction [8].

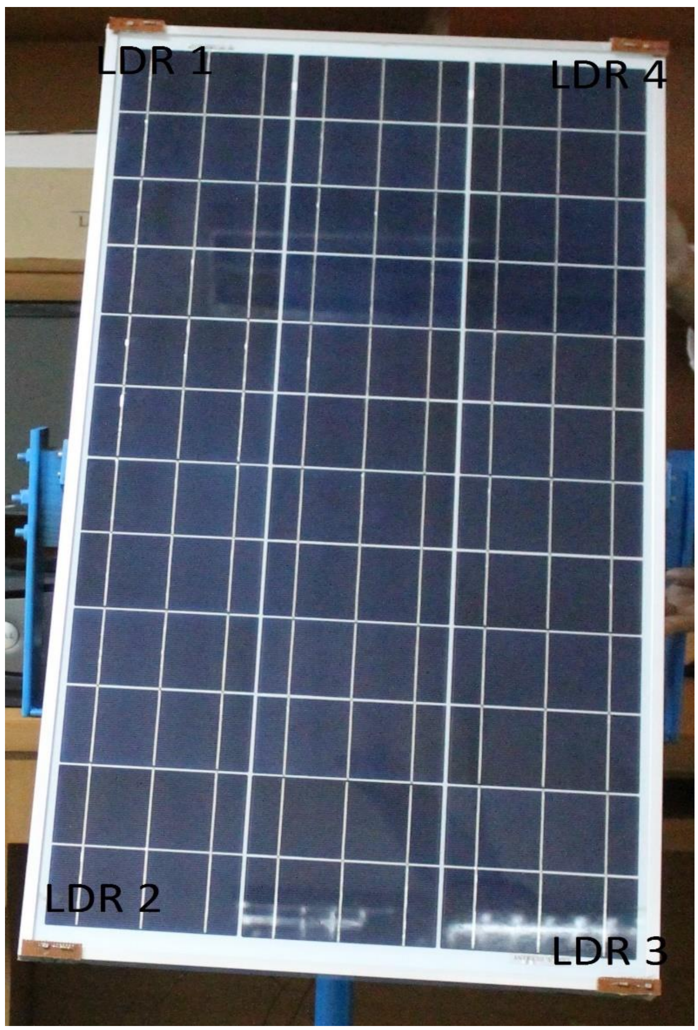


Figure 5.j

3.2.2.2 Initial Testing on Board

Testing was done on breadboard. 4 sets of LDR and 10kOhm resistors were mounted on the breadboard and tested for random values of light put on sensors by torches and spot lights. The basic purpose of this testing was to check the code that whether if the designed circuitry actuates the motors in both directions or not. The tests were successful and motors were getting actuated on both sides.

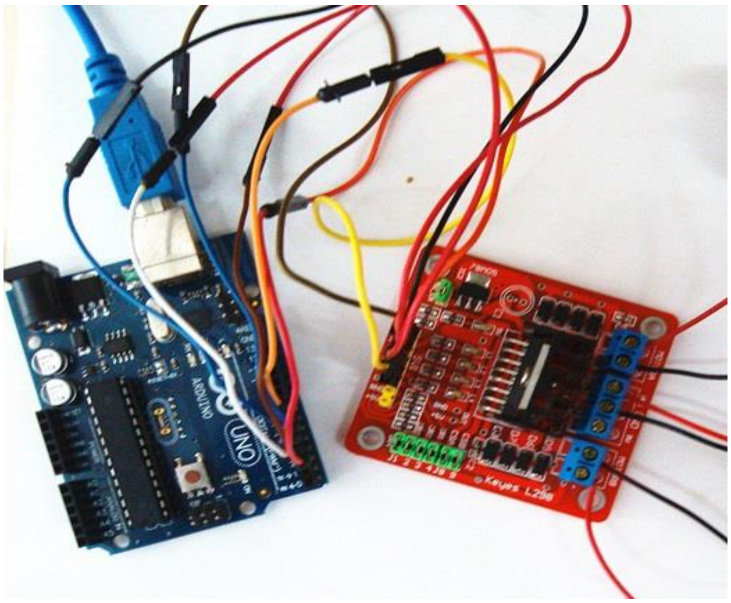


Figure 6.a

3.2.2.3 Attachment on the Actual Model

Now the remaining task was to connect the sensors and the controller circuit to the panel.
This was divided in to 2 major parts.

1. **Sensors mounting** was done by making a small Vero boards carrying an LDR sensor, 1 10kOhm resistor and connections for Vcc and Ground. Four identical boards were made and attached to the four corners using Silicone gel.
2. **Controller and H-Bridge Mounting** was also done by using Silicone Gel. They were mounted beneath the surface of the panel. A wooden plate was at first attached to the panel on the lower side. Then controller and bridge were attached using silicone gel to this wooden plate.
3. Arduino output pins are connected to dual H-bridge (L298N) in following way:
4. 4 output pins are used to give high or low to both motors for direction changing operation
5. 2 output pins are used to enable the respective motors.
6. 24 volt is supplied to the dual H-bridge through batteries.
7. 5V is supplied to Arduino through external supply.
8. Grounds of Arduino and h-bridge **must be common**.

4. Results

We have performed real time tests and the results have been keenly analyzed. Initially the tests were made on the following three sections to make sure that

1. The assembly holds PV panel smoothly without getting misbalanced.
2. If values of light intensity are varied on particular sensors, and as a result motor gets actuated, it does not make jerky movement.
3. Performance on real day test.

The experiment procedure was as follows. The plan we made to do the tests was such that we decided to charge a battery using the PV panel while it was placed stationery (without doing any tracking) and noting the time for it to charge the battery completely. After this we decided to employ tracking in to the panel and then note the same readings to time taken to charge the panel. By comparing these two times and output power, we collected and analyzed different results which are mentioned ahead in this section.

4.1 Constants and Variables

Whenever doing an experiment some constants and variables need to be predefined. In our study and experiment we had following constants.

1. Test times were 5am-2pm and 10am-8pm
2. Location was outside MRC building, SMME
3. Average Temperature was 40 degree Celsius.

4.2 Results of Stationery PV Panel

A lead acid battery of rating 40Amp.Hour (12V) was attached to the PV panel along with a regulator and a kit. We placed the panel on the assembly (without any control circuitry attached) and the panel was allowed to charge the battery. The charging time was noted. We took these tests for 3 days.

	Day 1	Day 2	Day 3	Average Time
Charging time	8 hours 10 minutes	7 hours 53 minutes	7 hours 59 minutes	8 hours 2 minutes

Table 7.a

Energy Rating = 40A.h (12 V)

Time taken to charge = 8.03 Hours

As we know,

Energy = Power x Time,

Hence,

Average Power Output = (Watt. Hours) / (Time Taken to Charge)

12 * 40 / 8.03 = **60W**

4.3 Results after employment of Tracking

The same battery was attached to the panel as it was mounted on the assembly with tracking system and complete control system. Readings of time taken to completely charge the battery were taken for three days as before. The table shows the results.

	Day 1	Day 2	Day 3	Average Time
Charging time	6 hours 2 minutes	6 hours 14 minutes	6 hours 10 minutes	6 hours 9 minutes

Table 7.b

Energy Rating = 40A.h (12 V)

Time taken to charge = 6.15 Hours

As we know,

Energy = Power x Time,

Hence,

Output power (Watts) = (Watt. Hours) / (Time Taken to Charge)

12 * 40 / 6.15 = **78W**

4.4 Efficiency Improvement Analysis

The results from the experiments have returned fruitful conclusions. The charging time of the battery before the tracking was roughly 8 hours and after tracking it has been reduced to 6 hours. Moreover output power increased from 60 to 78W, showing an efficiency improvement of 30%. Calculations below show the stated conclusions.

Initial output from panel (stationery) = 60W

Efficiency original = 60 / 80 = 75%

After tracking output from same panel = 78W

Efficiency after tracking = 78 / 80 = 97.5%

Output power has increased by 30%

Hence,

Efficiency Improvement (w. r. t. Power) = (97.5 – 75) / 75 = 30%

Initially charging time = 8.03hours

After tracking charging time = 6.15hours

Efficiency Improvement (w. r. t. Time) = (8.03 – 6.15) / 6.15 = 30%

If the battery gets charged in let's say, 5hours (just as an example). Then the efficiency improvement of the panel for battery charging will be

Efficiency Improvement = (8.03 – 5) / (5) = 60%

Improvement in Charging Time

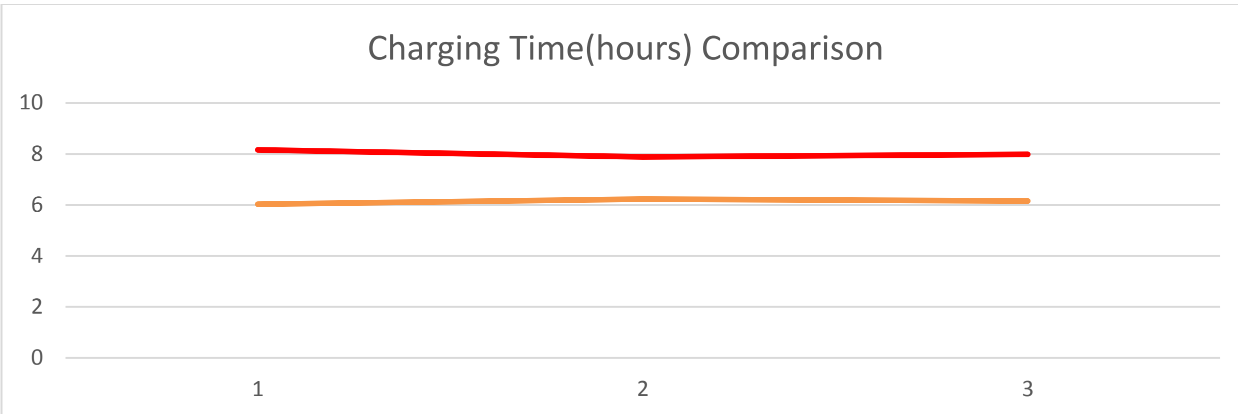


Figure 7.c

Efficiency Improvement with Time

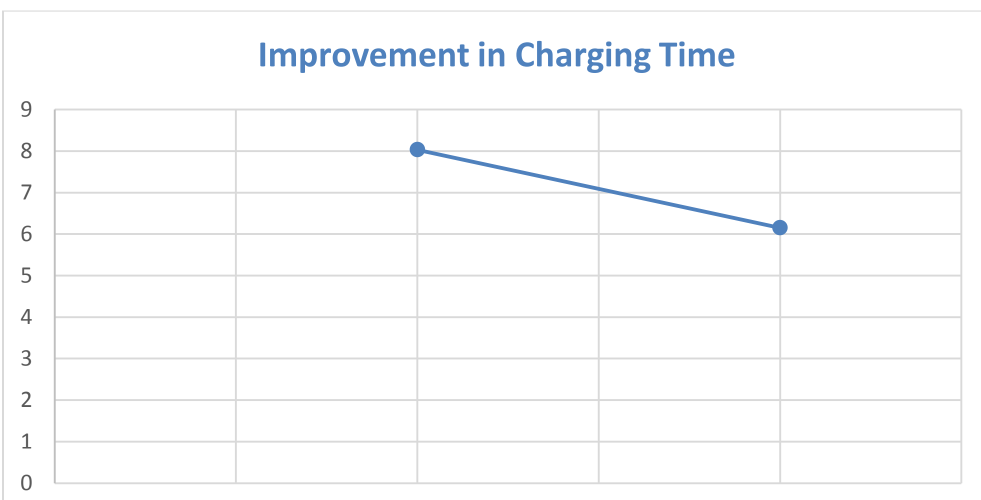


Figure 7.d

Efficiency Improvement in Output Power

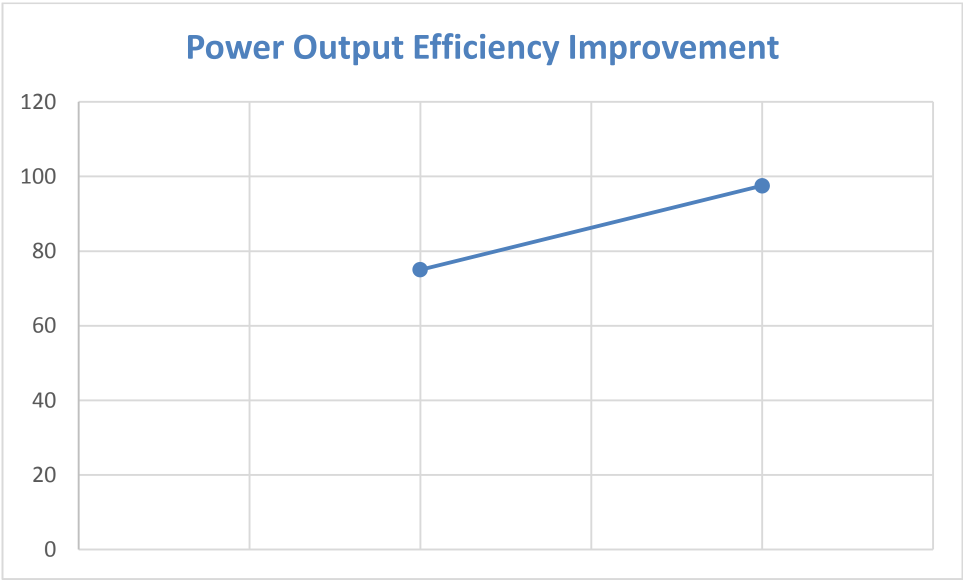


Figure 7.e

5.1 Performance Evaluation:

The performance of tracking system can be easy evaluated in morning and evening time when sun rises and sets as they are most effective on these times. The tracker motion is visible during these periods as compared to the afternoon period when sun is on the top for more time.

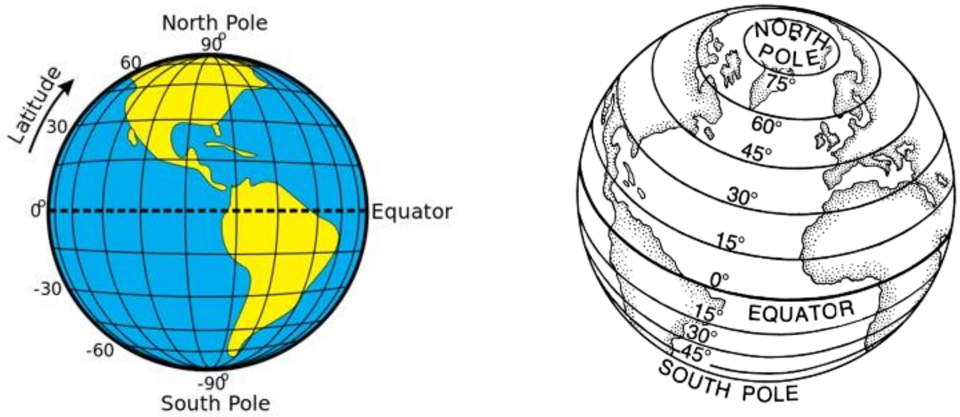


Figure 7.f

Tracking can be more efficient in those countries which are not on or near **equator** and also in those countries whose **latitude** is greater than +/- 10 degrees [7]. In Pakistan areas where we have a very less amount of sun these systems can help to solve the energy problems especially during energy crisis months. Tracking systems improve performance for two main reasons. First, when a solar panel is perpendicular to the sunlight, it receives more light on its surface than if it were angled. Second, direct light is used more efficiently than angled light. Special Anti-reflective coatings can improve solar panel efficiency for direct and angled light, somewhat reducing the benefit of tracking. In this project, an appreciable amount of efficiency gain was achieved. A standalone system with minimal amount of power consumption was manufactured. Only power source in constant use is a 5V battery that drives Arduino UNO. Motors are only consuming using the power from battery for a maximum 1-2 hours a day. Motors actuate only when a movement is desired, usage of energy by Arduino UNO controller = 5V * 0.0465A= 0.23W). This power is being used from batteries that are being charged by the PV panel itself.

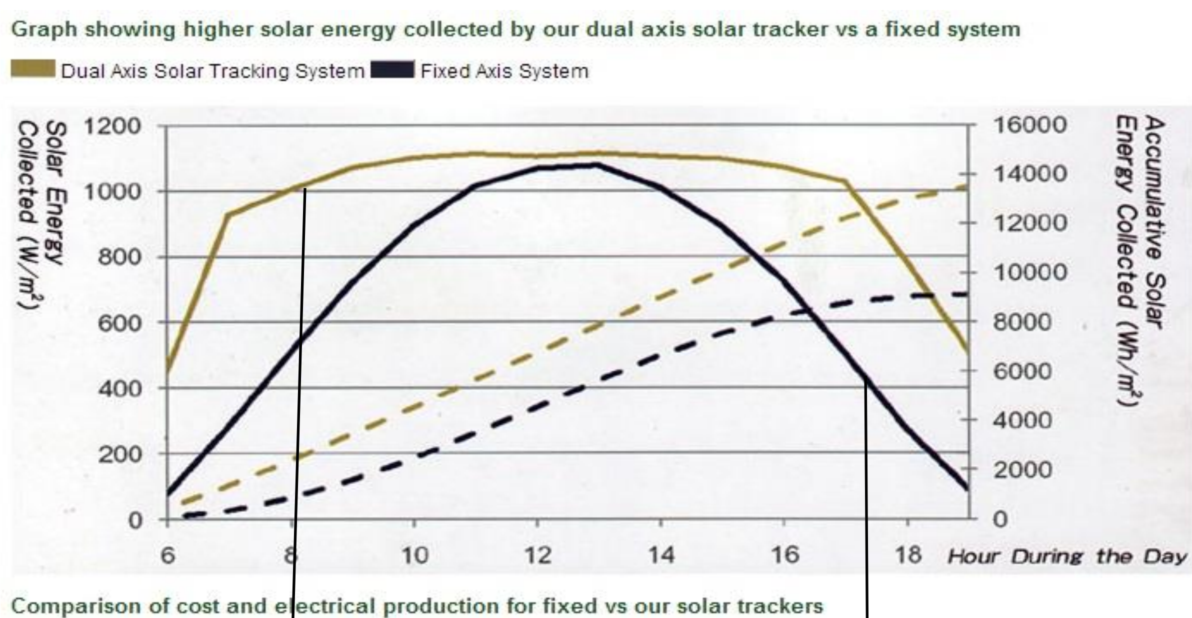


Figure 7.g

Dual axis Tracking Performance

Fixed Axis Performance

5.2 Cost Analysis:

The price of tracker assembly is Rs. 5,000. Moreover the total price of this model is around Rs. 13,400 out of which Rs. 8,000 account for the prices of PV panel and two dry batteries. Photovoltaic panel mounted on the assembly is 80 W, but assembly can support 250-300 W panels. This statement has been said keeping in view the dimensions and weight of 250W PV panel and the strength of the assembly.80 W panel costs Rs.6000 and 250-300 W panel costs Rs.15000-20000. Tracking cannot be justified for 80 W panel in cost aspect. Testing shows that 80 W panel produces 60 W when it is stationary and no tracking is employed but it produces 76-78 W when tracking is employed. Efficiency improvement of 30% is observed. It can be easily justified for 250-300 W panels as the cost of assembly is 1/4th of the panel's price and we can get maximum output of same panel instead of purchasing more panels. This maximum output will be about 244W from a 250W panel which otherwise would have been 188W (without tracking).

Component	Price in Pakistan (Rupee)
PV Panel (80W)	6000
Dry batteries	1500
2 DC Motors	1200
Material	2500
Arduino UNO & H bridge	1800
Wiring	200
Silicone & other helping material	200

Total price = Rs. 13,400/-

Table 8.a

5.3 Applications:

- Those countries where **sun rarely rises** throughout the year.
- In areas where we have a **very less amount** of sun these systems can help to solve the energy problems especially during energy crisis months.
- If applied in Industries where power is produced on a larger scale, this technology can provide very fruitful results that may lead us towards an **energy secure future**.
- Can maintain required power output for small scale systems **on a cloudy day**.
- **Clean energy source** in those countries where environmental concerns are major.
- Those countries where other fuels are too expensive, so it can be used due to **free fuel** advantage (Sun).

5.4 Future recommendations:

- Use of Gear and Chain Assembly instead of Pulley and Belt System.
- Use more Efficient Sensors. (Temperature issue)
- Use more Efficient Cooling System. (Panel overheating)
- Less material with greater strength.
- Angle Restriction

REFERENCES

[1] Page2-3, Solutions for Energy Crisis in Pakistan by Islamabad Policy Research Institute (IPRI) & Hanns Seidel Foundation (HSF)

[2] http://energyinformative.org/solar-panel-tracking-systems

[3] World Fossil Fuels Reserves and projected Depletion by THE COLORADO RIVER COMMISSION OF NEVEDA, March 2002.

[4] Page 3, World Fossil Fuels Reserves and projected Depletion by THE COLORADO RIVER COMMISSION OF NEVEDA, March 2002

[5] www.digipak.org

[6] http://www.instructables.com/id/Arduino-2-axis-servo-solar-tracker/?ALLSTEPS

[7] http://www.rimlifegreentech.com/products/tracker/why.htm

[8] //x-axis motor MOTORB


```
if((ldr14avg - ldr23avg) > xthreshold)
{    digitalWrite(m2in1, HIGH);
digitalWrite(m2in2, LOW);
digitalWrite(en2, HIGH);  }
else if((ldr23avg - ldr14avg) > xthreshold)
{    digitalWrite(m2in1, LOW);
  digitalWrite(m2in2, HIGH);
  digitalWrite(en2, HIGH);}
else  {
  digitalWrite(en2, LOW);}
```

```
  //z-axis motor MOTORA
if((ldr12avg - ldr34avg) > zthreshold)
{    digitalWrite(m1in1, HIGH);
  digitalWrite(m1in2, LOW);
  digitalWrite(en1, HIGH);}
else if((ldr34avg - ldr12avg) > zthreshold)
{    digitalWrite(m1in1, LOW);
  digitalWrite(m1in2, HIGH);
  digitalWrite(en1, HIGH);}
else {    digitalWrite(en1, LOW);}
```

[9] http://www.altenerg.com/back_issues/index.php-content_id=77.htm