SOLAR TRACKER

Abstract:

In this advancing era of technology we are more concerned about the advancements made in technology rather than thinking upon the alternative sources of energy. Energy costs and decreasing supplies of fossil fuels, emphasis on protecting the environment and creating sustainable forms of power have become vital, high priority projects for modern society. The output power produced by high-concentration solar thermal and photovoltaic systems is directly related to the amount of solar energy acquired by the System, and it is, therefore necessary to track the sun's position with a high degree of accuracy. There are three major approaches for maximizing power extraction from a solar array. They are sun tracking, Maximum Power Point Tracking (MPPT) or a combination of both.The purpose of this paper is to present a dual-axis sun tracker using Light Dependent Resistors (LDR) as sensors. The LDR's incorporated on solar panel helps to detect sunlight which in turn moves the panel accordingly such that maximum solar irradiation is absorbed by the panel. To enhance the overall performance of the system, a PID controller was included in the feedback loop.

Introduction

India's energy consumption set to grow at a CAGR (Compound annual growth rate) of 4.2% till 2035 – faster than all major economies of the world. As Asia's second-biggest and the world's third-largest energy consumer, its share in global energy demand is expected to rise to 9% by 2035. The country boasts of having the world's fifth-largest capacity for power generation, with no signs of production slowing down. It also has one of the most diversified power sectors in the world, with both conventional and non-conventional sources being used to meet its energy needs. The total installed power capacity in India, as of March 2017 stands at 326.85 GW.[2]

Solar energy is rapidly advancing as an important means of renewable energy resource. Many of the solar panels throughout the world are positioned with the fixed angles. Solar tracking enables more solar energy to be generated because the solar panel is able to maintain a perpendicular profile to the sun's rays. Solar trackers move the solar panel to follow the sun trajectories and keep the orientation of the solar collector at an optimal tilt angle. Renewable energy sources play an important role in electric power generation. There are various renewable sources which used for electric power generation, such as solar energy, wind energy, geothermal etc.

Solar Energy is a good choice for electric power generation, since the solar energy is directly converted into electrical energy by solar photovoltaic modules. These modules are made up of silicon cells. Many such cells are connected in series to get a solar PV module. The current rating of the modules increases when the area of the individual cells is increased, and vice versa. When many such PV modules are connected in series and parallel combinations, we get solar PV arrays, that suitable for obtaining higher power output.

There are two main types of solar energy technologies—photovoltaic (PV) and concentrating solar power (CSP). We are most likely to be familiar with PV, which is utilized in panels. When the sun shines onto a solar panel, photons from the sunlight are absorbed by the cells in the panel, which creates an electric field across the layers and causes electricity to flow. The second technology is concentrating solar power, or

CSP. It is used primarily in very large power plants and is not appropriate for residential use.Sun tracking is a technique to constantly track the sun’s direction throughout the day so as to increase the efficiency of the system. The use of solar trackers can increase electricity production by around a third, and some claim by as much as 40% in some regions, compared with modules at a fixed angle. In any solar application, the conversion efficiency is improved when the modules are continually adjusted to the optimum angle as the sun traverses the sky. As improved efficiency means improved yield, use of trackers can make quite a difference to the income from a large plant.The sun’s position in the sky varies both with the seasons (elevation) and time of day as the sun moves across the sky. Hence there are also two types of solar tracker:

- Single Axis Solar Tracker
- Dual Axis Solar Tracker

In India: Single-axis trackers about a CUF (Capacity Utilization Factor) of 21%. In comparison with solar plants without trackers, this means an increase in performance of around 20-25%.
Dual-axis trackers does not make sense in the Southern states due to their proximity to the equator. But, in northern parts of India like Punjab, Rajasthan etc, which are located at a higher latitude, these could be beneficial. They can produce an increase in performance of up to 35%
. It has been estimated that the use of a tracking system, over a fixed system, can increase the power output by 30% — 60%. The increase is significant enough to make tracking a viable preposition despite of the enhancement in system cost. It is possible to align the tracking heliostat normal to sun using electronic control by a microcontroller.

Need for Solar Tracker

The sun travels through 360 degrees east-west a day, but from the perspective of any fixed location the visible portion is 180 degrees during a ½ day period. Local horizon effects reduce this somewhat, making the effective motion about 150 degrees. A solar panel in fixed orientation between the dawn and sunset extremes will see a motion of 75 degrees on either side and thus, according to the table below, will lose 75% of the energy in the morning and evening. Rotating the panels to the east and west can help recapture these losses. A tracker rotating in the east-west direction is known as a single-axis tracker.

The sun also moves through 46 degrees north-south over the period of a year. The same set of panels set at the midpoint between the two local extremes will thus see the sun move 23 degrees on either side, causing losses of 8.3%. A tracker that accounts for both the daily and seasonal motions is known as a dual axis tracker.
The energy contributed by the direct beam drops off with the cosine of the angle between the incoming light and the panel.

Misalignment (angle i)	Direct power lost (%) = 1-cos(i)
0	0
1	.015
3	.14
8	1
23.4	8.3
30	13.4
45	30
60	>50
75	>75

[1]

System Block Diagram(Prototype and Simulation)

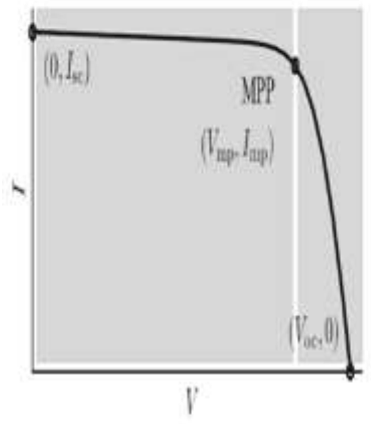
Block diagram consists of a Microcontroller, LDR's, Solar Panel, Stepper motor.

Prototype: We have employed the use of Arduino uno ,LDR sensors,Serco motors(MG995) for designing a light tracker.The dynamic control algorithm on sensors and developed a the threshold value with which error is being calculated is not fixed.

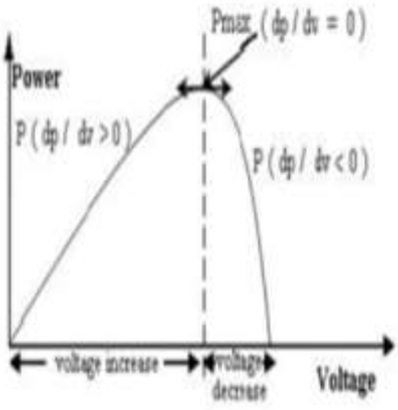
Pid control for limiting the error in the sensor reading

The basic ideas of PID control is to choose the methods for choosing the parameters of the controllers, to reduce the error.

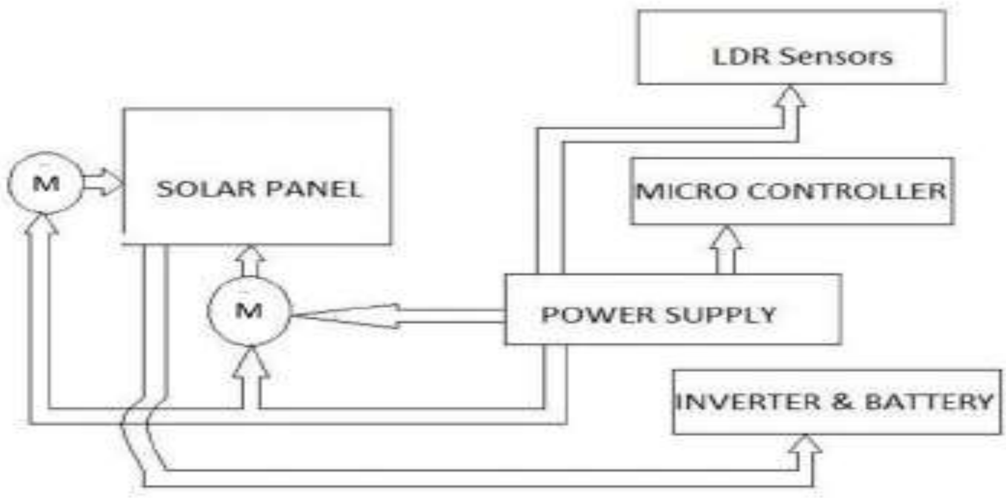
- The Controller the ideal version of the PID controller is given by the formula
  - u(t) = kpe(t) + ki Z t 0 e(τ) dτ + kd de dt
  - where u is the control signal and e is the control error (e = r − y). The reference value, r, is also called the setpoint. The control signal is thus a sum of three terms:
  - A proportional term that is proportional to the error
  - An integral term that is proportional to the integral of the error and,
  - A derivative term that is proportional to the derivative of the error.
  - The controller parameters are proportional gain kp, integral gain ki.



I-V curve of a solar panel



P-V characteristic curve



Block Diagram of Rotating Solar Panel(Prototype)

Hardware Design

The important components to develop the rotating solar tracking system using microcontroller are explained as:

A. Microcontroller(ATmega328 -Arduino Uno) Operating Voltage: 5V. Input Voltage (recommended): 7-12V. Input Voltage (limits): 6-20V. Digital I/O Pins: 14 (of which provide PWM output) Analog Input Pins: 6. DC Current per I/O Pin: 40 mA. DC

Current for 3.3V Pin: 50 mA.

B. Servo motor (MG 995)

Servo motors are commonly used in precision positioning control applications. It has many features due to which it is selected for the system such as it is brushless, load independent, has open loop positioning capability, good holding torque and excellent response characteristics.

C. Light Dependent Resistor

It is a variable resistor whose value decreases with increasing incident light intensity. An LDR is made of a high-resistance semiconductor, often cadmium-sulfide. If light falling on the device is of high enough frequency, photons absorbed by the semiconductor give bounded electrons enough energy to jump into the conduction band. The resulting free electron (and its hole partner) conduct electricity, thereby lowering resistance.

For sensing the sunlight we mount the photosensor on the top of the solar seeker/panel. Photosensor senses the light and provides a signal to the microcontroller. If the light is sufficient then Ldr provides a signal to the microcontroller and microcontroller signals to stop the motor at this position.

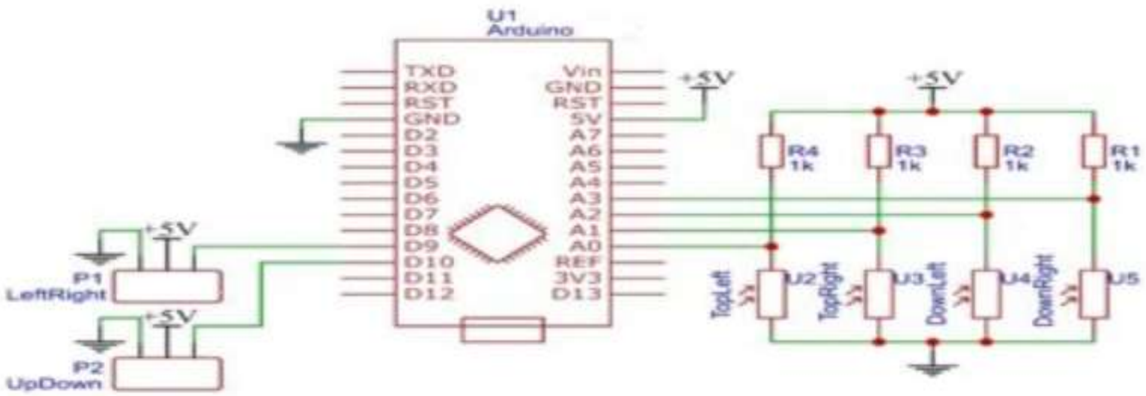


Fig. 2. LDR used in Circuit

We have installed four LDRs in the circuit which are responsible for detecting the intensity of sunlight in the four corners of the solar panel.

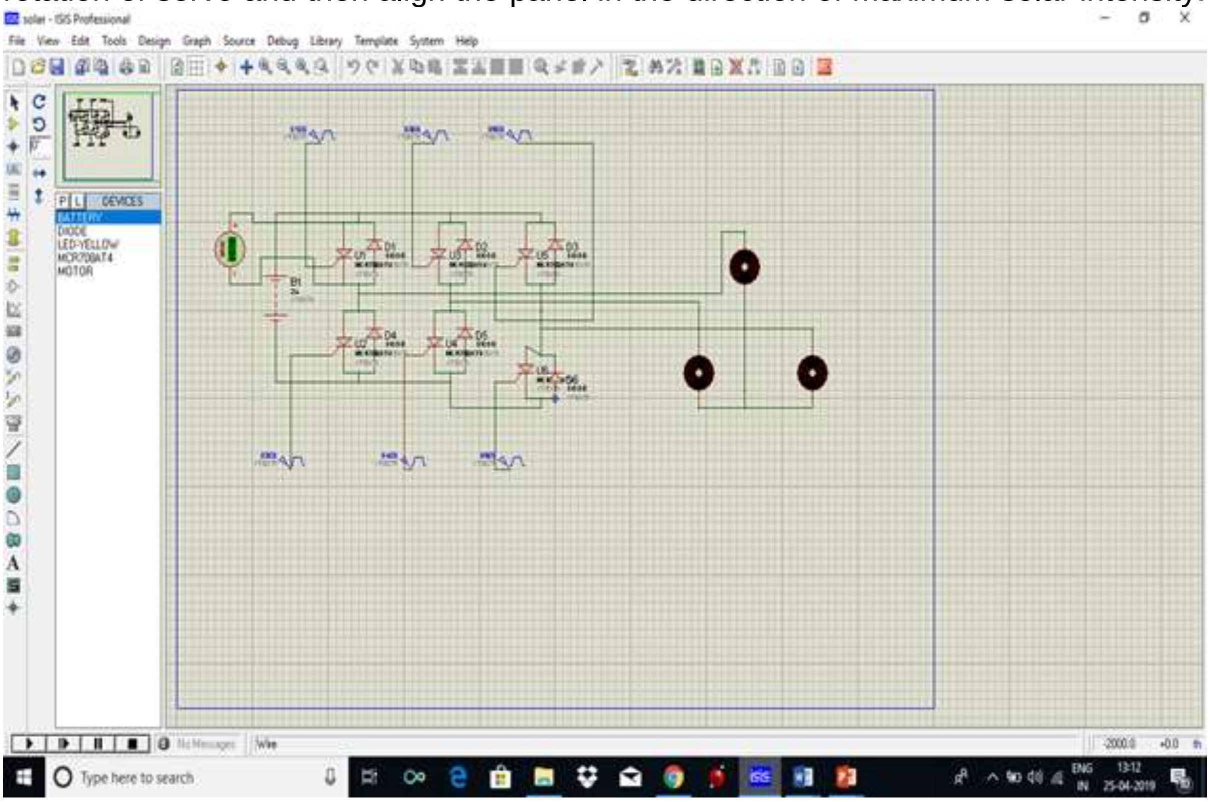
D. Solar Panel

Photovoltaic solar panels absorb sunlight as a source of energy to generate electricity. A photovoltaic (PV) module is a packaged, connected assembly of typically 6x10 photovoltaic solar cells. Photovoltaic modules use light energy (photons) from the Sun to generate electricity through the photovoltaic effect.

E. Software Design:

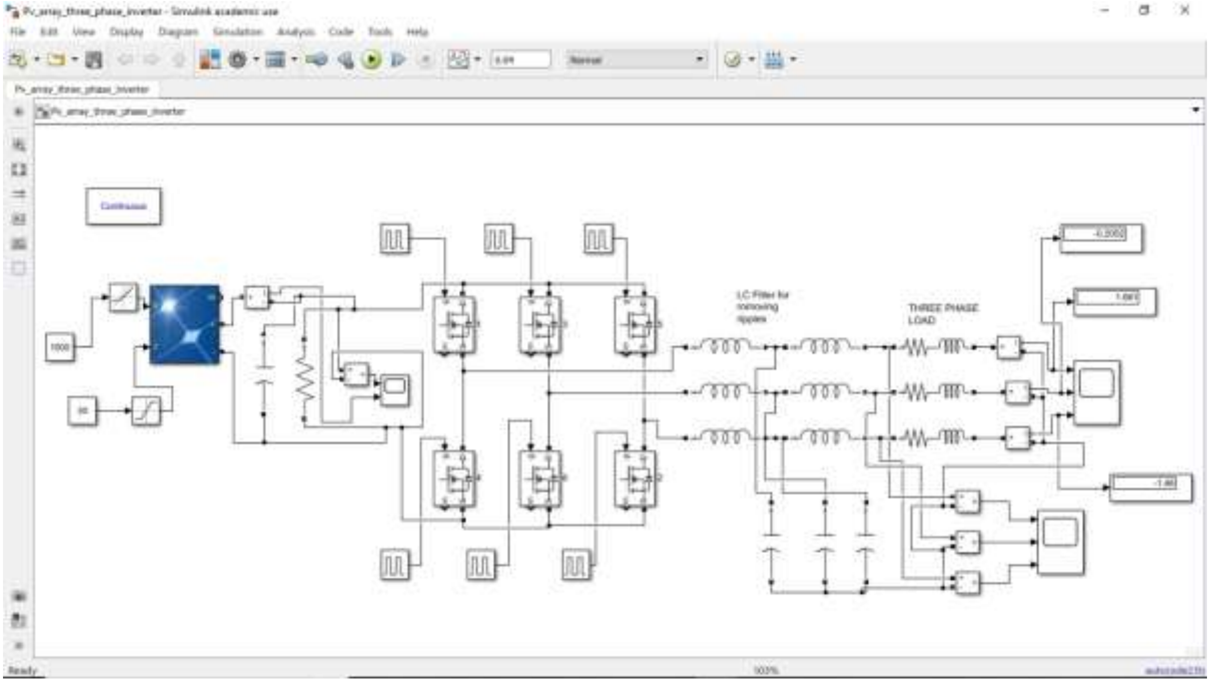
As we have discussed earlier that microcontroller(here Arduino) is the heart of our solar tracking device so we have to program it for the functioning of the tracker such that the readings from four LDRs decide the rotation of servomotor.The analog input pins of the arduino takes the feed from the LDRs and then process that through PID control to decide the suitable threshold suiting the immediate environment of the tracker.

It is this threshold that is matched against the real time readings in order to decide the rotation of servo and then align the panel in the direction of maximum solar intensity.

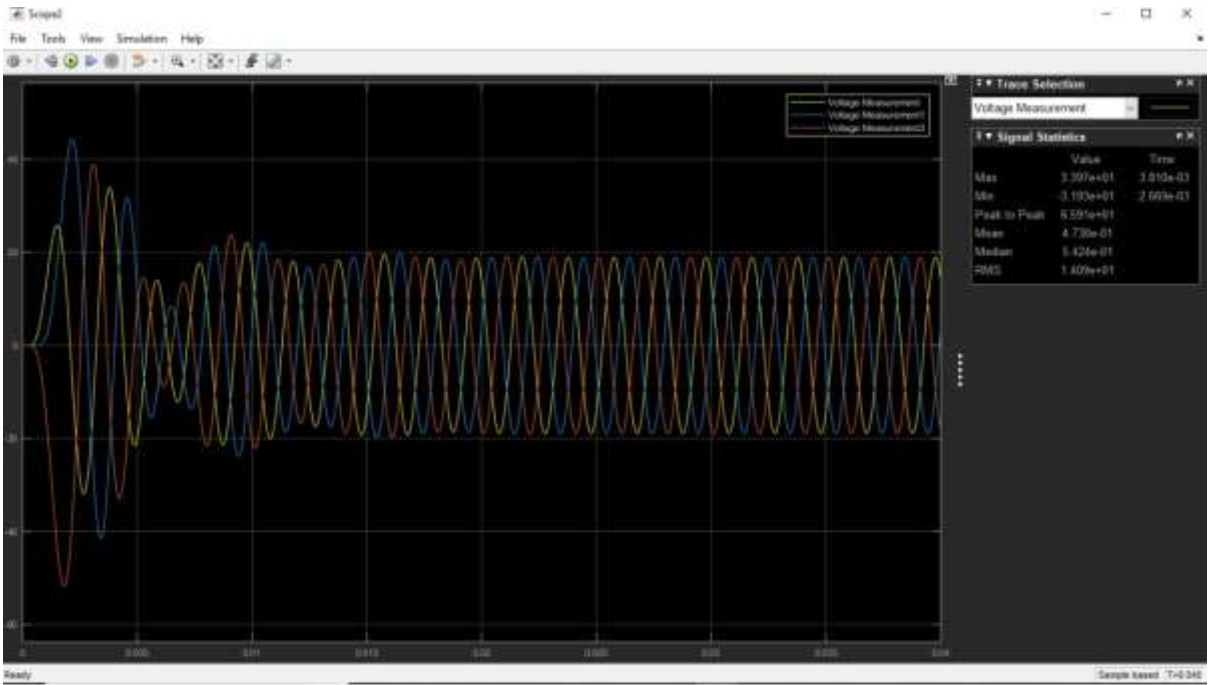


PROTEUS Simulation of the tracker (control through servos)

A further extension of the project includes processing the output by a three phase inverter that uses the DC output of the PV panel to convert it into a three phase ac supply. The practical application of this approach is to rule out the need to amplify the DC output from the Pv array, which includes an extra boost-converter circuit, so as to match the household requirement.The output generated through three phase inverter is high enough to match the receiving end needs despite of undergoing some attenuation.



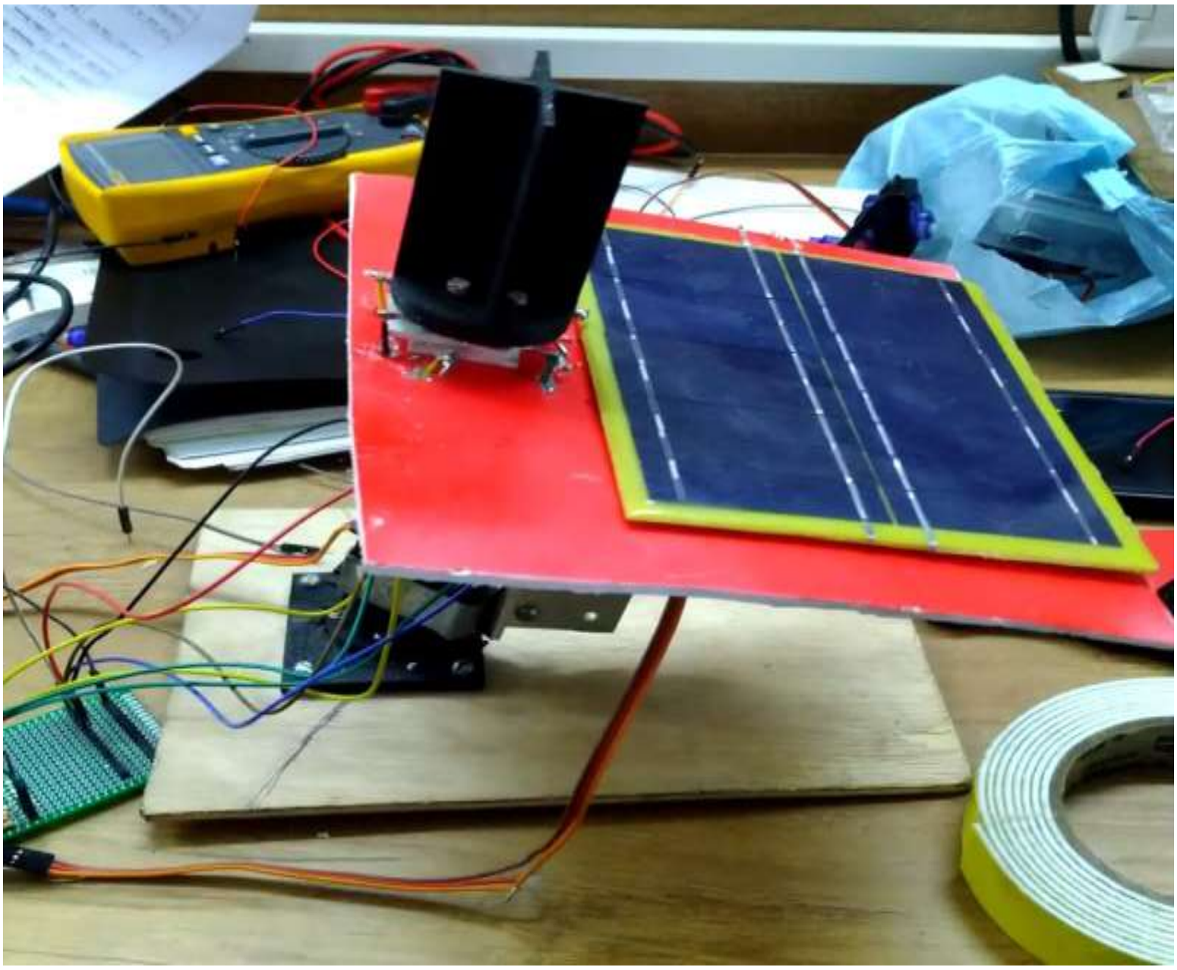
Simulation of Three Phase Inverter in MATLAB



Waveform at Receiving end three Phase Supply

Final Assembly:

The final assembly of solar tracking system using Microcontroller is shown in the figure as under.



Formula Used

The difference between an ideal PV cell and practical PV devices are the presence of resistances (both series and parallel). Solar cell equivalent circuit [6], where is the current through the circuit, Vs the voltage in the circuit, R_0 is the series resistance in the PV circuit, is the parallel resistance in the PV circuit,is the reverse saturation current of the diode. The Figure 1 shows an ideal solar PV cell equivalent circuit which mathematically describes the I-V characteristics of the PV circuit given by,

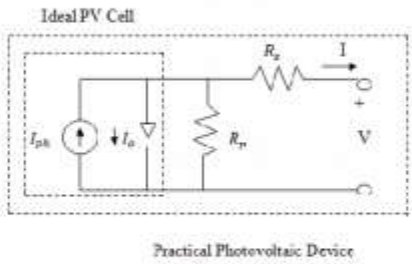


Figure 1 Circuit of a Practical PV Solar Cell [6].

$$I \quad I_{ph} \quad I_o\left[\exp\left(\frac{V+R_sI}{V_b\,a}\right) - 1\right] \quad \frac{V+R_sI}{R_p}$$

The other equation are given by:

$$I \quad I_{ph} \quad I_o\left[\exp\left(\frac{qV_b}{akT}\right) - 1\right]$$

where I_{ph}-the current solar cell generates at optimum conditions.

Iph,nom is the - current generated in solar cell circuit at nominal conditions at

$$I_{ph} \quad I_{ph,nom} + K_{cur}\Delta_{Tem} + \left(\frac{G}{G_{nom}}\right) \qquad I_{o,nom} \quad \frac{I_{sc}}{exp\left(\frac{V_{oc}}{a\,V_b}\right) \quad 1}$$

Io,nom is the Diode Saturation current nominal conditions and ے is the bandgap energy of the semiconductor .

Δ_{Tem} - T-T_{nom} T is actual temperature and T_{nom} is the nominal temperature,

G is the actual irradiation and G_{nom} is the nominal irradiation (usually $1000\frac{W}{m^2}$).

The diode saturation current I_o and its dependence on temperature can be given by,

$$I_o \quad I_{o,nom}+exp\left(\frac{T_{nom}}{T}\right)^3 exp\left[\frac{qEg}{ak}\left(\frac{1}{T} \quad \frac{1}{T_{nom}}\right)\right]$$

Experimental Results:-

As we have discussed above sunlight has two components, the “direct beam” that carries about 90% of the solar energy, and the “diffuse sunlight” that carries the remainder — the diffuse portion is the blue sky on a clear day and increases proportionately on cloudy days. As the majority of the energy is in the direct beam, maximizing collection requires the sun to be visible to the panels as long as possible.

Through the above research, we can conclude that the fuzzy logic controller increases the efficiency of the overall system by 33.416%. Stepper motor used for the direction control gives a precise position control and MPP is tracked efficiently throughout the day with the change in sun/ panel position.
Fuzzy logic demonstrates efficient control, faster response and good conversion of human/ operator knowledge. It has also shown a better result over the conventional methods. Arduino Uno turned out to be an easy platform implement the control strategy.

Table IV shows the comparison between the output values at fixed and variable angles:

Table IV: Output power at fixed and variable angles

Time of the day	*PV panel output values at fixed angle*			*PV panel output values at variable angles*		
	V(V)	*I (A)*	*P(W)*	*V(V)*	*I(A)*	*P(W)*
7:00 am	6.47	0.016	0.1039	9.93	0.058	0.585
8:00 am	8.76	0.067	0.5931	12.16	0.141	1.724
9:00 am	10.33	0.160	1.658	12.92	0.256	3.319
10:00 am	12.75	0.192	2.456	13.14	0.234	3.077
11:00 am	12.37	0.258	3.201	12.61	0.267	3.377
11:30 am	12.35	0.262	3.24	12.55	0.267	3.359
12:00 pm	12.78	0.258	3.304	12.81	0.262	3.36
1:00 pm	12.82	0.243	3.124	12.82	0.244	3.134
2:00 pm	12.81	0.239	3.062	12.39	0.261	3.236
3:00 pm	12.88	0.233	3.01	13.14	0.240	3.165
4:00 pm	12.75	0.141	1.808	12.88	0.169	2.188
5:00 pm	12.68	0.101	1.289	13.2	0.149	1.979
6:00 pm	12.29	0.085	1.052	12.97	0.139	1.805
7:00 pm	9.61	0.034	0.334	13.01	0.053	0.696
Total	161.65	2.289	28.235	176.53	2.74	35.004

Efficiency of the system is calculated as:

$$\textbf{\textit{Efficiency}}=\left[\frac{(35.004+28.235)*100}{28.235}\right]=23.973\ \%$$

Table V shows the comparison between the output values with/without the tracker:

Table V: Output power with/without tracker

Time of the day	*PV panel output values without tracker*			*PV panel output values with tracker*		
	V(V)	*I (A)*	*P(W)*	*V(V)*	*I(A)*	*P(W)*
7:00 am	6.47	0.016	0.103	8.10	0.103	0.84
8:00 am	8.76	0.067	0.593	11.44	0.169	1.942
9:00 am	10.33	0.160	1.658	11.638	0.285	3.324
10:00 am	12.75	0.192	2.456	12.03	0.274	3.307
11:00 am	12.39	0.258	3.201	11.83	0.288	3.412
11:30 am	12.37	0.262	3.240	11.85	0.2885	3.419
12:00 pm	12.75	0.258	3.29	11.88	0.2881	3.423
1:00 pm	12.80	0.244	3.124	11.83	0.283	3.36
2:00 pm	12.79	0.239	3.062	11.70	0.2885	3.377
3:00 pm	12.88	0.233	3.010	11.76	0.283	3.342
4:00 pm	12.75	0.141	1.808	11.96	0.20	2.397
5:00 pm	12.68	0.101	1.289	12.09	0.177	2.152
6:00 pm	12.29	0.085	1.052	12.09	0.173	2.104
7:00 pm	9.61	0.034	0.334	11.76	0.106	1.259
Total	161.62	2.29	28.22	161.95	3.206	37.65

Efficiency of the overall system with the tracker can be calculated as:

$$\textbf{\textit{Efficiency}}=\left[\frac{(37.65+28.22)*100}{28.22}\right]=33.416\ \%$$

- Fig. 22 shows the graph for Voltage through the solar panel

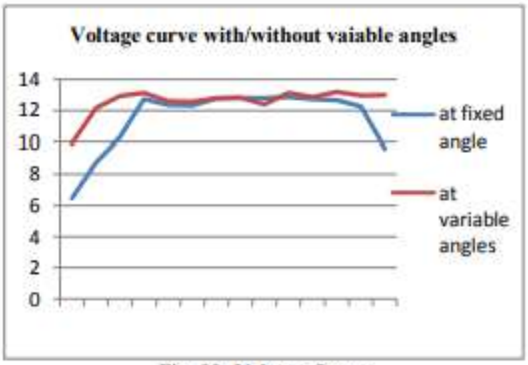


Fig. 22: Voltage Curve

- Fig. 23 shows the graph for current through the solar panel

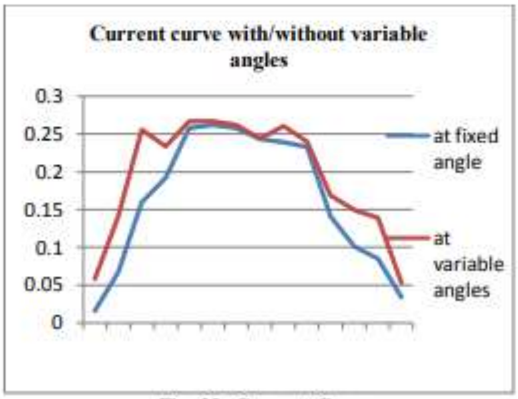


Fig. 23: Current Curve

- Fig. 24 shows the graph for power through the solar panel

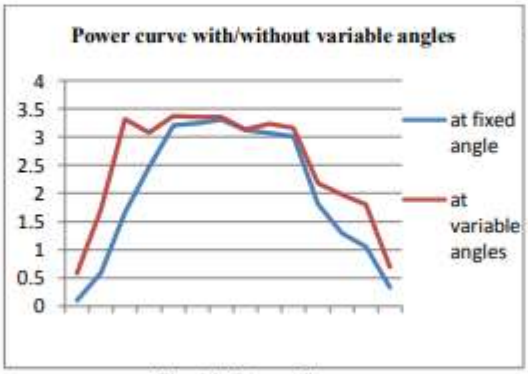


Fig. 24: Power Curve

- Fig. 26 shows the graph for Current through the solar panel with/ without the tracker:

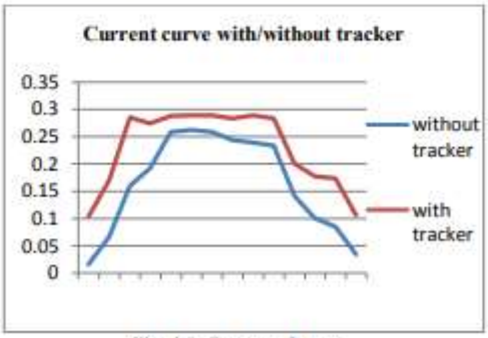


Fig. 26: Current Curve

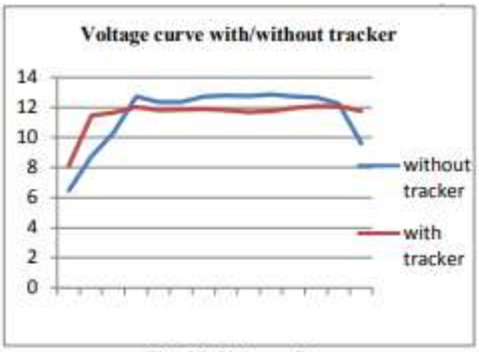


Fig. 25: Voltage Curve

- Fig. 27 shows the graph for Power through the solar panel with/ without the tracker:

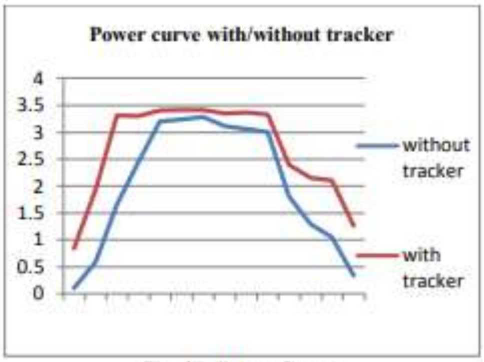


Fig. 27: Power Curve

It has been observed that the efficiency of the system increases by 33.416% when implemented with the tracking mechanism.

CONCLUSION:

In this paper we have described a more improved way to maximize the power consumption by solar panel from sun by just rotating the solar panel according to sun's position. Since we are tracking the sun in dual axis we are increasing photovoltaic irradiance as well as which result in concentrating more solar power. Dual axis tracker perfectly aligns with the sun direction and tracks the sun movement in a more efficient way and has a tremendous performance improvement.

In this paper, the combination of hardware and simulation results has been described. The details designs and explanations of sensor circuit and DC motor driver circuit are included. Using DC servo motors for sensing method can cause to rotate solar panel with more precise angle. Using the light dependent resistor (LDR) sensor can be better sensitive of light intensity for various voltage levels. The experimental results clearly show that dual tracking is superior to fixed module system. Solar trackers are beneficial and it is dependent on v factors including weather, location, obstruction and cost. This is a more cost effective solution than purchasing additional solar panels when dealing with large panel arrays. Moreover, another benefit is the space saved rather than adding extra pan equipments in this solar tracking system are very cheap, so this system provides that the total cost for tracking is low.

By comparing the results above we have discovered that direct beam of sun helps in generating more energy than it is produced when the solar panel is kept fixed.

Exploratory Project:

Department of Electrical Engineering

Name of Project:- **Solar Tracker**

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