A Novel Low Cost Automatic Solar Tracking System

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ABSTRACT
This paper presents the hardware design and implementation of a system that ensures a perpendicular profile of the solar panel with the sun in order to extract maximum energy falling on it. Renewable energy is rapidly gaining importance as an energy resource as fossil fuel prices fluctuate. The unique feature of the proposed system is that instead of taking the earth as its reference, it takes the sun as a guiding source. Its active sensors constantly monitor the sunlight and rotate the panel towards the direction where the intensity of sunlight is maximum. The light dependent resistor's do the job of sensing the change in the position of the sun which is dealt by the respective change in the solar panel's position by switching on and off the geared motor. The control circuit does the job of fetching the input from the sensor and gives command to the motor to run in order to tackle the change in the position of the sun. With the implementation of the proposed system the additional energy generated is around 25% to 30% with very less consumption by the system itself. In this paper, an improvement in the hardware design of the existing solar energy collector system has been implemented in order to provide higher efficiency at lower cost.

Keywords
Photovoltaic (PV), Light Dependent Resistor (LDR), Automatic Solar Tracking System (ASTS).

1. INTRODUCTION
In recent years, the need for energy will increase many fold, while the reserves of conventional energy will get depleted at a rapid pace. To meet this growing demand for energy, harnessing of non-conventional / renewable energy becomes a necessity. Solar energy is the most abundant and uniformly distributed from among all the available non-conventional sources. Even though technology for trapping solar energy is already in existence, the process can be further improved to increase its efficiency [9], thereby making it more Cost effective. Solar energy is freely available, needs no fuel and produces no waste or causes any pollution. Moreover solar power is renewable. The sun will keep on shining anyway, so it makes sense to utilize it.

2. SOLAR TRACKING SYSTEM
Using geared motor which is controlled by an electronic In the existing system maximum energy from the sun is receives only from morning 11 am to afternoon 2 pm, because solar panel is always kept tilted 30°north and charges a small alkaline (12 volts) battery [3]. A new method has been introduced, where sun light is tracked from morning 6 am to 6 pm by moving the solar panel along with the movement of the sun using geared motor which is controlled by an electronic control circuit. On implementation of the proposed system, at least 30% extra energy will be trapped compared to the existing system [2].The solar cells forms the fundamental solar-energy conversion component. Conventional solar panel, tilted and rigidly fixed at a certain angle, limits their area of exposure to the sun during the entire course of the day. Therefore, the average solar energy is not maximized. Solar tracking systems are essential for solar energy based power generation systems [6].

The change in sun's position is monitored and the position of the panel is maintained always at normal to the direction of the sun. By doing so, maximum irradiation from the sun takes place. The elevation angle of the sun remains almost invariant during a month and varies little (latitude ± 10°) in a year [5]. The proposed system uses a single axis position control scheme which is sufficient for the collection of solar energy.

3 .AUTOMATIC SOLAR TRACKING SYSTEM
The proposed system automatically provides best alignment of solar panel with the sun, to get maximum output (electricity). The proposed automatic solar tracking system (ASTS) is shown in figure.1.

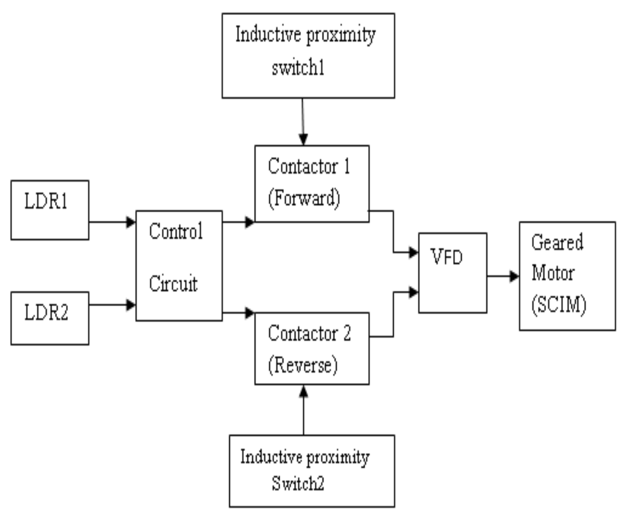

Fig.1 Automatic solar tracking system

The Light Dependent Resistor (LDR) 1 senses the change in the sun's position and gives signal to the control circuit in order to tackle the change in the position of the solar panel. The control circuit gives signal to run the motor in forward direction. LDR 2 detects the sun set and gives signal to the control circuit to run the motor in reverse direction until the proxy switch gets activated.

This paper shows the hardware implementation and its experimental results that validate the proper operation of the proposed system.

4. SOLAR PANEL AND STAND ASSEMBLY

In this section, the solar panel and its stand assembly are described in detail.

4.1 Solar Panel

A photovoltaic module or photovoltaic panel is a packaged interconnected assembly of photovoltaic cells, also known as solar cells. A typical silicon PV cell is composed of a thin wafer consisting of an ultra-thin layer of phosphorus-doped (N-type) silicon on top of a thicker layer of boron-doped (P type) silicon [7] Regardless of size, a typical silicon PV cell produces about 0.5 – 0.6 volt DC under open-circuit and no-load conditions. The current (and power) output of a PV cell depends on its efficiency and size (surface area), and is Proportional to the intensity of sunlight striking the surface of the cell. The photovoltaic module, known more commonly as the solar panel, uses light energy (photons) from the sun to generate electricity through the photovoltaic effect. The majority of modules use wafer-based crystalline silicon cells or a thin-film cell based on cadmium telluride or silicon [4].

The mechanical characteristic of the solar panel is illustrated in table I.

Table1- Mechanical Characteristics

S.No	Parameters	Measurements with units
1	Dimensions (L x W x T)	45.86 x 38.98 x 1.81" / 1165 x 990 x 46mm

Crystalline silicon, which is commonly used in the wafer form in photovoltaic (PV) modules, is derived from silicon, a commonly used semi-conductor. The solar panel used in the proposed system is of $70W_P$ rating.

4.2. Stand Assembly

The frame for the solar panel is made up of L shaped steel rod of 1'5" depth. The length is 1.22m and width is 0.54m. A square plate of dimensions 10x10 cm is made out of steel plate is fixed to the main structure at the height of 120cm from the base. A detailed blue print of the stand assembly has shown in figure.2. The main frame is also made up of L shaped steel rod.

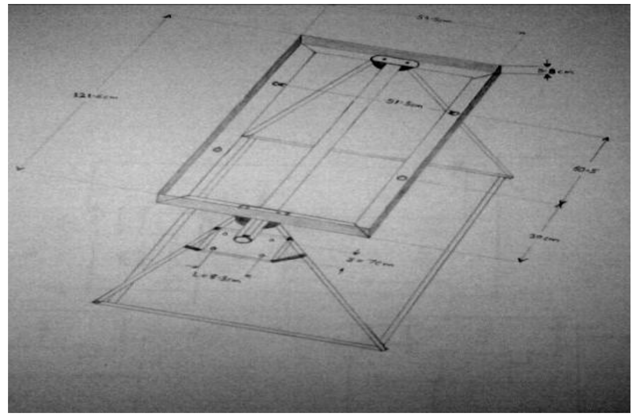

Fig .2. Blue print of the Stand Assembly

Fig .3. Stand Assembly

Figure.3.shows the stand assembly that was fabricated for the proposed system.

5 .ROTATING MECHANISM

The solar panel will be fixed in a frame which is attached to the rotatable shaft. The shaft is connected with the gearbox that is coupled with the induction motor. When the motor is ON the shaft rotates and that makes the solar panel to rotate. The panel frame is fixed with the shaft which is fixed on the either sides of the stand using ball bearings in order to make the rotation smooth and free. The shaft is attached to the gearbox which is coupled with the motor.

5.1. Geared Motor

The motor chosen for the proposed system is a three phase induction motor with a horse power of 0.5hp coupled with a worm gear. The gear ratio is 25:1. The main reason for the selection of the geared motor is that it will for a very small span of time and hence consumes very less power. Also the torque required to rotate heavy PV arrays is sufficient enough.

Table II-Gear Motor specifications

S.No	Parameters	Rating
1	Kw/Hp	0.37/.5
2	Volts/phase	415/3
3	Amp/conn	0.7/star
4	RPM	1440
5	Frequency	50Hz
6	Ambient temp.	45 deg. c

The choice was made by taking the weight of panels and the energy consumption into account not only for this prototype but also for the PV arrays installed in grids.

5.2. Variable Frequency Drive

A variable-frequency drive (VFD) is a system for Controlling the rotational speed of an alternating current electric motor by controlling the frequency of the electrical power supplied to the motor. The specification of the variable frequency drive has been illustrated in table III

Table III-Specification of variable frequency drive

S.No	Parameter	Specification
1	Kw/Hp	0.37/0.5
2	Input volts	400VAC
3	Output volts	Same as input
4	In put frequency	50Hz
5	Output frequency	0 – 400 Hz
6	Control method	v/f-control,
7	Torque	150 % torque at 0.5Hz starting

The speed is reduced at the starting and it is ideal to use VFD for low speed application. After the start of the VFD, the applied frequency and voltage are increased at a controlled rate or ramped up to accelerate the load without drawing excessive current. This starting method typically allows a motor to develop 150% of its rated torque while the VFD is drawing less than 50% of its rated current from the mains in the low speed range. A VFD can be adjusted to produce a steady 150% starting torque from standstill right up to full speed. Note, however, that cooling of the motor is usually not good in the low speed range. With a VFD, the stopping sequence is just the opposite as the starting sequence. The frequency and voltage applied to the motor are ramped down at a controlled rate. When the frequency approaches zero, the motor is shut off. A small amount of braking torque is available to help decelerate the load a little faster than it would stop if the motor were simply switched off and allowed to coast.

5.3. Contactors

A contactor is an electrically controlled switch used for switching a power or control circuit. A contactor is controlled by a circuit which has a much lower power level than the switched circuit.

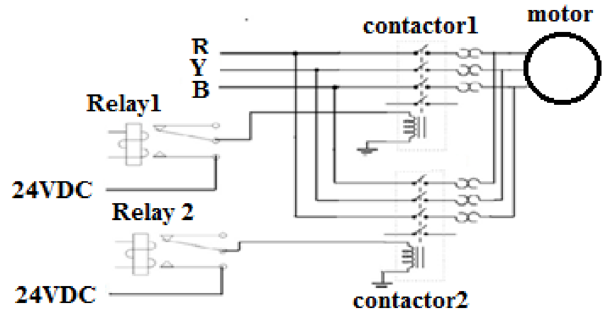

Fig .4. Circuit diagram for switching the geared motor

The circuit diagram for switching the geared motor as shown in figure.4.

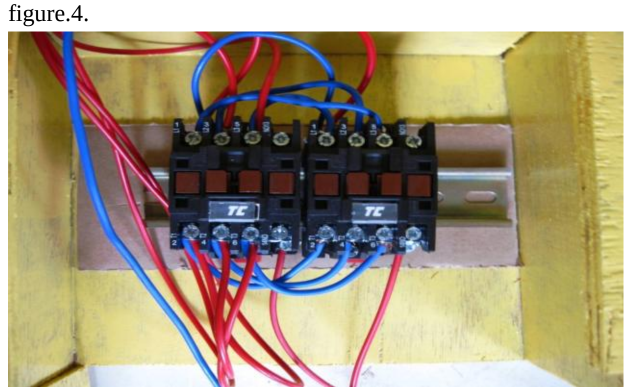

Fig .5.Contactors

Figure.5. shows the contactors that were designed for the proposed system .Contactors are used here to switch on and off the power supply to the motor. Two different contactors are used for forward and reverse direction of rotation of motor. When the forward contactor is switched on the reversing contactor should not get the supply and vice versa.

6. SENSORS

A sensor is a device that measures a physical quantity and converts it into a signal which can be read by an observer or by an instrument. Sensor can also be defined as a device which receives a signal and converts it into electrical form which can be further used for electronic devices. A sensor differs from a transducer in the way that a transducer converts one form of energy into other form whereas a sensor converts the received signal into electrical form only. The sun's position is required to be sensed continuously. The presence of the solar panel is required to be sensed at the extreme ends.

6.1. Types of sensors used

The light dependent resistors are used in the circuit to sense the change in the sun's position. The Proximity sensor is used at one corner in order to sense the presence of the solar panel while rotating. A photo resistor or light dependent resistor or cadmium sulphide (CdS) cell is a resistor whose resistance decreases with increasing incident light intensity. A photo resistor requires a power source because it does not generate Photocurrent; a photo effect is manifested in the change in the material's electrical Resistance. Figure. 6. Shows a photo resistive cell.

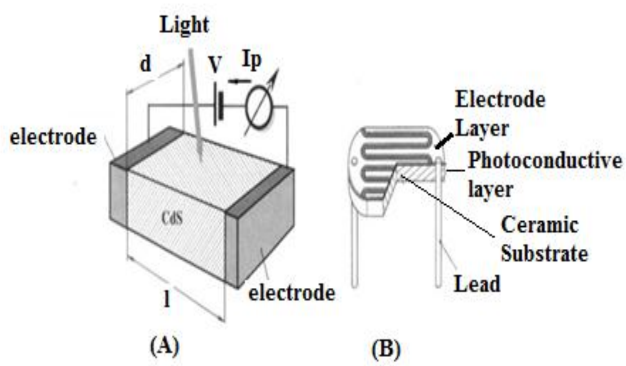

Fig . 6. (A) Structure of a photo resistor and (B) a plastic-coated photo resistor having a serpentine shape

An Electrode is set at each end of the photoconductor. In darkness, the resistance of the material is high. Hence, the applied voltage V results in a small dark current which is attributed to temperature effect. When light is incident on the surface, the current *i*, flows

A Proximity sensor can detect objects without physical contact. A proximity sensor often emits an electromagnetic field or beam and look for changes in the field. The object being sensed is often referred to as the proximity sensor's target. Different proximity sensor targets demand different sensors. For example, a capacitive or photoelectric sensor might be suitable for a plastic target; an inductive proximity sensor requires a metal target.

Inductive proximity sensors operate under the electrical principle of inductance. Inductance is the phenomenon where a fluctuating current, which by definition has a magnetic component, induces an emf in a target object. In circuit design, one measures the inductance in henrys. To amplify a device's inductance effect, a sensor manufacturer twists wire into a tight coil and runs a current through it.

An inductive proximity sensor has four components; the coil, oscillator, detection circuit and output circuit. The oscillator generates a fluctuating magnetic field the shape of a doughnut around the winding of the coil that locates in the device's sensing face. build up in the metallic object, When a metal object moves into the inductive proximity sensor's field of detection, Eddy circuits magnetically push back, and finally dampen the Inductive sensor's own oscillation field. The parts of inductive proximity sensors shown in figure.7. Inductive proximity sensors categorize in five specific types; cylindrical, rectangular, miniature, harsh environment, and special purpose. 70% of all inductive proximity sensor purchases are of the standardized cylindrical threaded barrel type.

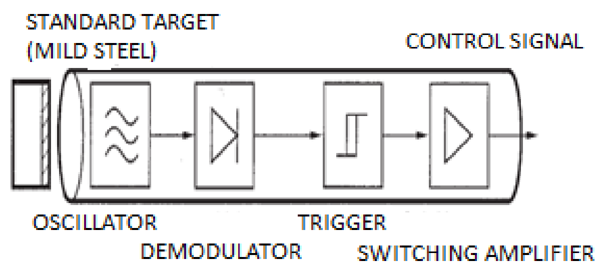

Fig .7. Parts of inductive proximity sensor

For the proposed system, a cylindrical type inductive proximity sensor is chosen whose details are given in table IV

Table IV -Specification of inductive proxy sensor

S.No	Parameter	Specifcations
1	Type	Flush
2	Sensing Distance	0 – 8mm
3	Max output current	200mA
4	Supply voltage	10 – 30VDc
5	Output type	NPN NO

7. CONTROL CIRCUIT DESIGN

The control circuit is used to sense sunlight falling on the LDR, the switch in the circuit will be closed. The LDR and a trim pot form a voltage divider which is used to apply bias to a transistor. As the LDR changes resistance the change in potential is detected by the circuit and the relay is activated. The relay is connected to the energizing winding of a contactor. When the relay gets on, the contactor winding is energized which in turn makes the motor run in forward motion. Same type of circuit is used for the night detection and to operate the motor in reverse direction through small alteration. The control circuit is shown in figure 8

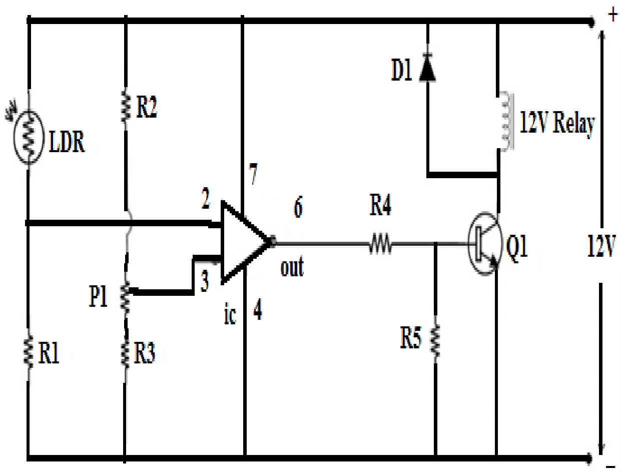

Fig .8. Circuit diagram showing the control circuit

This circuit is satisfactory if the changes in light level to be detected are large.

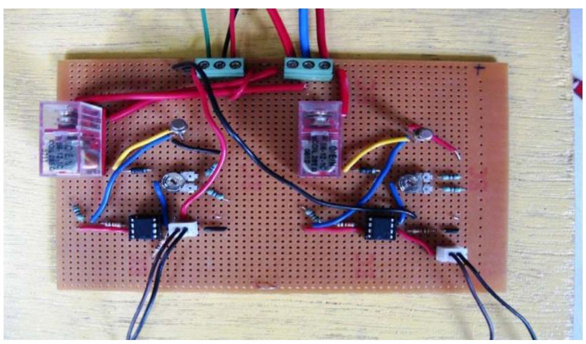

Fig **.9. Control circuit design**

Figure.9.shows the control circuit design which was fabricated for the proposed system. The complete control circuit with enclosed box is shown in figure.10.

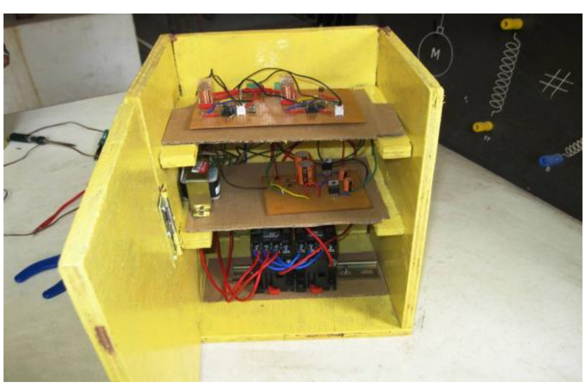

Fig .10. Complete control circuit

An inherent problem of the circuit is chattering of the relay for slowly changing light levels just at the transitions point between turning on/off and vice versa This leads to the relay chattering as it rapidly turns ON/OFF. This problem can be overcome in by having a hysteresis circuit using an op-amp or a Schmidt Trigger.

8. RESULTS

In order to validate the proposed ideas, the hardware implementation and experimental tests were carried out.

8.1. Hardware Implementation

The following table V shows the components are used in the proposed automatic solar energy trapping system.

Table V – Components list

S.No	Components name	Rating	Quantity
1	Solar panel	$70W_p$	1
2	Induction otor	415vac, 3Ph,50Hz	1
3	VFD	AC 200-230,0.5Hp	1
4	Gear Box	25 : 1	1
5	IC- OP AMP	UA741	2
6	LDR		2
7	Contactor	12VDc	2
8	Transistor	BC107	2
9	Stand assembly		1
10	Regulated power supply IC	7812 & 7912	2

The solar panel is to be rotated with the help of a motor in order to track the sun. The mechanism for rotation doesn't consist of a motor alone. This section describes with all the components associated with the rotating mechanism of the solar panel such as motor coupled with a gear box, contactors for switching operation and a shaft which is bolted with the solar panel holding frame and coupled with the gear box.

8.2. Experimental Results

The proposed design presents a cost effective and efficient system to harness solar energy which ensures 25 to 30% more energy conversion than the existing static orientation of solar module system [2]. The hardware implementation of the low cost automatic solar energy trapping system (ASETS) is shown in Figure.11.

Fig .11. Hardware Implementation of ASETS

The proposed system consists of a small and less complicated control circuits which is supplied with the output of light sensors and based upon these inputs it controls the operation of the geared motor. Also the circuits consume less power and are easy to implement with readily available electronic components. The experimental validation of the proposed system energy conversion over static system is shown in figure.12.

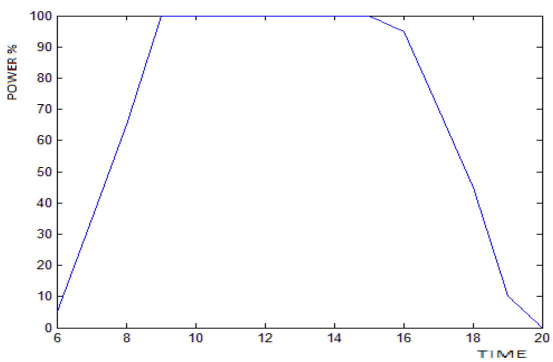

Fig .12.Experimental results of the ASETS

The initial cost of the designed trapping system has been remarkably reduced by the selection of geared motor. So, it can be concluded that the system terms as a cost effective solar energy trapping system.

9. CONCLUSIONS

In this paper, the hardware of a low cost automatic solar energy trapping system has been designed and successfully implemented. The designed that system which ensures 25 to 30% of more energy conversion than the existing static solar module system.

Several tracker technologies currently are available on the market. However, the different tracker technologies come with different characteristics such as the additional cost of maintenance, added cost of solar power unit at installation, accuracies of tracking, reliability and effectiveness in improving efficiency. The designed system requires minimum maintenance with a practically good level of improvement of system efficiency for the comparative cost of acquisition of systems of similar output capacity.

The fabricated system can be modified using microcontroller in the control circuitry. The designed system is a type of single axis tracking system which moves in one direction o to tackle the change in the sun's position. However a system can be developed which can make the solar panel to move in two directions, i.e., horizontally as well as vertically.

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