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Arduino based solar tracking system

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***Abstract*—With the impending scarcity of nonrenewable resources, people are considering using alternate sources of energy. From all other available resources sun energy is the most abundant and it's comparatively easy to convert it to electrical energy. Use of solar panel to convert sun's energy to electrical is very popular, but due to transition of the Sun from east to west the fixed solar panel may be able to generate optimum energy. The proposed system solves the problem by an arrangement for the solar panel to track the Sun.**

This paper is based on the use of solar panel coupled to a stepper motor to track the Sun so that maximum sun light is incident upon the panel at any given time of the day and year. This is better compared to fixed panel method that may not be so efficient. Moreover, the code is constructed using C++ programming language and targeted to Arduino UNO controller. The efficiency of the system has been tested and compared with static solar panel on several time intervals, and it shows the system react the best at the 10-minutes intervals with consistent voltage generated. Therefore, the system has been proven working for capturing the maximum sunlight source for high efficiency solar harvesting applications. Further the work can be enhanced by using RTC (Real Time Clock) to follow the Sun. This helps in maintaining the required position of the panel even if the power is interrupted for some time.

Keywords*—*Tracking, nonrenewable source, microcontroller, stepper motor, RTC

I. INTRODUCTION

The increasing demand for energy, the continuous reduction in existing sources of fossil fuels and the growing concern regarding environment pollution, have pushed mankind to explore new technologies for the production of electrical energy using clean, renewable sources, such as solar energy, wind energy, etc. Among the non-conventional, renewable energy sources, solar energy affords great potential for conversion into electric power, able to ensure an important part of the electrical energy needs of the planet. The conversion of solar light into electrical energy represents one of the most promising and challenging energetic technologies, in continuous development, being clean, silent and reliable, with very low maintenance costs and minimal ecological impact. Solar energy is free, practically inexhaustible, and involves no polluting residues or greenhouse gases emissions. Different researches estimate that covering 0.16% of the land on earth with 10% efficient solar conversion systems would provide 20 TW of power, nearly twice the world's consumption rate of fossil energy. This proves the potential of solar energy which in turn points out the necessity of tracking mechanism in solar systems.

Sunlight has two components, the direct beam that carries about 90% of the solar energy, and the diffuse sunlight that carries the remaining. The diffused portion is the blue sky on a clear day and it 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. A typical solar panel converts only 30 to 40 percent of the incident solar irradiation into electrical energy. Thus to get a constant output, an automated system is required which should be capable to constantly rotate the solar panel. The Sun Tracking System (STS) was made as a prototype to solve the problem, mentioned above. It is completely automatic and keeps the panel in front of sun until that is visible. "The unique feature of this 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.

A. Necessity

- **Solar energy in India:**

  In general India has relatively1 long sunny day for more than ten months and partly cloudy sky for most of the days for the rest two months. This makes our country, especially the desert sides in the west, involving Rajasthan, Gujarat, Madhya Pradesh etc. very rich in solar energy. Many projects have been done by using photovoltaic cells in collecting solar radiations and converting them to electrical energy. But most of these don't take into account the difference of sun's angle of incidence by installing the panels in a fixed orientation, which highly influences the solar energy collected by the panel. The proposed model of Dual Axis Solar Tracker is most compatible for obtaining maximum efficiency.

- **Present usage of solar energy**

<u>Current Global Scenario:-</u>

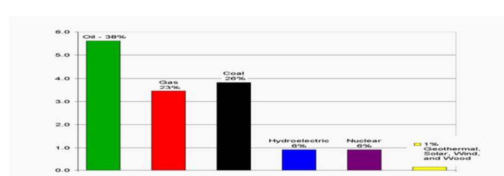

Figure 1: Current Global Scenario of sources used for generation of electricity

The above statistical graph shows the worldwide energy sources which are utilized for generation of electricity. In this graph, oil acquires the first position with a maximum utilization of 38%, while non conventional sources acquire 1% only.

B. Objectives

- **Purpose of Solar Tracker:**

As we know, the angle of incidence lies between -90 degrees after sunrise and 90 degrees before sunset passing zero degrees at noon. This makes the solar radiations to be 0% during sunrise and sunset and 100% during noon. This variation causes solar panel to lose more than 40% of the collected energy. Fig. shows sun's path yearly at a latitude of 30 degrees. From the fig. we can estimate the exact position of the sun.

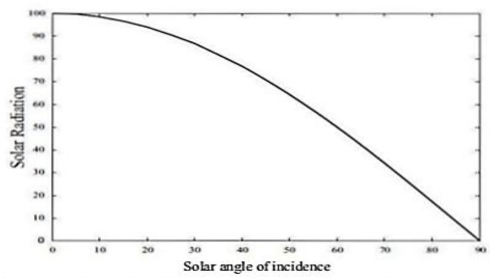

Fig1. 2 Curve for the relationship between the solar radiation and the solar angle of incidence.

Figure 2: Curve for relation between solar radiation and solar angle of incidence

At any time of the month or a day, the position of the sun is decided by two angles in the spherical co-ordinate system- the Altitude angle which is the angle of the sun n the vertical plane in which the sun lies and the Azimuth angle which represents the angle of the projected position of the sun in the horizontal plane. Above figure shows that the sun rays received are maximum when the angle of incidence is 0 degrees i.e. the solar panel is perpendicular to the sun. The Dual Axis Solar Tracker used to solve this problem consists of two essential parts:

1. **The solar panel**
2. **The tracking system.**

II. PROPOSED MODEL

A. Tracker Types

Solar tracking is a widely-applied proven technology that increases energy production by directing or concentrated the photovoltaic to track the sun on its path from dawn until dusk. Instantaneous solar radiation collected by the photovoltaic modules, assembled in a tracking system, is higher than the critical irradiance level for a longer number of hours than in fixed systems. There are numerous types of solar trackers, of varying costs, performance and sophistication. They are:

- **Single Axis Trackers**

Single axis trackers have one degree of freedom that acts as an axis of rotation. The axis of rotation of single axis trackers is typically aligned along a true North meridian. It is possible to align them in any cardinal direction with advanced tracking algorithms. Their types are –

1. Horizontal Single Axis Tracker (HSAT)
2. Vertical Single Axis Tracker (VSAT)
3. Tilted Single Axis Tracker (TSAT)

- **Dual Axis Trackers**

Dual axis trackers have two degrees of freedom that act as axes of rotation. These axes are typically normal to one another. The axis that is fixed with respect to the ground can be considered a primary axis. The axis that is referenced to the primary axis can be considered a secondary axis.

B. Main components of solar tracking system

The Solar tracking system consists of two main parts:

1. Circuit for sensing and controlling the microcontroller (Arduino UNO) and motor driver.
2. The circuit required for solar panel.

III. METHODOLOGY

A. Block-diagram

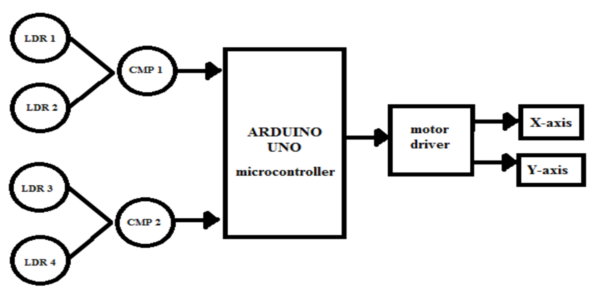

Figure 3: Block diagram of Solar tracking system using LDR, OP-Amp and a microcontroller

B. Hardware

- **The main components are**

1. Solar panel
2. Sensors(LDRs)
3. Stepper motors
4. Motor driver
5. Microcontroller(Arduino UNO)

- **Solar panel**

Solar panels are devices that convert light into electricity. The word solar is used as they derive energy for operation from the sun. They are sometimes called photovoltaic which means "light-electricity". Solar cells or PV cells rely on the photovoltaic effect to absorb the energy of the sun and cause current to flow between two oppositely charge layers. A solar panel is a packaged, connected assembly of photovoltaic cells. The solar panel can be used as a component of a larger photovoltaic system to generate and supply electricity in commercial and residential applications. Several types of solar cells available in the market are:

1. Monocrystalline silicon (mono-silicon or single silicon)
2. Polycrystalline silicon (multicrystalline, multisilicon, ribbon)
3.

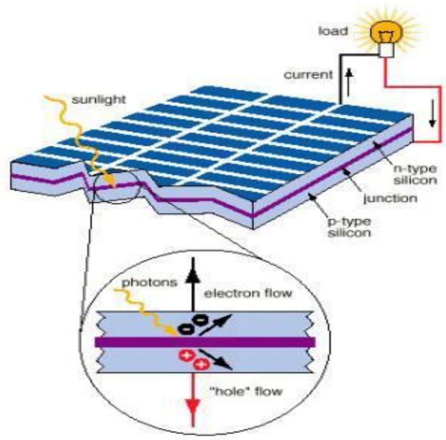

Figure 4: Solar panel

- **Sensors**

The main impulsion is to design a high quality solar tracker. 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.

Light Dependent Resistor: Light Dependent Resistor (LDR) is made of a high-resistance semiconductor. It can also be referred to as a photo-sensor. LDRs or Light Dependent Resistors are very useful especially in light/dark sensor circuits. Normally the resistance of an LDR is very high, sometimes as high as 1000 000 ohms, but when they are illuminated with light resistance drops dramatically. LDR's have low cost and simple structure. The behavior of LDRs with change in the intensity of light is shown in the table below:

Table 2: Light intensity measurement

LIGHT INTENSITY	LDR OUTPUT(V)
Dark	0.56
Average	3.39
Bright	4.6

- **Micro Controller**

OP Amp compares the two voltages, and gives output to microcontroller when the panel rotates in either clockwise and anti clockwise direction. When the microcontroller receives output from the comparator, it gives output to the motor driver to rotate the motor in either sense of rotation and it continues to operate within a given permissible time.

The microcontroller used is Arduino UNO. Arduino is an open-source electronics prototyping platform based on flexible, easy-to-use hardware and software. Arduino can sense the environment by receiving input from a variety of sensors and can affect its surroundings. Arduino projects can be stand-alone, or they can communicate with software running on a computer. In this development, Arduino UNO is used as the main controller because it satisfies these conditions:

1. Microcontroller board based on the A Tmega32S.
2. 14 digital input/output pins (of which 6 can be used as PWM outputs), 6 analog inputs, a 16 MHz crystal oscillator, a USB connection, a power jack, an ICSP header, and a reset button

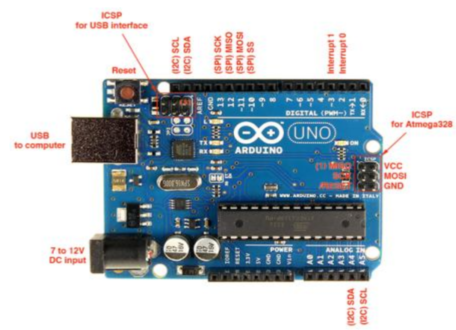

Figure 5: Microcontroller Arduino UNO

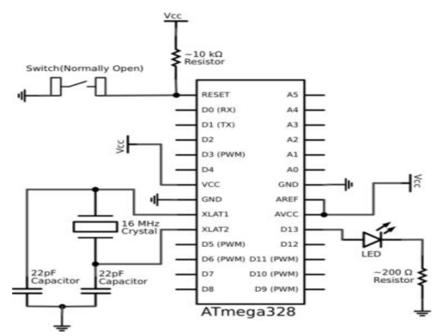

Figure 6: Pin Diagram of Arduino

- **Motor Driver L298N**

L298N is a dual bridge motor driver, so with one motor driver board we can interface two DC motors which can be controlled in both clockwise and anticlockwise direction. If we have motor with fix direction of motion we can make use of all the four I/O's to connect the DC motors.

It has output current of 600mA and peak output current of 2A per channel more ever for the protection of circuits back EMF output diodes.

Features of IC L298N

1. Light weight, small dimension
2. Super driver capacity
3. 600mA output current capability per channel.
4. High noise immunity
5. Power selection switch
6. Motor direction indication LED

7. 4 standard mounting holes.

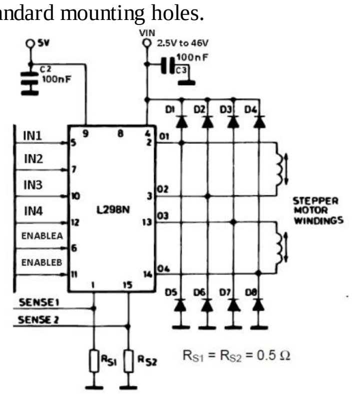

Figure 7: Pin configuration of L298N Dual DC Motor Controller

- **Stepper Motor**

A stepper motor is an electromechanical device which converts electrical pulses into discrete mechanical movements. The shaft or spindle of a stepper motor rotates in discrete step increments when electrical command pulses are applied to it in the proper sequence. There are three main types of stepper motors, they are:

1. Permanent Magnet Stepper Motor

2. Variable Reluctance Stepper Motor.

3. Hybrid Synchronous Stepper Motor.

Advantages of stepper motor:

1. The rotation angle of the motor is proportional to the input pulse.
2. The motor has full torque at standstill.
3. Precise positioning and repeatability of movement since good stepper motors have an accuracy of 3 – 5% of a step and this error is non cumulative from one step to the next.
4. Excellent response to starting, stopping and reversing

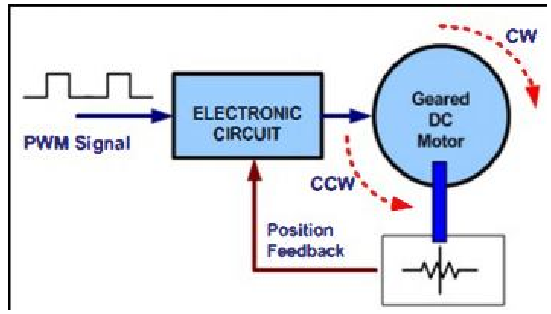

Figure 8: circuit diagram of stepper motor

- **Working**

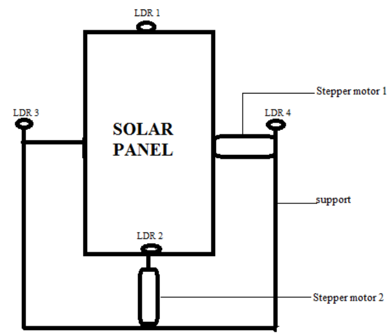

Figure 9: Basic diagram of Dual Axis Solar radiation tracker

The block diagram of the developed closed-loop solar tracking system describes the composition and interconnection of the system. For the closed-loop tracking approach, the solar tracking problem is how to cause the solar panel to follow the sunlight as closely as possible. The sensor-based system consists of the LDR sensor, comparator and microcontroller. In the tracking operation, the LDR sensor measures the sunlight intensity as a reference input signal. The unbalance in voltages generated by the LDR sensor generates a feedback error voltage. The error voltage is proportional to the difference between the sunlight location and the solar panel location. At this time the comparator compares the error voltage with a specified threshold (tolerance). If the comparator output goes high state, the motor driver is activated so as to rotate the dual-axis (azimuth and elevation) tracking motor and bring the PV panel to face the Sun. Accordingly, the feedback controller performs the vital functions: PV panel and sunlight are constantly monitored and send a differential control signal to drive the PV panel until the error voltage is less than a pre-specified threshold value.

IV. RESULTS AND DISCUSSION

The following table shows the current and voltage values received from both the static and tracking panel for different times in a day. From the table it is seen that at 8:00 am there is much improvement in current by tracking panel compared to the static panel. But as time goes on this difference in current between this two technology decreases up to around 1:00 pm. After that when the sun rotates more towards west this difference increases again. The highest current of static panel and tracking panel is 0.28amp and 0.34amp respectively at 12:00 pm. But in case of voltage the variation is lesser compare with current as the voltage has no direct relation with the sun light intensity. Fig. shows the comparison of current curves for both the static and tracking panel.

Table shows the power values of both the static and tracking panel. The power gain of tracking panel over static panel for different times is also given in table. The maximum power output of the static panel and tracking solar panel is 3.18 and 4.03 watt respectively is found at 12:00 pm. Much more power gain is achieved in the morning and afternoon because the tracking system can accurately track the sun at these times while the static system not. For both technology power fall were very fast from 3:00 pm to 5:00 pm because of the low duration of day light. Fig. 8 shows the comparison of power collection bar diagrams for both static and tracking panel.

V. ADVANTAGES

- **The conservation of non-renewable energy resources**

Photovoltaic (PV) solar power eases the usage of diminishing natural resources such as oil, coal and gas. Today, we live in an exceptionally demanding environment where the use of energy is growing at an alarming rate. It is vital to preserve the earth's fossil fuels and other natural resources, not only for a healthier environment but also for the ability of future generations to meet their own needs.

- **Lower amount of Waste and Pollution**

PV solar power systems minimize the amount of waste production. For example, the entire process of converting coal to electricity produces a lot of dust, discarded solid waste, spillages of toxins and harmful emissions, as well as wasting energy, heat, land and water. Pollution from non renewable fuels is inevitable. Emissions such as Sulphur Dioxide, Nitrogen Oxide and Carbon Dioxide all can have a negative effect on farming, people's health and water. Ecosystems are also at risk of being destroyed. Furthermore, pollutants from kerosene used for lighting purposes is reduced with the use of solar power systems, as well as the decrease in use of diesel generators for the production of electricity.

- **Offsetting Green House Gases**

PV Solar power systems produce electricity without giving off carbon dioxide. One PV Solar system can offset approximately six tons of CO2 emissions over a twenty year life span.

- **Limitting the use of conventional energy sources**

Solar power improves energy efficiency and is therefore it is beneficial to us. Use of solar energy for generation of electricity reduces the consumption of conventional power for built up cities. It is cheaper and hence can be used for industrial and commercial purposes to run various operations. Thus, the use of photovoltaic systems to generate power is one of the most efficient ones ways of generating power.

- **Universal application –**

The versatility of the solar tracker is that, it can be used for various applications and can be implemented in various parts of world except for Polar Regions.

- **Generating efficiency**

Over 40% increase in radiation reception from sun comparing with fixed installation. With dual axis tracker, additional over 45% increase in radiation reception from sun will be gained.

- **Independent control**

The important factor concerning the system is that, it can be installed anywhere, where no manual operation is involved. LDR sensors play a vital role in making the system automated by sensing the intensity resulting in generation of pulse, thus making the system independent.

VI. LIMITATIONS

1) When there is cloudy atmosphere it is difficult to tracking the sun.
2) Panel rotations require an extra power from outside of power used that produce by panel itself.
3) Fixing arrangement of LDR at perpendicular to sun light is somewhat problematic
4) LDRs are very sensitive elements and so may get damaged in extreme climatic conditions.

VII. CONCLUSION

- **Increase in efficiency**

Solar radiation Tracker has played a vital role in increasing the efficiency of solar panels in recent years, thus proving to be a better technological achievement. The vital importance of a dual axis solar tracker lies in its better efficiency and sustainability to give a better output compared to a fived solar panel or a single axis solar tracker. The tracking system is designed such that it can trap the solar energy in all possible directions. Generally, in a single axis tracker that moves only along a single axis it is not possible to track the maximum solar energy. In case of dual axis trackers, if the solar rays are perpendicular to panel throughout the year. Hence, maximum possible energy is trapped throughout the day as well as throughout the year. Thus, the output increases indicating that the efficiency more than a fixed solar panel (about 30 -40% more) or a single axis solar tracker (about 6-7% more).

- **Future Scope**

In Future the conventional energy is not sufficient for use so there is need of use non conventional energy sources .This Project is very useful for power supply in rural areas where we can use high sensitive solar panels which can work in mild sun light also and by connecting number of solar tracker assemblies we will able to produce sufficient large quantity of power which will be able to supply power to medium size village. We can make use of solar panels in our day to day life for street lighting, in mobile phone chargers, water heaters, etc.

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