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Automatic solar tracking system used for irrigation

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Abstract
Choice of proper methods is always important in the field of irrigation. By indulging the optimum methods, we can ensure maximized yield from the field. In this era of sensors and technological development, it is the ripest time to involve these advancements in this domain as well. Water being one of the most precious resources, it is never to be wasted. Again sunlight which is such an abundant resource must be utilized. The method we put in this paper correlates two different techniques viz. measuring water content in a field and employing solar power to drive motors for running submersible pumps as and when required. Adding on to these we have developed an arrangement so that the solar panels can track the orientation of the sunlight and adjust themselves accordingly. 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. Active sensors constantly monitor the sunlight and rotate the panel towards the direction where the intensity is most. The light dependent resistors do the job of sensing the change in the position of the sun. An electro mechanical arrangement aligns the panels accordingly. The entire set up is controlled by an Arduino Atmel AVR microcontroller which will trigger the relays as and when required. The expectations agree to great extent to the desired efficiency.

Keywords: Inverters, solar tracking system, water pump, battery

1. Introduction
Energy plays an important role in the material, social and cultural life of mankind. The energy needs are increasing day by day. This is the result of population growth and increase in the standard of living which is directly proportional to energy consumption. As we know that mankind will be never lacking in energy [1]. Today, it is liquid fluid, tomorrow it may be uranium with an element of risk. Risk exists where ever there is human activity and production of energy. Just as the supply of fossil fuel is finite thus there will be the supply of uranium. Perhaps, uranium would be exhausted quickly if it is used on a large scale. It is therefore, harnessing the gigantic inexhaustible solar energy source reduces the dependence on fossil fuels. For the environmental concerned, the solar energy harnessing system offers advantages in that, it emits no pollutants in to the atmosphere as they are with the combustion of fossil fuels. Thus, as a long term option solar energy system can be considered as an alternate to all the finite fuel system. Therefore, there is no energy shortage today nor will there be in the near future? The lifting of water for drinking or irrigation purposes is of great importance in widely distributed villages with little or no rural electrification and where underground water is available [1, 9]. Solar energy is converted to mechanical energy to drive small water pumps it would be of great help to the rural inhibitions [5]. From many centuries, sun has been the primary source of energy for the globe [5]. Technically, solar energy can be defined as Electromagnetic energy transmitted from the sun (solar radiation). The amount of energy that reaches the earth is equal to one billionth of total solar energy generated. But is that small? No. The amount of energy which strikes the surface of the earth in one day exceeds daily consumption by 10,000 to 15,000 times. In other words, the amount of solar energy intercepted by the earth every minute is greater than the amount of energy the world uses in fossil fuels each year [2]. Moreover, of all the renewable energy sources available, solar energy has the smallest environmental impacts. Electricity produced from photovoltaic cells does not result in air or water pollution, deplete natural resources, or endanger animal or human health [6].

1.1 Solar panel
The Basic of Photovoltaic: The density of power radiated from the sun (referred to as the “solar energy constant”) at the outer atmosphere is 1.373 kW/m^2. Part of this energy is absorbed and scattered by the earth’s atmosphere.

The final solar energy that reaches the earth's surface has the peak density of 1 kW/m2 at noon in the tropics. The technology of photovoltaic PV) is essentially concerned with the conversion of the solar energy into suitable electrical energy. The basic element of PV system is a solar cell. By settling solar cells under the sunlight, they can convert solar energy directly to electricity. This electricity can be modified to any consumer applications such as lighting, water pumping, refrigeration, telecommunications, and so on. Solar cells rely on a quantum-mechanical process known as the "photovoltaic effect" to produce electricity. A typical solar cell consists of a p-n junction formed in a semiconductor material similar to a diode. Solar cells are semiconductor devices that are designed to generate electric power when exposed to electromagnetic radiation. The spectrum of light given off by the sun is shown in Fig.1.

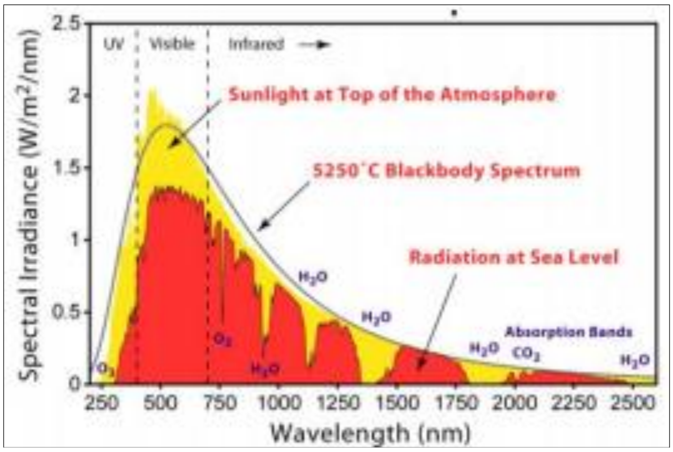


Fig 1: Spectrum of solar radiation in space and on earth

The distribution of light in outer space resembles the theoretical radiation provided by a black body. As the light passes through the atmosphere, some of the light is absorbed or reflected by gasses such as water vapour and the ozone. The typical distribution of light on the surface of the earth is different than the distribution of light in space. Engineers must consider the spectrum of incident light when designing solar cells [6].Solar cells consist of one or more p-n junctions. Light enters the semiconductor material through the n region and generates an electron-hole pair (EHP) in the material due to the photoelectric effect. The n region is designed to be thin while the depletion region is thick. If the EHP is generated in the depletion region, the built-in electric field drifts the electron and hole apart. The result is a current through the device called the photocurrent. If the EHP is generated in the n or p regions, the electron and hole drift in random directions and may or may not become part of the photocurrent.

Performance of a solar cell: The following terms deal with the performance of a solar cell.

Short-circuit current, JSC: The current of a solar cell when the top and bottom (negative and positive leads) are connected with a short circuit. This is the horizontal intercept on the I-V curve shown in Fig. 2. Open-circuit voltage, Voc: The voltage between the top and bottom of a solar cell. This is the vertical intercept on the I-V curve shown in Fig. 2

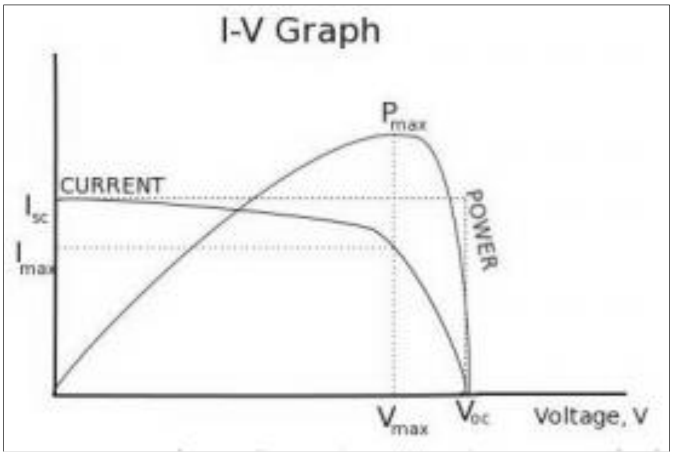


Fig 2: Current versus voltage curve (I-V curve) for a typical solar cell

Power point: The point on the I-V curve of a solar cell at (JPP VPP) (that generates the maximum amount of power for the device. This is the point that encloses the most amount of area in the first quadrant when vertical and horizontal lines are drawn from the point. This represents power since the area is equivalent to the current times voltage of the cell.

Fill factor, FF: A percentage given by Equation.1 that describes how close the I-V curve of a solar cell resembles a perfect rectangle, which represents the ideal solar cell.

Quantum efficiency: The number of EHPs that are created and collected divided by the number of incident photons. This is a percentage since each photon can produce at most one EHP.

Overall efficiency: The percent of incident electromagnetic radiation that is converted to electrical power. Often the overall efficiency for a given solar cell depends on many factors including the temperature and amount of incident radiation.

2. Methodology

The original and still the most common semi-conducting material used in PV cells is single crystal silicon. Single crystal silicon cells have are generally the most efficient type of PV cells, converting up to 23% of incoming solar energy into electricity. These cells are also very durable and have proved their long life in many space related applications. The main problem with single crystal silicon cells is their production costs. Growing large crystals of silicon and then cutting them into thin (0.1-0.3 mm) wafers is slow and expensive. For this reason, researchers have developed several alternatives to single crystal silicon cells, with hopes of reducing manufacturing costs.

A solar cell is a PV cell designed to convert sunlight to electricity [5]. The simplest cells consist of a circular silicon wafer with apn-junction sandwiched in the middle, a metallic bottom contact (e.g. aluminium) and a transparent top contact (either a transparent conducting oxide or a grid-like metal structure). Solar panels with cells like this have played a vital role in space technology since the late '50s, powering space satellites. They are expensive to produce because silicon wafers are expensive to produce (mainly because they are high-purity single crystals) but their cost was unimportant in the space race [5, 6].

2.1 Solar tracking system

A Solar tracker is a device for orienting a solar photovoltaic panel towards the sun. In solar tracking systems the surface of the module tracks the sun automatically throughout the day. Tracking system [5] increases the efficiency of the system considerably there by reducing the cost per unit of output energy.

Why to use solar tracking system: From many centuries, sun has been the primary source of energy for the globe. Technically, solar energy can be defined as Electromagnetic energy transmitted from the sun (solar radiation).The amount of energy that reaches the earth is equal to one billionth of total solar energy generated. But is that small? No. The amount of energy which strikes the surface of the earth in one day exceeds daily consumption by 10,000 to 15,000 times. In other words, the amount of solar energy intercepted by the earth every minute is greater than the amount of energy the world uses in fossil fuels each year. Moreover, of all the renewable energy sources available, solar energy has the smallest environmental impacts. Electricity produced from photovoltaic cells does not result in air or water pollution, deplete natural resources, or endanger animal or human health [3].

In spite of these benefits, man is not able to use this energy completely and economically. Two billion people in the world still have no access to electricity. For most of them, solar energy would be their cheapest electricity source, but they cannot afford it. This is because the price of electricity produced from solar cells is still significantly more expensive than it is from fossil fuels like coal and oil. This is because of cost involved in converting the solar energy into required form of electrical energy and low efficiency of solar system i.e., the output from the solar system is not completely sufficient for our needs. The problem here is that the sun's position is not constant throughout the day. The output from the solar system depends on the intensity of sunlight and the angle at which radiation is being incident. Hence there is a need to track the sun in order to produce maximum output throughout the day.

Analization of solar tracking system: A Solar tracker is a device for orienting a solar photovoltaic panel towards the sun. In solar tracking systems the surface of the module tracks the sun automatically throughout the day. Tracking system increases the efficiency of the system considerably there by reducing the cost per unit of output energy. Concentrators, especially in solar cell applications require a high degree of accuracy to ensure that the concentrated sunlight is directed precisely to the powered device, which is at the focal point of the reflector or lens. The output greatly depends on the angle of incidence, Zenith angle and azimuth angle. Some solar trackers may operate most effectively with seasonal position adjustment and most will need inspection and lubrication on an annual basis.

2.2 Block diagram

The proposed system is single axis solar tracker used for irrigation system along with GSM. The LDR placed on solar panel (12V, 5W) helps to track maximum intensity of sunlight and thus generate more electricity. The electricity produced is stored in battery (12V) which is further used to power the irrigation system. The analog values from LDR and moisture sensor are given to ADC0808 for its digital conversion. The digital values are taken as input by microcontroller 89s51 which is interfaced along with 12V DC pump, LCD and GSM module. With the use of GSM, farmer can switch on and off the pump at his own discretion just by sending a message.

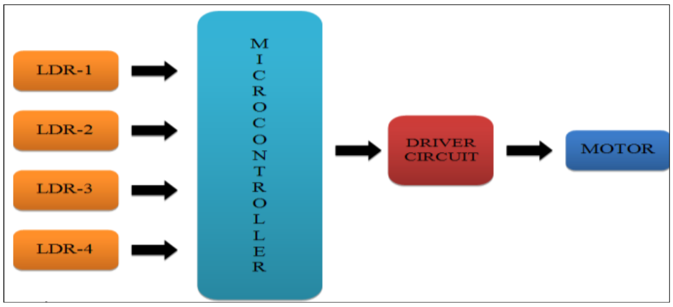


Fig 3: Block Diagram

Actual design requirements

1. During the time that the sun is up, the system must follow the sun's position in the sky.
2. This must be done with an active control, timed movements are useful. It should be totally automatic and simple to operate. The operator interference should be minimal and restricted to only when it is actually required.

The major components of this system are as follows

I. Mounting unit: In this system we have options like One Axis Tracker and Two Axis Tracker to mount solar panel. We can use one of them which is more convenient and efficient.

As solar tracking implies moving parts and control systems that tend to be expensive, single-axis tracking systems seem to be the best solution for small PV power plants. A single-axis solar tracking system uses a tilted PV panel mount and one electric motor to move the panel on an approximate trajectory relative to the Sun's position. The rotation axis can be horizontal, vertical, or oblique.

There are subcategories of single axis tracker

- Polar tracking North-South; East-West
- Azimuthal Axis Tracking

Fig 4: Monitoring Unit

With the help of two-axis trackers, maximum energy collection can be achieved because, due to its total freedom of movement (north–south and east–west), the tracker can face the sun's rays throughout the day

II. Solar panel unit: Solar energy is reliable and efficient, producing electricity during peak periods — hot afternoons — when the demand is highest and air conditioners are going full blast. On highways, the sun's energy is captured during the day to enable highway signs to shine at night.
Active solar power is what you are most likely to install to cut your energy costs and usage. There are five basic parts to the process of actively harnessing solar energy for everyday use:

Fig 5: Solar Cell

Solar panels, made up of photovoltaic (PV) cells, capture sunlight particles or photons. Using a semiconducting material such as silicon, the PV cells convert the sunlight into useable direct current (DC) electricity.
An inverter connected by wires to the solar panels turns those direct currents (DC) into alternating current (AC) electricity on a much grander scale than the AC/DC plug on your small appliance. The AC goes to the electrical or breaker box panel in your home or business to power the lights, computers and other appliances.
The utility company meter at your home or business will measure how much energy is used, and how much is generated by the solar panels. This will tell you whether your system is generating enough energy from solar power to fully meet your needs or whether you are still taking some power from the electric grid. "Grid-tie" solar power customers tie their solar system into the local utility's power grid, which allows them to sell any excess energy they generate into the grid for others to use. Others prefer to set up a stand-alone solar power system, keeping their homes "off-grid" and generating power solely for their own use.

III. Motor unit: A DC motor is an electric motor that runs on direct current power. In any electric motor, operation is dependent upon simple electromagnetism. A current carrying conductor generates a magnetic field, when this is then placed in an external magnetic field, it will encounter a force proportional to the current in the conductor and to the strength of the external magnetic field. It is a device which converts electrical energy to mechanical energy. It works on the fact that a current carrying conductor placed in a magnetic field experiences position.

Advantages of DC Motor
1. Provide excellent speed control for acceleration and deceleration
2. Easy to understand design
3. Simple, cheap drive design

IV. Photo sensor unit: A Light Dependent Resistor (LDR) is also called a photoresistor or a cadmium sulfide (CdS) cell. It is also called a photoconductor. It is basically a photocell that works on the principle of photoconductivity. The passive component is basically a resistor whose resistance value decreases when the intensity of light decreases. This optoelectronic device is mostly used in light varying sensor circuit, and light and dark activated switching circuits. Some of its applications include camera light meters, street lights, clock radios, light beam alarms, reflective smoke alarms, and outdoor clocks.
The snake like track shown below is the Cadmium Sulphide (CdS) film which also passes through the sides. On the top and bottom are metal films which are connected to the terminal leads. It is designed in such a way as to provide maximum possible contact area with the two metal films.
The structure is housed in a clear plastic or resin case, to provide free access to external light. As explained above, the main component for the construction of LDR is cadmium sulphide (CdS), which is used as the photoconductor and contains no or very few electrons when not illuminated.
A potential divider circuit is used to get the output voltage from the sensors (LDRs).

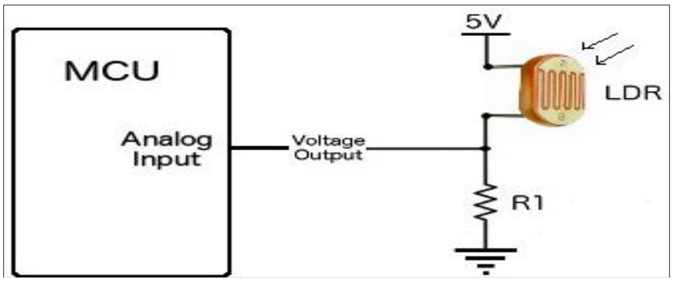


Fig 6: Photo sensor

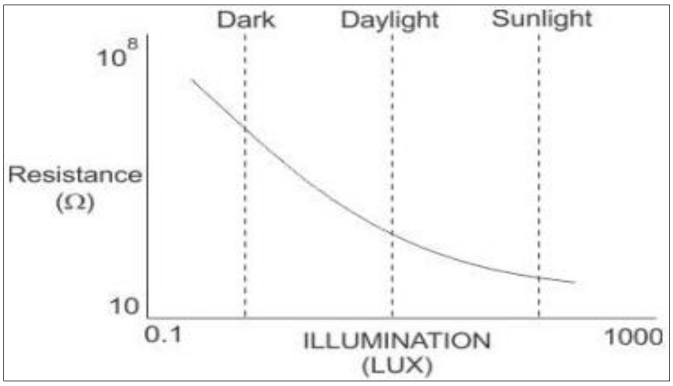
The LDR senses the analogue input in voltages between 0 to 5 volts and provides a digital number at the output which generally ranges from 0 to 1023.
Now this will give feedback to the microcontroller using the arduino software (IDE).

- It is a photo-resistor is a device whose resistivity is a function of the incident electromagnetic radiation. Hence, they are light sensitive devices. They are also called as photo conductors, photo conductive cells or simply photocells.
- They are made up of semiconductor materials having high resistance.
- LDR works on the principle of photo conductivity. Photo conductivity is an optical phenomenon in which the material's conductivity is increased when light is absorbed by the material.

The most common type of LDR has a resistance that falls with an increase in the light intensity falling upon the device (as shown in the image above). The resistance of an LDR may typically have the following resistances:

Daylight = 5000Ω
Dark = 20000000Ω

Therefore, it is seen that there is a large variation between these figures. If this variation is plotted on a graph, something similar to the figure given below can be seen.



V. Microcontroller unit: Arduino is an open-source electronics platform based on easy-to-use hardware and software. Arduino boards are able to read inputs - light on a sensor, a finger on a button, or a Twitter message - and turn it into an output - activating a motor, turning on an LED, publishing something online. You can tell your board what to do by sending a set of instructions to the microcontroller on the board. To do so you use the Arduino programming language (based on Wiring), and the Arduino Software (IDE), based on Processing.

Over the years Arduino has been the brain of thousands of projects, from everyday objects to complex scientific instruments. A worldwide community of makers - students, hobbyists, artists, programmers, and professionals - has gathered around this open-source platform, their contributions have added up to an incredible amount of accessible knowledge that can be of great help to novices and experts alike.

Arduino was born at the Ivrea Interaction Design Institute as an easy tool for fast prototyping, aimed at students without a background in electronics and programming. As soon as it reached a wider community, the Arduino board started changing to adapt to new needs and challenges, differentiating its offer from simple 8-bit boards to products for IoT applications, wearable, 3D printing, and embedded environments. All Arduino boards are completely open-source, empowering users to build them independently and eventually adapt them to their particular needs. The software, too, is open-source, and it is growing through the contributions of users worldwide.

Fig 7: Microcontroller

- **CPU**

The CPU of the AVR microcontroller is same but so simple like the one in a computer. The main purpose of the CPU is to confirm correct program performance. Therefore, the CPU must be able to access perform calculations, memories, control peripherals & handle interrupts. The CPUs of Atmel's 8-bit and 32-bit AVR are based on an innovative "Harvard architecture" thus every IC has two buses namely one instruction bus and data bus. The CPU reads executable instructions in instruction bus, wherein the data bus, is to read or write the corresponding data. The CPU core of the AVR consists of the ALU, General Purpose Registers, Program Counter, Instruction Register, Instruction Decoder, Status Register and Stack Pointer

- **Flash program memory**

The program of the AVR microcontroller is stored in non-volatile programmable Flash program memory which is just similar to the flash storage in your SD Card or Mp3 Player. The Flash program memory is separated into two units. The first unit is the Application Flash section. It is where the program of the AVR is stored. The second section is named as the Boot Flash section and can be fixed to perform directly when the device is powered up. One significant fact to note is that the microcontrollers Flash program memory has a resolution of at least 10,000 writes/erase cycles.

- **SRAM**

The SRAM (Static Random Access Memory) of the AVR microcontroller is just like computer RAM. While the registers are used to execute calculations, the SRAM is used to supply data through the runtime. This volatile memory is prearranged in 8-bit registers.

- **EEPROM**

The term EEPROM stands for Electrically Erasable Read-Only Memory is like a non-volatile memory, but you can't run a program from it, but it is used as long time storage. The EEPROM doesn't get removed when the IC loses power.

VI. Battery

The lead acid battery is made up of plates, lead, and lead oxide (various other elements are used to change density, hardness, porosity, etc.), with a 35% sulfuric acid and 65% water solution. This solution is called electrolyte, which causes a chemical reaction that produces electrons. When you test a battery with a hydrometer, you are measuring the amount of sulfuric acid in the electrolyte. If your reading is low, that means the chemistry that makes electrons is lacking. So where did the sulfur go? It's resting on the battery plates so that when you recharge the battery, the sulfur returns to the electrolyte.

Fig 8: Battery

VII. Water pump: A Water Pump, also called an electric Water Pump, is a pump that can either be submerged in water. The motor is hermetically sealed and close-coupled to the body of the pump.

A Water Pump pushes water to the surface by converting rotary energy into kinetic energy into pressure energy. This is done by the water being pulled into the pump: first in the intake, where the rotation of the impeller pushes the water through the diffuser. From there, it goes to the surface.

viii. Hardware Model: As we see in this diagram, there are Light Dependent Resistors (LDRs) which are placed on a common plate with solar panel. Light from a source strikes on them by different amounts. Due to their inherent property of decreasing resistance with increasing incident light intensity, i.e. photoconductivity, the value of resistances of all the LDRs is not always same.

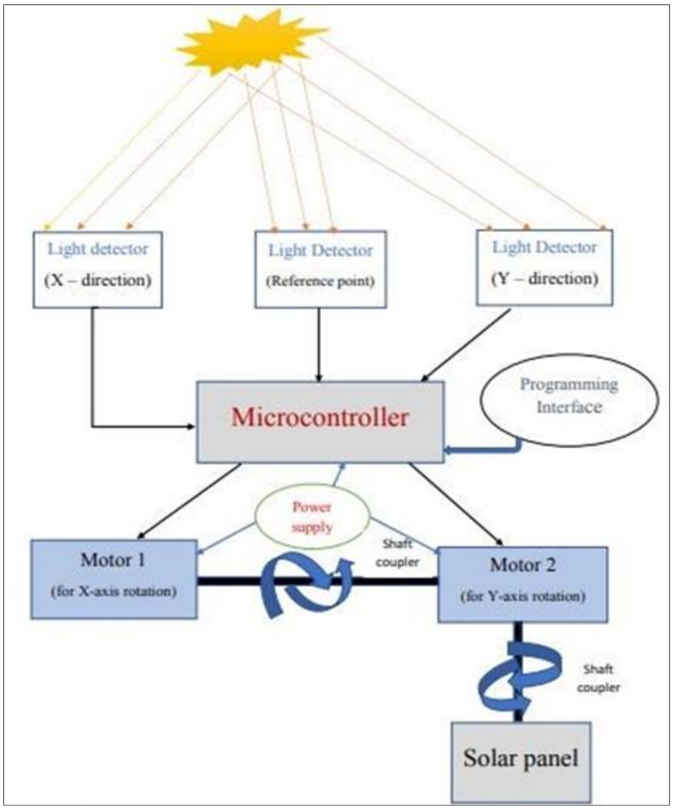
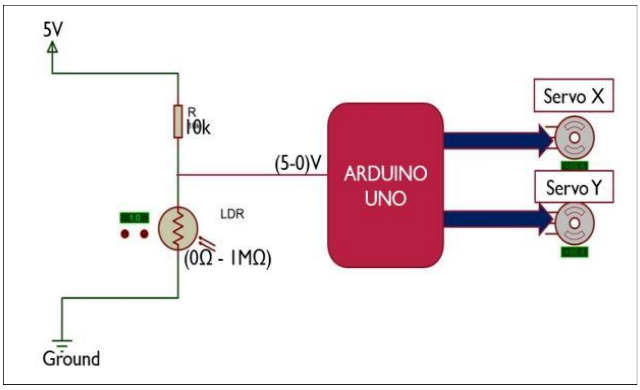


Fig 9: Basic components and hardware

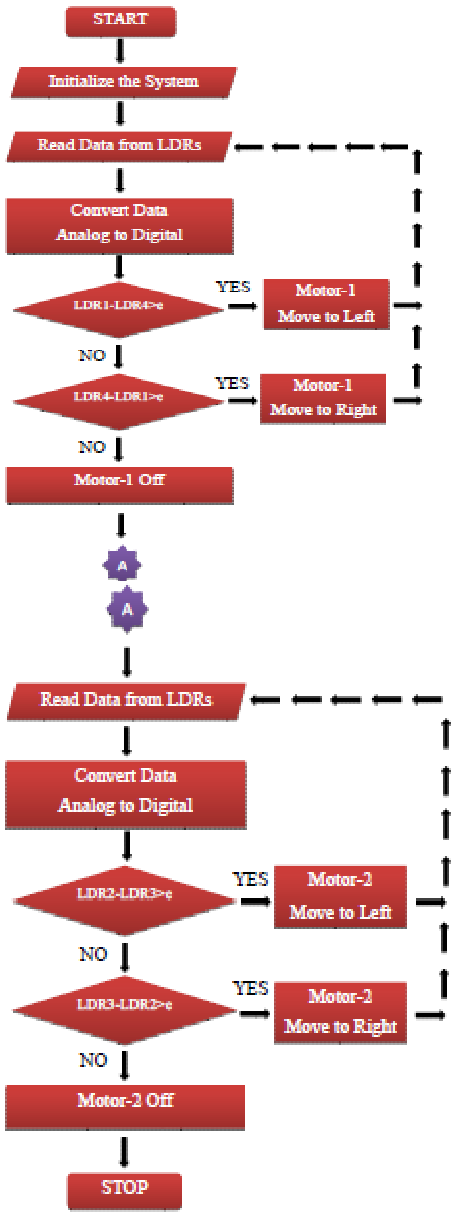
Each LDR sends equivalent signal of their respective resistance value to the Microcontroller which is configured by required programming logic. The values are compared with each other by considering a particular LDR value as reference.
One of the two geared dc motors is mechanically attached with the driving axle of the other one so that the former will move with rotation of the axle of latter one. The axle of the former geared DC motor is used to drive a solar panel. These two-geared DC motors are arranged in such a way that the solar panel can move along X-axis as well as Y-axis.
The microcontroller sends appropriate signals to the geared DC motors based on the input signals received from the LDRs. One geared DC motor is used for tracking along x-axis and the.

2.5 System operation

This project is designed with solar panels, LDR, ADC, Microcontroller, Motors, its driving circuit along with the application of an Irrigation System i.e. Water Pump. In this project four LDRs are fixed on the solar panel at a distinct point. LDR (Light Dependant Resistor) varies the resistance depending upon the light fall. The varied resistance is converted into an analogue voltage signal.
The analogue voltage signal is then fed to an ADC. ADC is nothing but analogue to digital Converter which receives the four LDR voltage signals and converts them to corresponding digital signal. Then the converted digital signal is given as the input of the microcontroller. Microcontroller receives the four digital signals from the ADC and compares them. The LDR signals are not equal except for normal incidence of sunlight. When there is a difference between LDR voltage levels the microcontroller programme drives the stepper motor towards normal incidence of sunlight.
The voltage and current generated by solar panel is then used to drive the Water Pump (Irrigation System Application).



2.6. Flow diagram: The flow diagram of tracking system are as follows



3. Result

In this Dual Axis Solar Tracker, when source light falls on the panel, the panel adjusts its position according to maximum intensity of light falling perpendicular to it.

The objective of the project is completed. This was achieved through using light sensors that are able to detect the amount of sunlight that reaches the solar panel. The values obtained by the LDRs are compared and if there is any significant difference, there is actuation of the panel using a servo motor to the point where it is almost perpendicular to the rays of the sun. This was achieved using a system with three stages or subsystems. Each stage has its own role.

The input stage is designed with a voltage divider circuit so that it gives desired range of illumination for bright illumination conditions or when there is dim lighting. The potentiometer was adjusted to cater for such changes. The LDRs were found to be most suitable for this project because their resistance varies with light. They are readily available and are cost effective. Temperature sensors for instance would be costly.

The control stage has a microcontroller that receives voltages from the LDRs and determines the action to be performed. The microcontroller is programmed to ensure it sends a signal to the servo motor that moves in accordance with the generated error.

The final stage was the driving circuitry that consisted mainly of the servo motor. The servo motor had enough torque to drive the panel. Servo motors are noise free and are affordable, making them the best choice for the project.

4. Conclusion

Dual Axis Solar Tracker, we've developed a demo model of solar tracker to track the maximum intensity point of light source so that the voltage given at that point by the solar panel is maximum. After a lot of trial and errors we've successfully completed our project and we are proud to invest some effort for our society. Now, like every other experiment, this project has couple of imperfections.

1. Our panel senses the light in a sensing zone, beyond which it fails to respond.
2. If multiple sources of light (i.e. diffused light source) appear on panel, it calculates the vector sum of light sources & moves the panel in that point. This project was implemented with minimal resources. The circuitry was kept simple, understandable and user friendly.

Avenues for further work

With the available time and resources, the objective of the project was met. The project is able to be implemented on a much larger scale. For future projects, one may consider the use of more efficient sensors, which should also be cost effective and consume little power. This would further enhance efficiency while reducing costs. If there is the possibility of further reducing the cost of this project, it would help a great deal. This is because whether or not such projects are embraced is dependent on how cheap they can be. Shading has adverse effects on the operation of solar panels. Shading of a single cell will have an effect on the entire panel because the cells are usually connected in series. With shading therefore, the tracking system will not be able to improve efficiency as is required.

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