Republic of Iraq
Ministry of Higher Education
Scientific Research
University of Diyala
Electronic Engineering Department

Design and Implementation of Solar Tracking System

A project

Submitted to the Department of Electronic Engineering University of Diyala in partial fulfillment of the Requirements for the Degree of Bachelor in Electronic Engineering

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2٠16 م \١٤٣٧هـ

بسم الله الرحمن الرحيم

إنْا جَعلناهُ قُرْاناً عَرَبياً لَعَلَكُمْ تَعْقِلونْ

صدق الله العظيم

سورة الزخرف الاية(٣)

1.1. introduction

Photovoltaic (PV) Solar Panels generate electricity by the Photovoltaic Effect. Discovered in 1839 by 19 year old Edmund Becquerel, the photovoltaic effect is the phenomenon that certain materials produce electric current when they are exposed to light. A fundamental understanding of how a photovoltaic panel works is essential in producing a highly efficient solar system. Solar panels are formed out of solar cells that are connected in parallel or series. When connected in series, there is an increase in the overall voltage, connected in parallel increases the overall current. Each individual solar cell is typically made out of crystalline silicon; although other types such as ribbon and thin-film silicone are gaining popularity.PV cells consist of layered silicon that is doped with different elements to form a p-n junction. The p-type side will contain extra holes or positive charges. The n-type side will contain extra electrons or negative charges. This difference of charge forms a region that is charge neutral and acts as a sort of barrier. When the p-n junction is exposed to light, photons with the correct frequency will form an extra electron/hole pair. However, since the p-n junction creates a potential difference, the electrons can’t jump to the other side only the holes can. Thus, the electrons must exit through the metal connector and flow through the load, to the connector on the other side of the junction.

1.2. **Solar cells**

Photovoltaic (PV) Solar Panels generate electricity by the Photovoltaic Effect., the photovoltaic effect is the phenomenon that certain materials produce electric current when they are exposed to light.

1.2.1 .PN Junction Semiconductors

For traditional PV solar panels two halves of one pure silicon crystal are doped with two different adopts (e.g. arsenic, gallium, aluminum, phosphorus). One half of the crystal is left electron deficient - i.e. the atoms it contains are short of electrons. This is called the p-type layer. The other half of the crystal has an excess of electrons - this is called the n-type layer.

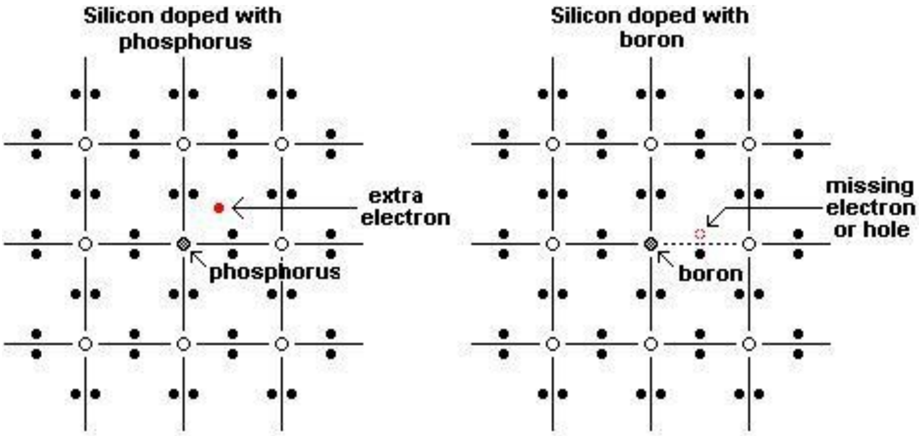


Fig (1-1) P-N junction semiconductor

where the two halves of the crystal meet is called a PN junction, and this doped crystal is a semiconductor.

Fig (1-2) depletion Region

Pictured above is a representation of PN junction semiconductor. The half labeled p- has a shortage of electrons so contains acceptor atoms each with a hole which could be 'filled' by an electron. The half labeled n- has excess electrons and so contains donor atoms which have an extra electron.

1.2.2 The Depletion Region

Where the two halves of the crystal meet, there is a depletion region, so called because it is depleted of charge carriers (the electrons and holes). Here electrons have moved from the n-type (negative) side to the p-type (positive) side of the crystal recombining with holes. Likewise holes have moved from the p-type side to the n-type side. As the silicon atoms themselves do not move, any holes which remain uncovered by electrons in the n-type side are left positively charged, and any electrons without holes to cover in the p-type side remain negatively charged. This leaves positive material close to the junction in the n-type side, and negative material close to the junction in the p-type side with a potential between the two sides of around 0.6-0.7 volts in a silicon PN junction.With this equilibrium position reached there are two equal and opposite electric currents flowing - holes in one direction and electrons in the other direction - across the depletion region.

1.3 How Solar Power Works

Solar cells, also called photovoltaic cells, are used to convert the electromagnetic radiation from the sun into electricity that can be used to power today's .The simplest photovoltaic cells are comprised primarily of three materials, silicon, and two doping agents. Silicon, which comprises a majority of the photovoltaic cell, has several chemical properties that make it well suited for the use in solar cells. It is the second most abundant element on Earth and has four valence electrons. Valence electrons, in layman's terms, can be thought of as "free" electrons. These "free" electrons are capable of bonding atoms together, as well as doing electro-magnetic work. In pure silicon, atoms bond together via their valence electrons to form a crystalline structure. However, because these valence electrons are tied up bonding atoms together, they cannot be used to produce electricity. This is the primary reason two doping agents are applied to the silicon material. Silicon, on its own, cannot produce electricity. Instead, atoms with greater than or less than four valence electrons are added to the silicon structure to produce an impurity. Adding this impurity to the silicon structure is what allows the flow of electricity. If a Phosphorous doping agent, which has five valence electrons, is added to a group of silicon atoms, it produces a crystalline structure with a "free" valence electron. This "free" valence electron can be used to generate electricity. This type of material is given the name "n-type material". The only thing needed is a place for this "free" electron to flow. No electrical work can be done if there is no potential between two points. The solution to this problem lies within our second doping agent. The second doping agent, unlike the first, has fewer than four valence electrons. As a result, when a structure of Silicon and Boron, an element with only three valence electrons, is formed, "holes" begin to develop within the material structure. These "holes" are the absence of an electron and are capable of being filled by other electrons within the structure. This material is given the name "p-type" material. Now we have two parts to this puzzle. One puzzle piece is Silicon doped with a material that produces "free" electrons. The second is Silicon doped with an element that produces "holes" within the structure that is capable of being filled by "free" electrons. A solar panel is comprised of both n-type material and p-type material. Both materials are sandwiched together to produce what is referred to as a "p-n junction".

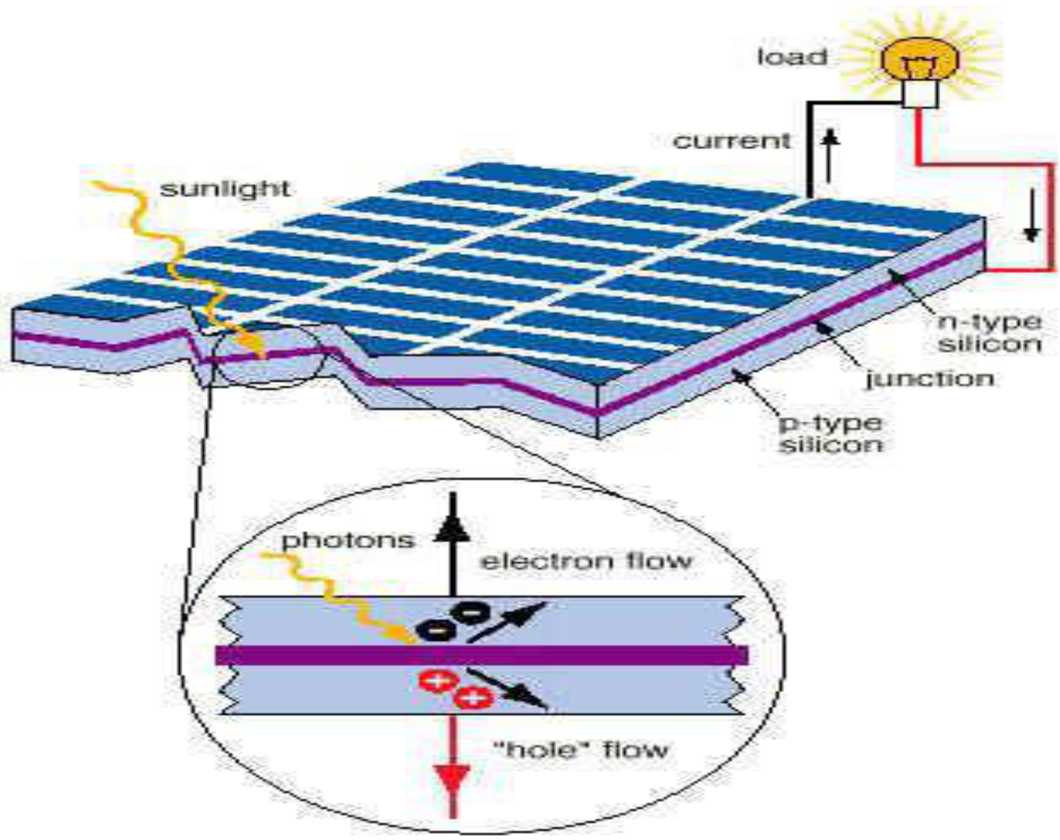


Fig (1-5) work of solar cell

1.4 Storage Batteries

There are two types of storage batteries being used for solar power storage, acid or alkaline .Alkaline batteries are made with nickel cadmium or nickel iron. The main difference between the two is nickel cadmium batteries have a faster discharge rate. However, nickel cadmium batteries are bad for the environment while the nickel iron does not have any environmental problems . Nickel iron batteries are slower to respond when a load is applied and , have to be broken in before they can reach their maximum charging capacity . . Both types of batteries will not freeze so there are no problems when operating in cold climates. The most common type of battery used in solar systems is the lead-acid battery. They are used because they have a low initial cost and are common

1.5.Types of solar cells

1.5.1.the four general types of silicon photovoltaic cells are:

1. Types of solar cells Single-crystal silicon.
2. Poly- crystal silicon (also known as multi-crystal silicon).
3. Ribbon silicon.
4. Amorphous silicon (abbreviated as "aSi," also known as thin film silicon).

1.5.2 Single-crystal silicon

Most photovoltaic cells are single-crystal types. To make them, silicon is purified, nelted, and crystallized into ingots. The ingots are sliced into tthin wafers to make ndividual cells. The cells have a uniform color, usually blue or black. Typically, nost of the cell has a slight positive electrical charge. A thin layer at the top has a light negative charge. The cell is attached to a base called a "backplane." This is ısually a layer of metal used to physically reinforce the cell and to provide an lectrical contact at the bottom. Since the top of the cell must be open to sunlight, a hin grid of metal is applied to the top instead of a continuous layer. The grid muse e thin enough to admit adequate amounts of sunlight, but wide enough to carry ıdequate amounts of electrical energy (Figure 1-6)

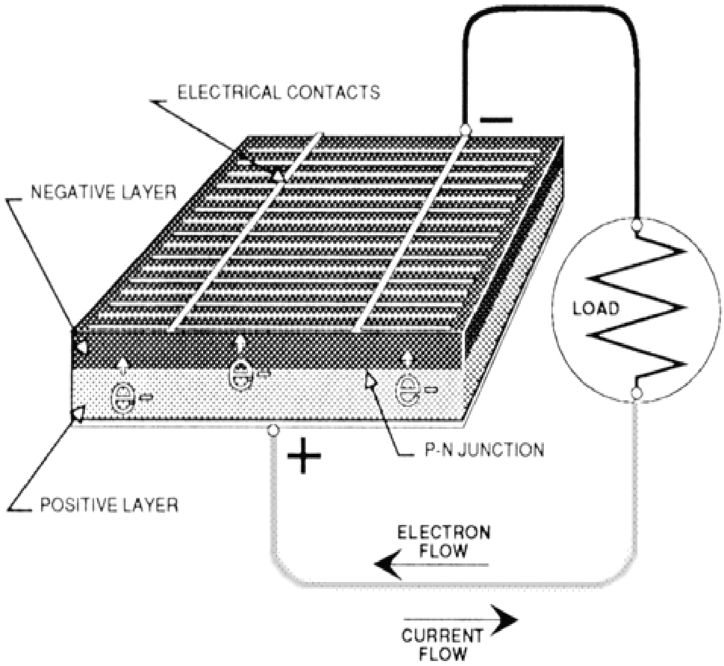


Fig (1-6) operation of a photovoltaic

Light, including sunlight, is sometimes described as particles called "photons." As sunlight strikes a photovoltaic cell, photons move into the cell.

1. When a photon strikes an electron, it dislodges it, leaving an empty "hole". The loose electron moves toward the top layer of the cell. As photons continue to enter the cell, electrons continue to be dislodged and move upwards (Figure 1-6)
2. If an electrical path exists outside the cell between the top grid and the backplane of the cell, a flow of electrons begins. Loose electrons move out the top of the cell and into the external electrical circuit. Electrons from further back in the circuit move up to fill the empty electron holes.
3. Most cells produce a voltage of about one-half volt, regardless of the surface area of the cell. However, the larger the cell, the more current it will produce.
4. Current and voltage are affected by the resistance of the circuit the cell is in. The amount of available light affects current production.The temperature of the cell affects its voltage. Knowing the electrical performance characteristics of a photovoltaic power supply is important, and is covered in the next section.

1.5.3.Polycrystalline silicon

1.Polycrystalline cells are manufactured and operate in a similar manner. The difference is that lower cost silicon is used. This usually results in slightly lower efficiency, but polycrystalline cell manufacturers assert that the cost benefits outweigh the efficiency losses.

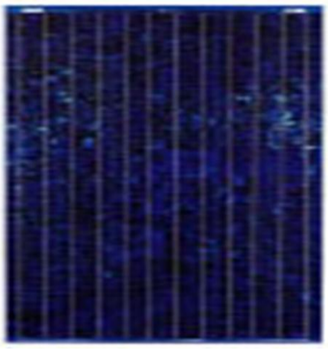


Fig (1-7) poly crystal cell

The surface of polycrystalline cells has a random pattern of crystal borders instead of the solid color of single crystal cells (Figure 1-7).

1.5.4 Ribbon silicon

Ribbon-type photovoltaic cells are made by growing a ribbon from the molten silicon instead of an ingot. These cells operate the same as single and poly-crystal cells.The anti-reflective coating used on most ribbon silicon cells gives them a prismatic rainbow appearance.

1.5.5 . Amorphous or thin film silicon

The previous three types of silicon used for photovoltaic cells have a distinct crystal structure. Amorphous silicon has no such structure. Amorphous silicon is sometimes abbreviated "Asia" and is also called thin film silicon.Amorphous silicon units are made by depositing very thin layers of vaporized silicon in a vacuum onto a support of glass, plastic, or metal.Amorphous silicon cells are produced in a variety of colors.

1.6 Tracking arrays

Arrays that track, or follow the sun across the sky, can follow the sun in one axis or in two (Figure 1-8). Tracking arrays perform best in areas with very clear climates. This is because following the sun yields significantly greater amounts of energy when the sun's energy is predominantly direct. Direct radiation comes straight from the sun, rather than the entire sky.Normally, one axis trackers follow the sun from the east to the west throughout the day. The angle between the modules and the ground does not change. The modules face in the "compass" direction of the sun, but may not point exactly up at the sun at all times.Two axis trackers change both their east-west direction and the angle from the ground during the day. The modules face straight at the sun all through the day. Two axis trackers are considerably more complicated than one axis types.

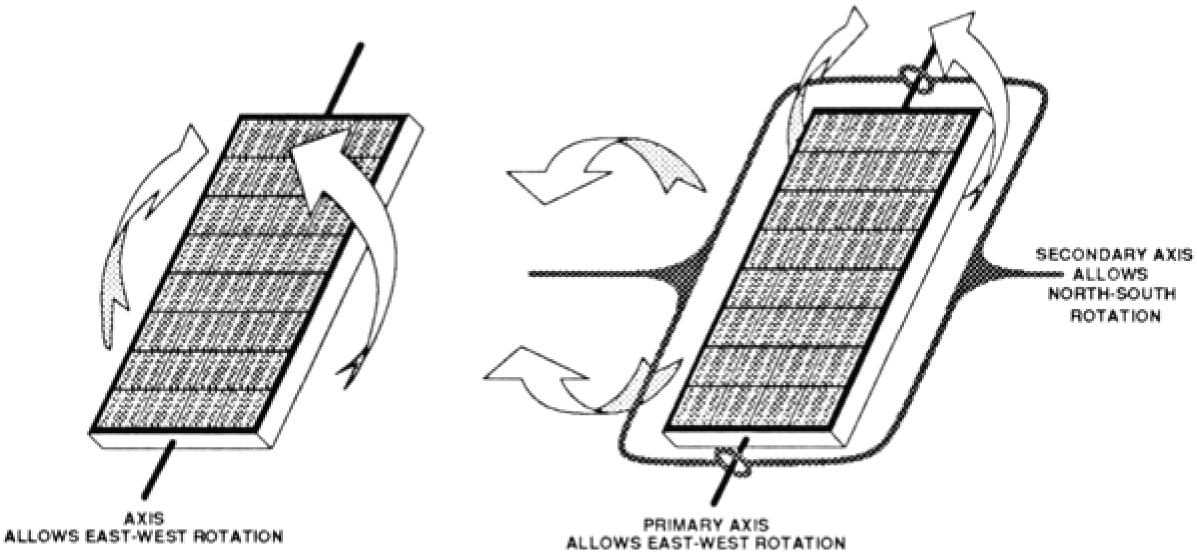


Fig (١ – ٨)

One Axis and Two Axis Tracking Arrays

Three basic tracking methods are used. The first uses simple motor, gear, and chain systems to move the array. The system is designed to mechanically point the modules in the direction the sun should be. No Sensors or devices actually confirm that the modules are facing the right way.The second method uses photovoltaic cells as sensors to orient the larger modules in the array. This can be done by placing a cell on each side of a small divider, and mounting the package so it is facing the same way as the modules (Figure 1-9).

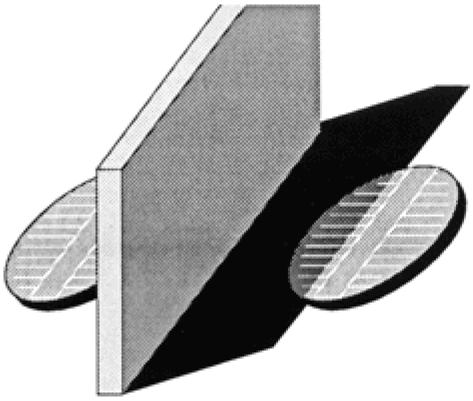


Fig (1-9) photovoltaic cells used as solar
Orientation sensor

An electronic device constantly compares the small current flow from both cells. If one is shaded, the device triggers a motor to move the array until both cells are exposed to equal amounts of sunlight. At night or during cloudy weather, the output of both sensor cells is equally low, so no adjustments are made. When the sun comes back up in the morning, the array will move back to the east to follow the sun again. Although both methods of tracking with motors are quite accurate, there is”parasitic" power consumption. The motors take up some of the energy the photovoltaic system produces’ method which has no parasitic consumption uses two small photovoltaic modules to power a reversible gear motor directly. If both modules are in equal sunlight, as shown in Figure (1-10), current flows through the modules and none flows through the motor.

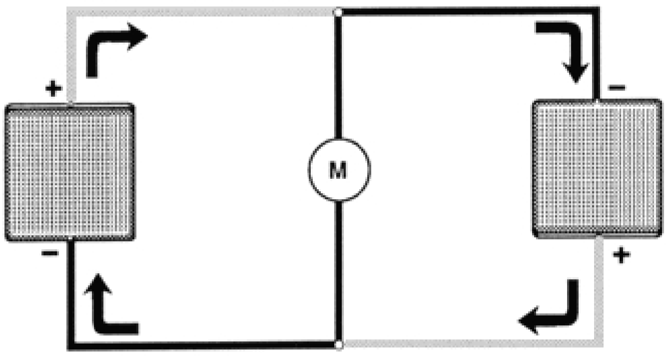
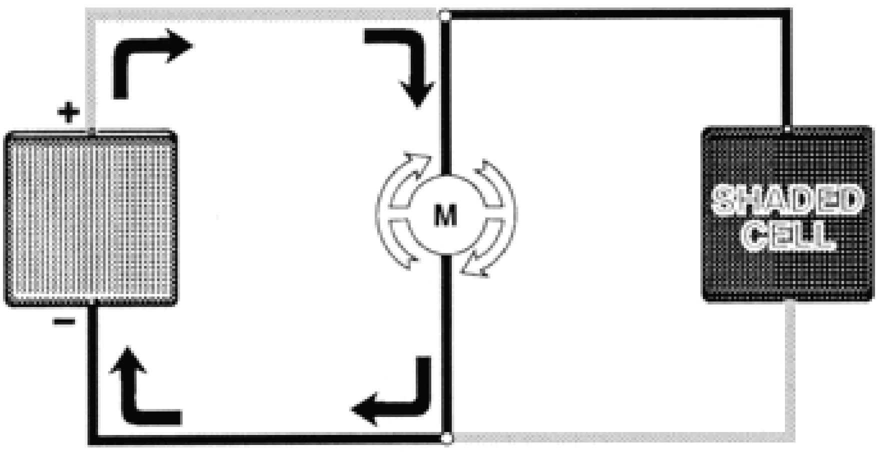


Fig (1-10) current flow with both modules

In equal Sun light

If the right module is shaded, it acts as a resistor (Figure 1-11). Now the current will flow through the motor, turning it in one direction.



Fig(1-11) current flow with one module shaded

If the other module, shown in Figure (1-12) on the left, is shaded, the current from the right module flows in the opposite direction. The motor will turn in the opposite direction as well.

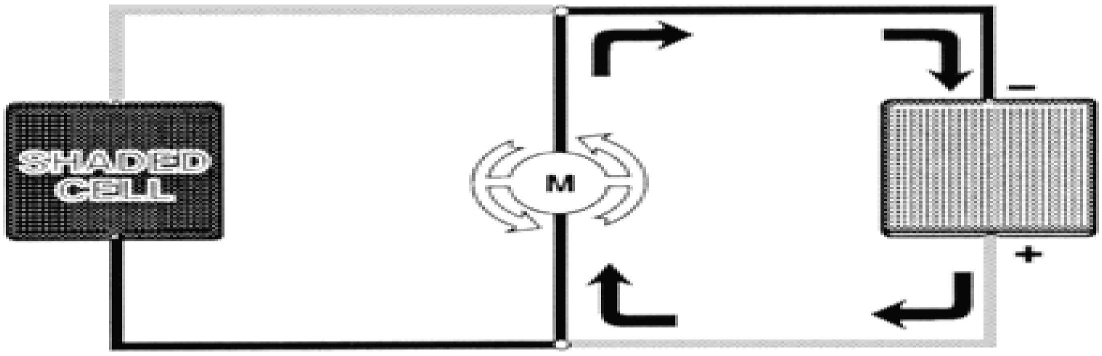


Fig (1-12) current flow with the other module shaded

The motor must be able to turn in both directions.

A third tracking method uses the expansion and contraction of fluids to move the array. Generally, a container is filled with a fluid that vaporizes and expands considerably whenever it is in the sun. It condenses and contracts similarly when in the shade. These "passive" tracking methods have proven to be reliable and durable, even in high wind situations. One system, the "SUN SEEKER" TM from Robbins Engineering, uses the pressure of the expansion and contraction to operate a hydraulic cylinder. Flexible piping from two containers filled with freon goes to opposite sides of a piston in the cylinder (Figure 1-13).

Fig (1.13) sun seeker system without modules

2.1 Introduction of solar tracker

A Solar tracker is a device used   for orienting a solar photovoltaic panel or lens towards the sun by using the solar or light sensors connected with the machine (ex: stepper motor, servo motor, gas filled piston).

2.2 Describe on the conventional solar tracker (fixed-mount)

Solar panel mounts is the most simple and least expensive type of solar panel mounting system, it will be completely stationary. The solar panels should always face the equator. (Due south in the northern hemisphere). True south varies from magnetic south. This can make a huge difference. For example, true south in eastern Washington State is 161 on a compass instead of 180. The angle of inclination (tilt) in degrees should be set to about your latitude. Slightly more than your latitude will favor the winter sun and slightly less will favor the summer sun. Below is example of fixed mount solar panel.

Figure (2.1)Mounted Solar Panel at Rooftop

2.3 How does the conventional solar tracker works? Discuss on the limitation.

It is a mechanical structure that moves with the suns movement over the course of the day. The sun's rays reflect directly on a solar reflector that initiates the physical movement of the solar modules into precise positions for the modules to create optimum energy production. The tracker will move your solar array into the needed position over the course of the day as the sun moves so it will produce the maximum Kw hours .The limitation the system is only work when there is a sunlight . the system has to focus on the intensity of light which it will able to track the maximum intensity of light so when the intensity of light decreasing the system will automatically change it direction and follow the movement of sun.

2.4 Type & characteristics of solar trackers.

2.4.1 Single axis trackers will track the sun from east to west on a single pivot point.

- ❖ Track the sun from east to west using a single pivot point
- ❖ Increase solar yield up to 34%
- ❖ Simple, effective design
- ❖ Low maintenance minimal points of failure
- ❖ Lower cost compared to dual axis

Minimal points of failure

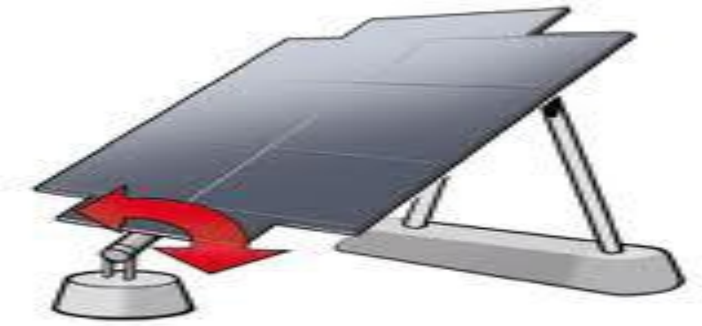


Fig (2.2) single axis horizontal

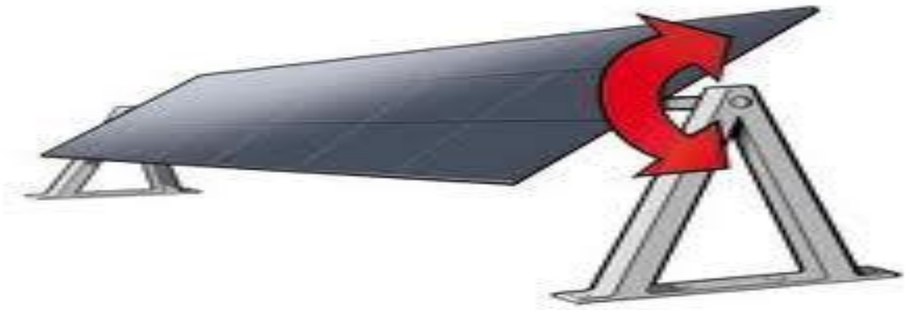


Fig (2.3) single axis vertical

2.4.2 Dual Axis trackers track east to west and tilt for north to south tracking.

1. Track the sun from east to west, and north to south using two pivot points

2. Increases solar yield up to 37%

3. Complex design – more motors and sensors

4. Higher maintenance

5. Higher cost due to additional parts and installation time

6. Additional points of failure.

Fig (2.4) dual axis vertically & horizontally

Dual axis trackers are more complex in design, using additional motors and sensors to track the sun. Dual axis also use an “eye” sensor which visually follows the sun, while the single axis tracks the sun using a predictable s

2.5 Why Track?

1. The most energy is absorbed when a surface’s face is perpendicular to the sun

2. Stationary mounted PV panels are only perpendicular to the sun once a day

3. Improved performance from each panel means fewer panels are need

2.6. Applications.

The Solar Tracking System has the following applications:-

1. The Solar Tracking system can be utilized for tracking the sun and thus pointing the solar panel at the point of maximum solar intensity.

2.It can also be utilized for automatic switching ON/OFF the street lights by mounting it over a street lights and switch ON whenever the solar intensity goes below a threshold value as dictated by the program.

3.It can also be employed with Sterling engine.

4. We can use this in some home appliance like solar water heater or something like that.

2.6 Advantages of solar electricity

1. The 89 petal-watts of sunlight reaching the earth's surface is plentiful – almost 6,000 times more - compared to the 15 terawatts of average power consumed by:-Humans. Additionally, solar electric generation has the highest power density (global mean of 170 W/m^2) among renewable energies.

2. Solar power is pollution free during use. Production end wastes and emissions are manageable using existing pollution controls. End-of-use recycling technologies are under development.

3. Facilities can operate with little maintenance or intervention after initial setup.

4. Solar electric generation is economically superior where grid connection or Fuel transport is difficult, costly or impossible. Examples include satellites; island Communities, remote locations and ocean vessels.

5. When grid-connected, solar electric generation can displace the highest cost Electricity during times of peak demand (in most climatic regions), can reduce grid loading and can eliminate the need for local battery power for use in times of darkness And high local demand; such application is encouraged by net metering. Time-of-use net metering can be highly favorable to small photovoltaic systems.

6. Grid-connected solar electricity can be used locally thus reducing Transmission/distribution losses (transmission losses were approximately 7.2% in 1995).

7. Once the initial capital cost of building a solar power plant has been spent, Operating costs are extremely low compared to existing power technologies.

2.7 Dis-advantages of solar electricity

1.Solar electricity is almost always more expensive than electricity generated by other sources.

2.Solar electricity is not available at night and is less available in cloudy weather conditions. Therefore, a storage or complementary power system is required.

3.Limited power density: Average daily isolation in the contiguous U.S. is 3-7 kW·h/m^2 and on average lower in Europe.

4.Solar cells produce DC which must be converted to AC (using a grid tie Inverter) when used in currently existing distribution grids. This incurs an energy loss of 4-12%.

3.1 design of track

Given the availability of parts used in the design of this project, as well as provided for in the domestic markets and ease linked and integrated electronic gathered a circle these parts are used below in the design of this project

3.2 parts of design

3.2.1 Solar panels

Fig (3.1) NTR5E3E Solar Module 175 Watt 24 volt

Electrical Characteristics	
Cells	Mono-crystal silicon
No. of Cells & Connections	72 cells in series
Open circuit voltage_Voc	44.4 V
Maximum Power Voltage – Vpm	35.4 V
Short Circuit Current – Isc	5.55 A
Maximum Power Current – Ipm	4.95 A
Maximum Power – Pm	175 W
Minimum Power	166.3 W
Encapsulated Cell Efficiency	16.4 %
Module Efficiency	13.5 %
Maximum System Voltage	1000V DC
Series Fuse Rating	10 A
Type of Output Terminal	Lead Wire with MC connector
Mechanical Characteristics	
Dimensions	1575L x 826W x 46D mm
Weight	17 kg

Table (3-1) Electrical Characteristics

3.2.2 Power Tech" REGULAR LINEAR ACTUATOR" Arm Dish Mover(TD)

Fig (3.2) regular linear actuator

3.2.3 Work Electronics card

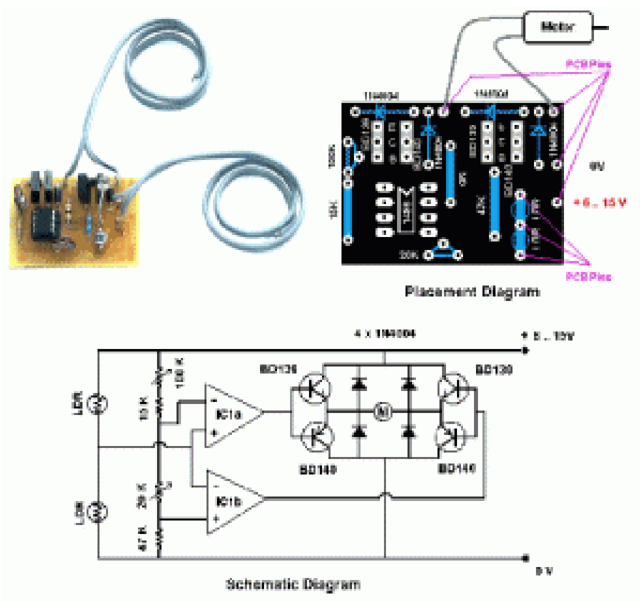
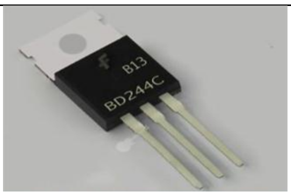
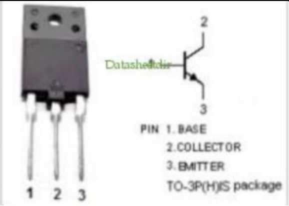
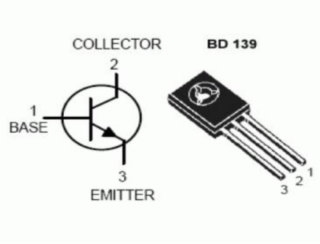


Fig (3.3) electronic cards

Fig (3.4) integration circuit

Trans. Type	Electronic manufacturer	Electronic description	Pictures illustrate
B13 BD 244C	Faire child semiconductor Corporation	Trans.GP BJT PNP 100V, 3A 3-Pin(3+tab) To-220AB Bulk	
B13 BD 243C	Faire child semiconductor corporation	BD243C series NPN 100v-6A	
MV140 BD	Microelectronics	Trans. GP PNP 80V, 3A,3-pin SOT-32 Tube	
O148 BD 139 ST MRC	Si semiconductor	NPN, P = 12w Vcb =80v Vce=8v Veb=5v Ic=1A	
LM324N 4183Y	0peration amplifier Comparator	4-channel Total V supply =(+5v=5,+/-5v=10)	

Features:-

1. Internally frequency compensated for unity gain
2. Large DC voltage gain 100 dB
3. Wide bandwidth (unity gain) 1 MHz (temperature compensated)
4. Wide power supply range:

Single supply 3V to 32V sor dual supplies ±1.5V to ±16V
5.Very low supply current drain (700 μA)—essentially independent of supply voltage
6.Low input biasing current 45 nA (temperature compensated) (temperature compensated)
7.Low input offset voltage 2 mV and offset current: 5 nA
8.Input common-mode voltage range includes ground
9.Differential input voltage range equal to the power supply voltage
10.Larg output voltage swing 0V to V+ − 1.5V

Fig (3.5) picture of project

Ten Benefits of Solar

A lot of technological and financial efforts are being made on solar energy research and development facilities, so why all the effort?

To find out the answer would probably be worthwhile to identify a small number of important benefits that will get them Basthaddamna Solar. Some of these benefits will be obvious while others may be in doubt, and some might be a surprise to some people, but regardless of the critics, must be our conviction that solar energy is an important source to develop and improve our lives.

Here we have ten of the benefits of solar enforced,

1. they are a natural source of energy and can be used to generate other forms of energy, we can use it as fuel for cars can be heating the water or to light their homes.

2. Through the use of solar panels we can generate electricity from the private Our source, and therefore will allow us to abandon the public electricity network, in other words, we will not be in need of power companies in the provision of electric power, and will not be forced to pay electricity bills.

3. Access to solar energy will not require later a lot of maintenance work, where they will be installing solar panels or docks once, and then will work as efficiently as possible, and it remains our only little to do to maintain the regularity of her work.

4. Solar energy product silent, certainly not cause photovoltaic panels any noise when you convert sunlight into usable electrical energy.

5.Solar energy supplies is almost a phenomenon, especially when using the solar panels that are installed on the roofs of buildings.

6.Many governments around the world to offer generous incentives and

cash rebates with respect to the installation of solar panels and water heating systems, the Sun card.
The governments of various countries recognize the importance of the production of electricity from renewable energy sources to the whole world, and accepted by as ideas as attractive as it is possible at the level of individuals.

7.If we produce enough solar such as electricity, or if we did not use all the electricity produced, we can sell it to service companies to get the balance of power, but this is rare in most cases, except in special cases such as traveling on vacation out of the house for a week or two, where the solar panels will continue to produce electrical energy will not be used by one.

8. Can large installations for the production of solar energy to produce solar energy, regardless of the weather, whether it is sunny or not, making them sustainable and reliable production of electricity, usually be the thermal installations where you store the heat generated, which makes use of them in case you do not sunny.

9. What continues to progress in solar technology continues more effective in economic terms to make them, and in addition to the decline in the cost of installing solar energy kits, will make solar energy costs continue to fall to become close to the cost of conventional electricity or produced from fossil fuels.

10. Solar power stations and solar panels in homes do not cause any emissions, nor any adverse impact caused to the environment.

Reference

[1] Report on Saudi Arabia's energy and economic statistics, as well as an up to data analysis of its oil and gas industry . United states Energy Information Administration, January 2000[report available on Internet ,MAY 2000:http://www.eia .doe.gov/emeu/cabs/saudfull.html].

[2]Huraib FS,Hasnain SM,Alawaji S.Lessons learned from solar energy projects in Saudi Arabic .
In :proceeding's of the world Renewable Energy Congeress IV,June 15-21 ;CO,USA,1996.
[3]Thompson C.summary of administration and management of October 1987.
[4] Alawaji s,SMIAI M. performance and development of pv –plant for water pumping and desalination

For remote areasin Saudi Arabia. In :proceedings of the World Renewable Energy Congress IV;

CO,USA,1996:441-6.

[5] Hasnain SM,Alajalan S. Coupling of PV-powered RO brackish water desalination plant with solar
Stills. Desalination – The International Journal on the Science and Technology of Desisting and

Water Purification 1998;116(1):57-64 [also presented at the Sixth Arab International Solar Energy
Conference (AISEC-6),1998 March 29-April 1;Muscat, Oman, and earned the Best Paper
Award certificate]

[6]Renewable Resource Data Center. Data available on the Internet:

, MAY 2000.http://rredc.nrel.gov/solar/newFdata/SandiFArabia

[7]Alawaji SH.Wind energy resource assessment in Saudi Arabia-1 :Network design and description.
Renewable Energy 1996;7(4):319-28.

[8]Alawaji SH,Eugenio Tunnel lighting –a remote area application for photovoltaic power system .

Washington, DC:ASES,1993.
[9]Smiai MS, AL Awaji S. Performance of variously tilted PV modules in the Riyadh area.In: Proceedings
Of the 12th European Photovoltaic Solar Energy Conference,vol.2,1994
;1938-41.

Abstract

This project will be a design and implementation of a polar single axis solar panel tracker. It will have a fixed vertical axis and an adjustable horizontal motor controlled axis. The tracker will actively track the sun and change its position accordingly to maximize the energy output. To prevent wasting power by running the position accordingly to maximize the energy output. To prevent wasting power by running the motor continuously, the tracker will correct its position after 2 to 3 degrees of misalignment the sensors will compare the light intensities of each side and move the panels until the tracker detects equal light on both sides. Additionally, it will prevent rapid changes in direction that might be caused by reflections, such as cars passing by. A rear sensor circuit is also incorporated to aid in repositioning the solar panels for the next sunrise. The gear motor will have overturn triggers to prevent the panel from rotating 360° and entangling wires. The motor control and sensing circuitry will run on batteries charged by the solar panel. This project will use one solar panels of approximately (150 cm) length and (50 cm) width to model larger panel with (12V, 5A, 50W). Setup is similar to an office swivel chair. The tracker will actively track the sun and change its position accordingly to maximize the energy output.