PHOTOVOLATIC TEST RIG

By

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DICLARATION OF ORIGINALITY

I declare that this report entitled “PHOTOVOLATIC TEST RIG” is my own work except as cited in the references. The report has not been accepted for any degree and is not being submitted concurrently in candidature for any degree or other award.

Signature : __________________________________________________________
Name : _____________________________________________________________
Date : _______________________________________________________________
Abstract

The photovoltaic test rig device is that testing the factors which affect the solar panels, it controls the rotation angle and the brightness then measure the outage power generated from the solar panel.

The microcontroller (ARDUINO UNO) was used to control the D.C motor and the source light.

Many experiments were done and we got results and analyzed them, we found the relation between the angle f rotation of the panel, the amount of brightness and the outage power.

The test rig was successfully design. We faced many problems because there were no experiments of similar device like ours. But we accessed to solve them.

We suggest many improvements to the device in the future working.
المستخلص

جهاز اختبار الطاقة الضوئية عبارة عن جهاز اختبار للعوامل المؤثرة على خلايا الطاقة الشمسية يتحكم في زاوية ميلان لوحة الطاقة الشمسية وأسهم الضوء الساقطة عليه ومن ثم يقيس الطاقة المتولدة. تم استخدام جهاز مايكركنترول للتحكم في ذلك بالإضافة لاستخدام مصدر خارجي للطاقة.

قمنا بعمل عدد من التجارب على ذلك وحصلنا على نتائج قمنا بتحليلها. تم تصميم الجهاز بنجاح لكن واجهتنا عدة عقبات في سبيل ذلك لعدم وجود تجارب سابقة على هذا التصميم لكن تم تجاوز كل هذه العقبات. كما قمنا بتقترح بعض التطورات للجهاز كجزء من العمل المستقبلي.
ACKNOWLEDGMENT

All praise is due to ALLAH Lord of all the worlds, the One God to whom praise is due forever.

I am heartily thankful to my beloved parents who had supported me, helped me, encouraged me, guided me to the right way and always been there for me when I need them.

I am deeply indebted to my supervisor Prof. SAMI SHARIEF for his patience, unlimited support, motivation, humility, continuous encouragement and great supervision.

Special thanks to my 012 friends in the Department of Electrical and Electronics Engineering for their appreciated support and I would like to say that I am really honored to be a student in such a Department.

My great respect and wishes for my partner ALI ABD ALAZEEM for her hard work, faithful sharing of knowledge, team spirit and invaluable assistance.
DEDICATION

To the soul of my teacher
Dr. Mohamed Osman
May he rest in peace
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1 Introduction

1.1 Overview:
This chapter is intended to give an overview about the project’s problem, background, Motivation and objectives. In addition, a thesis layout is presented at the end of the chapter.

1.2 Problem Statement:
There is no computerized device for testing the solar panel and reading the results

1.3 Motivation:
• To reach the most efficient and cost effective design for the test rig device
• To promote the knowledge about the effect of rotation angle and brightness of solar panel

1.4 Objectives:
• To control the rotation angle and brightness of light source on solar panel

1.5 Methodology:
Microcontroller and computer command prompt used to control the D.C motor and light source and we used A.D.C to read the outage of power

1.6 Report Layout:
This report is organized in 5 chapters:

Chapter 2 (Literature Review):
In this chapter we discuss generally the principle of renewable energy, solar energy, P.V panels, the efficiency and the analog to A.D.C convertor.

Chapter 3 (Methodology):
In this chapter we discuss the mechanism of the test rig device by talking about the ARDUINO UNO and the window lifting motor and amplifier LM358n. and computer command prompt and IR obstacle detector

Chapter 4 (implementation and results):
In this chapter we wrote the results of our experiments and draw curves show the relation between the factors.

Chapter 5 (Conclusion and Future Work):
This chapter talks generally about the objectives of the project, methodology of controlling the device, the problems we faced and the suggested solutions for further studies.
References: This part shows the titles of references and websites that helped in writing the thesis indexed by numbers.

Appendix A: This appendix contains the codes developed through the project.
2 Literature review

2.1 Renewable energy:

Renewable energy is generally defined as energy that comes from resources which are naturally replenished on a human timescale such as sunlight, wind, rain, tides, waves and geothermal heat.

The five major renewable energy resources are solar, wind, water (hydro), biomass, and geothermal.

Most renewable energy comes either directly or indirectly from the sun. Solar energy can be used directly for heating and lighting and generating electricity.

The sun's heat also drives the winds, whose energy, is captured with wind turbines. Then, the winds and the sun's heat cause water to evaporate. When this water vapor turns into rain or snow and flows downhill into rivers or streams, its energy can be captured using hydroelectric power.

Along with the rain and snow, sunlight causes plants to grow. The organic matter that makes up those plants is known as biomass. Biomass can be used to produce electricity, transportation fuels, or chemicals. The use of biomass for any of these purposes is called bioenergy.

Hydrogen also can be found in many organic compounds, as well as water. It's the most abundant element on the Earth. But it doesn't occur naturally as a gas. It's always combined with other elements, such as with oxygen to make water. Once separated from another element, hydrogen can be burned as a fuel or converted into electricity.

Not all renewable energy resources come from the sun. Geothermal energy taps the Earth's internal heat for a variety of uses, including electric power production, and the heating and cooling of buildings. And the energy of the ocean's tides come from the gravitational pull of the moon and the sun upon the Earth.

In fact, ocean energy comes from a number of sources. In addition to tidal energy, there's the energy of the ocean's waves, which are driven by both the tides and the winds. The sun also warms the surface of the ocean more than the ocean depths, creating a temperature difference that can be used as an energy source. All these forms of ocean energy can be used to produce electricity.
2.1.1 Importance of renewable energy:

There are many benefits of the Renewable energy. The key benefits are:

1-Environmental Benefits:

Renewable energy technologies are clean sources of energy that have much lower environmental impact than conventional energy technologies.

2-Energy for our children's children:

Renewable energy will not run out Ever Other sources of energy are finite and will someday be depleted.

3-Jobs and the Economy:

Most renewable energy investments are spent on materials and workmanship to build and maintain the facilities, rather than on costly energy imports.

4-Energy Security:

Energy security is the association between national security and the availability of natural resources for energy consumption. Access to cheap energy has become essential to the functioning of modern economies. However, the uneven distribution of energy supplies among countries has led to significant vulnerabilities.
2.2 Solar Energy:

2.2.1 Energy production in the sun (fusion):
The greatest increase in demand for energy is envisaged to come from developing countries where, with rapid urbanization, large-scale electricity generation will be required. With environmental requirements for zero or low CO\textsubscript{2} emission sources and the need to invest in a sustainable energy mix, new energy sources must be developed. Fusion will be available as a future energy option by the middle of this century, and should be able to acquire a significant role in providing a sustainable, secure and safe solution to tackle.

Fusion is the process which powers the sun and the stars. It is energy that makes all life on earth possible. It is called 'fusion' because the energy is produced by fusing together light atoms, such as hydrogen, at the extremely high pressures and temperatures which exist at the center of the sun (15 million °C). At the high temperatures experienced in the sun any gas becomes plasma, the fourth state of matter (solid, liquid and gas being the other three).

Plasma can be described as an ‘electr
cally-charged gas’ in which the negatively charged electrons in atoms are completely separated from the positively charged atomic nuclei (or ions). Although plasma is rarely found on earth, it is estimated that more than 99\% of the universe exists as plasma.

In order to replicate this process on earth, gases need to be heated to extremely high temperatures of about 150 million degrees °C whereby atoms become completely
The fusion reaction that is easiest to accomplish is the reaction between two hydrogen isotopes: deuterium, extracted from water and tritium, produced during the fusion reaction through contact with lithium. When deuterium and tritium nuclei fuse, they form a helium nucleus, a neutron and a lot of energy.

Every day, the sun radiates (sends out) an enormous amount of energy called solar energy. It radiates more energy in one day than the world uses in one year. This energy comes from within the sun itself.

Like most stars, the sun is a big gas ball made up mostly of hydrogen and helium gas. The sun makes energy in its inner core in a process called nuclear fusion.

It takes the sun’s energy just a little over eight minutes to travel the 93 million miles to Earth. Solar energy travels at the speed of light, or 186,000 miles per second, or $3.0 \times 10^8$ meters per second.

Only a small part of the visible radiant energy (light) that the sun emits into space ever reaches the Earth, but that is more than enough to supply all our energy needs.

Two ways to make electricity from solar energy are photovoltaics and thermal conversion.
2.2.2 Photovoltaic Electricity:

Photovoltaic comes from the words *photo*, meaning light, and *volt*, a measurement of electricity. Sometimes photovoltaic cells are called PV cells or solar cells for short. You are probably familiar with photovoltaic cells. Solar-powered toys, calculators, and roadside telephone call boxes all use solar cells to convert sunlight into electricity.

Solar cells are made up of silicon, the same substance that makes up sand. Silicon is the second most common substance on Earth. Solar cells can supply energy to anything that is powered by batteries or electric power. Electricity is produced when radiant energy from the sun strikes the solar cell, causing the electrons to move around. The action of the electrons starts an electric current. The conversion of sunlight into electricity takes place silently and instantly. There are no mechanical parts to wear out.

Compared to other ways of making electricity, photovoltaic systems are expensive and many panels are needed to equal the electricity generated at other types of plants. It can cost 10 to 30 cents per kilowatt-hour to produce electricity from solar cells. Most people pay their electric companies about 12.7 cents per kilowatt-hour for the electricity they use, and large industrial consumers pay less. Solar systems are often used to generate electricity in remote areas that are a long way from electric power lines.

In 2015, the Desert Sunlight solar project in California opened. It is the largest photovoltaic plant in the world, generating 550 megawatts of electricity—enough to power over 150,000 homes.

2.2.3 Solar Thermal Electricity

Like solar cells, solar thermal systems, also called concentrated solar power (CSP), use solar energy to produce electricity, but in a different way. Most solar thermal systems use a solar collector with a mirrored surface to focus sunlight onto a receiver that heats a liquid. The super-heated liquid is used to make steam to produce electricity in the same way that coal plants do. There are CSP plants in California, Arizona, Nevada, Florida, Colorado, and Hawaii. Some of the world’s largest CSP facilities are located in California. Solar energy has great potential for the future. Solar energy is free, and its supplies are unlimited. It does not pollute or otherwise.
About 43% of the total radiant energy emitted from the sun is in the visible parts of the spectrum.

The bulk of the remainder lies in the near-infrared (47%) and ultraviolet section (7%).

Less than 1% of solar radiation is emitted as x-rays, gamma waves, and radio waves.

Solar radiation reaches the Earth’s surface at a maximum flux density of about 1.0kWm$^{-2}$ in a wavelength band between 0.3 and 2.5um.

### 2.3 The Photovoltaic panels:

The photovoltaic (PV) effect is the basis of the conversion of light to electricity in photovoltaic, or solar, cells.

Described simply, the PV effect is as follows: Light, which is pure energy, enters a PV cell and imparts enough energy to some electrons (negatively charged atomic particles) to free them. A built-in-potential barrier in the cell acts on these electrons to produce a voltage (the so-called photovoltage), which can be used to drive a current through a circuit.

This description does not broach the complexity of the physical processes involved. Although it is impossible here to cover fully all the phenomena that contribute to a PV-generated current, it is possible to go deeply enough into these phenomena to understand how an effective cell works and how its performance can be optimized. We can do this by answering some fundamental questions about processes central to the working of a PV cell:

We shall take the silicon cell as a model. Silicon is a widely used, typical cell material; understanding the silicon cell is a good groundwork for understanding any PV cell. We shall start by reviewing some of silicon's basic atomic characteristics.
2.3.1 AN ATOMIC DESCRIPTION OF SILICON:

The silicon atom has fourteen electrons arranged in such a way that the outer four can be given to, accepted from, or shared with another atom. These four outer electrons are called valence electrons.

Large numbers of silicon atoms, through their valence electrons, can bond together to form a solid. As a solid, each silicon atom usually shares each of its four valence electrons with another silicon atom. Each basic silicon unit, forming a tetrahedral arrangement, thereby contains five atoms (the one silicon atom plus the four others it shares electrons with).

Each atom in the silicon solid is held in place at a fixed distance and angle with each of the atoms with which it shares a bond. This regular, fixed formation of a solid's atoms is called a crystal lattice. Solids can form from several differently shaped crystal lattices. (All solids are not crystalline, however; some can have multiple crystalline forms and/or none at all.)

For silicon, the atoms are located so as to form the vertices of a cube with single atoms centered at each of the faces of the cubic pattern. The cubic arrangement repeats throughout the crystal.

2.3.2 Working mechanism of photovoltaic panels:

When sunlight strikes a solar cell, electrons are knocked loose. They move toward the treated front surface. An electron imbalance is created between the front and the back. When a connector, like a wire, joins the two surfaces a current of electricity occurs between the negative and positive sides. These individual solar cells can be arranged together in a PV module and modules can be grouped together in an array. Some arrays are set on special tracking devices to follow sunlight all day long.
Photovoltaic cells, like batteries, generate direct current (DC), which is generally used for small loads (electronic equipment). When DC from photovoltaic cells is used for commercial applications or sold to electric utilities using the electric grid, it must be converted to alternating current (AC) using grid inverters, solid-state devices that convert DC power to AC.

### 2.3.3 Method to Calculate the Electricity Generated by Photovoltaic panels:

The global formula to estimate the electricity generated in output of a photovoltaic system is:

\[ E = A \times r \times H \times PR \]

- **E** = Energy (kWh)
- **A** = Total solar panel Area (m²)
- **r** = solar panel yield (%)
- **H** = Annual average solar radiation on tilted panels (shadings not included)
- **PR** = Performance ratio, coefficient for losses (range between 0.5 and 0.9, default value = 0.75)

\( r \) is the yield of the solar panel given by the ratio: electrical power (in kW) of one solar panel divided by the area of one panel.

The maximum Power is:

\[ P_{\text{max}} = I_{\text{mp}} \times V_{\text{mp}} = I_{\text{sc}} \times V_{\text{oc}} \times \text{FF} \]

Where:

- \( I_{\text{sc}} \) - short circuit current
- \( V_{\text{oc}} \) - open circuit voltage
- \( \text{FF} \) - fill factor

\( I_{\text{sc}} \) is proportional to irradiation - \( F = \text{I}_{\text{sc}} = F \times k \)
$V_{oc}$ and FF (for most common PV-panels) are in low binding with irradiation. So You can use:

$$P_{\text{max}} = I_{sc} * K_{vf} = F * K_f$$

instead of:

$$P_{\text{max}} = I_{sc} * V_{oc} * FF$$

This assumption is not good for low irradiance conditions. But possible errors will mask by other more essential factors.

### 2.4 Effects of Dust on the Performance of PV Panels:

Studies related to dust accumulation is critical as a further decrease in the (practical) system efficiency will tend to make PV Systems an unattractive alternative energy source, particularly for the larger domestic markets. Current research into characterizing Deposition of dust and their impact on PV system performance is Limited given the fact that dust deposition is a complex phenomenon and is influenced by diverse site-specific environmental and weather conditions. Dust is a term generally applying to minute solid particles with diameters less than 500 mm. occurs in the atmosphere from various sources such as dust lifted up by wind, pedestrian and vehicular movement, volcanic eruptions, and pollution. Dust would also refer to the minute pollens (fungi, bacteria and vegetation) and microfibers (from fabrics such as clothes, carpets, linen, etc.) that are omnipresent and easily scattered in the atmosphere and consequently settle as dust.

The characteristics of dust settlement on PV systems are dictated by two primary factors that influence each other, viz., the property of dust and the local environment. The local environment comprises site-specific factors influenced by the nature of prevailing (human) activities, built environment characteristics (surface finishes, orientation and height of installation), environmental features (vegetation type) and weather conditions. The property of dust (type – chemical, biological and electrostatic property, size, shape and weight), is as important as its accumulation/aggregation. Likewise, the surface finish of the settling surface (PV) also matters. A sticky surface (furry, rough, adhesive residues, electrostatic buildup) is more likely to accumulate dust than a less sticky, smoother one. It is also a well-known that dust promotes dust, i.e. with the initial onset of dust, it would tend attract or promote further settlement,
i.e. the surface becomes more amenable to dust collection. Taking into account the effect of gravity, horizontal surfaces usually tend to accumulate more dust than inclined ones. This however is dependent on the prevalent wind movements. Generally a low-speed wind pattern promotes dust settlement while a high-speed wind regime would, on the contrary, dispel dust settlement and have a cleaning. However, the geometry of the PV system in relation to the direction of wind movements can either increase/decrease the prospects of dust settlement at specific locations of the PV system. Dust is likely to settle in regions of low-pressure induced by high-speed wind movements over inclined/vertical surface. The dispersal of dust attributed to wind movements and geometry of PV system depends on the property of dust (weight, size, type).

![Diagram showing factors influencing dust settlement](image)

Figure 5: Factors influencing dust settlement

A study on the impact of dust on the transmittance of various glazing materials conducted by in the desert environment in Thar (India) also concurred with the fact that dust settlement decreases with increase in tilt from the horizontal. The reduction in transmittance for glass was found to be 19.17%, 13.81% and 5.67% for tilt angles 0°, 45° and 90°, respectively. The reduction in transmittance for acrylic was found to be 23%, 13.98% and 8.29% for tilt angles 0°, 45° and 90°, respectively.
To justify the shape of the typical behavior of the relative transmittance losses due to the presence of dust in the solar panels. The model must be based on the following assumptions:

a) Dust grains are modelled as spheres homogeneously distributed on the surface of the panel.

b) Each sphere has a reflection coefficient $R$, which accounts for both specular and diffused reflection.

c) Total incoming radiation from the Sun ($I_T$) is composed of direct radiation ($I_0$) and diffuse radiation ($I_D$). We consider that this latter radiation comes homogeneously from any direction and it is kept constant along the day. Note that the total irradiance received by a clean solar cell is given by:

$$GCC = I_0 \cos \theta + I_D$$

Where $\theta$ is the angle of incidence of direct radiation on the panel. The albedo radiation has been neglected.

d) In the dirty solar cell, any sphere of dust shadows the panel thus reducing the light reaching it. However not all radiation reaching the spheres is lost because part of it is reflected (a factor $R$) and can be partially recovered by the panel. Both effects, the shadowing and the recovery of light, depend on the angle of incidence of the direct radiation and thus vary along the day. On the other hand, there is no such dependence in the diffuse radiation since we assume that $I_D$ is constant along the day. To quantify the irradiance losses $GL$ due to the presence of dust in the solar cell we use:
GL (%) = 100× (GCC-GDC)/GCC

Where GCC is the irradiance value measured by the clean reference solar cell (W m⁻²) and GDC is the irradiance value measured by the dirty reference solar cell (W m⁻²).

2.5 Effect of light on solar panels Light energy:

The sun is the seat of thermonuclear processes and produces a vast amount of energy. The energy emitted by the sun is called solar energy or solar radiation. At any one time, the earth intercepts approximately 180 x10⁶ GW of light power. The amount of power received at a given geographical site varies in time: between day and night due to the earth’s rotation and between seasons because of the earth’s orbit. The amount of solar radiation intercepted by the earth, is called extraterrestrial Radiation.

The spectral distribution of extraterrestrial radiation is such that about half of it lies in the visible part of the electromagnetic spectrum. It produces daylight and is well perceived by the human vision system. Other parts of it are in the near-infrared and ultraviolet ranges.

The dividing of light waves according to their wavelength is called special distribution or the spectrum.
Table 1: Special distribution of the spectrum.

<table>
<thead>
<tr>
<th>Wavelength</th>
<th>Frequency</th>
<th>Examples of use</th>
</tr>
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<tbody>
<tr>
<td>Gamma rays</td>
<td>&lt;0.01 nm</td>
<td></td>
</tr>
<tr>
<td>X-rays</td>
<td>0.01–10 nm</td>
<td>Radiography</td>
</tr>
<tr>
<td>Ultraviolet</td>
<td>10–400 nm</td>
<td>Sun tanning, water purification</td>
</tr>
<tr>
<td>Visible</td>
<td>400–800 nm</td>
<td>Daytime vision, photosynthesis</td>
</tr>
<tr>
<td>Near infrared</td>
<td>800 nm–10 mm</td>
<td>Nocturnal vision</td>
</tr>
<tr>
<td>Thermal infrared</td>
<td>10 mm–1 mm</td>
<td>Heating, cooking</td>
</tr>
<tr>
<td>Microwaves</td>
<td>1 mm–10 cm</td>
<td>Microwave ovens</td>
</tr>
<tr>
<td>Radar waves</td>
<td>10 cm–1 m 3 GHz–300 MHz</td>
<td>Mobile telephone, speed detectors</td>
</tr>
<tr>
<td>Radio waves</td>
<td>&gt;1 m &lt;300 MHz</td>
<td>Radio, TV, telecommunications</td>
</tr>
</tbody>
</table>

The Sun’s light energy before it reaches the Earth’s atmosphere has been precisely measured by NASA at 1357 W/m². This is the instantaneous solar radiation (irradiance) received at a given moment above the Earth’s atmosphere at normal incidence (at a plane perpendicular to the Sun’s direction). This value is called the solar constant, although it does change slightly because of the small variations in the distance between the Earth and the Sun and in solar activity. But the full force of this energy does not reach the surface of our planet because it undergoes transformations due to absorption and diffusion while passing through the atmosphere.

- Direct radiation is received from the Sun in a straight line, without diffusion by the atmosphere
- Diffuse radiation consists of light scattered by the atmosphere.
Albedo is the part reflected by the ground, which depends on the environment of the location. Total radiation is simply the sum of these various contributions.

### 2.5.1 Photovoltaic conversion

The photovoltaic conversion phenomenon is: the conversion of light into electricity.

The mechanics of this energy conversion make use of three physical phenomena closely linked and simultaneous:

1. the absorption of light into the material,
2. the transfer of the energy of the photons into electrical charges,
3. collection of the current.

#### 2.5.1.1 The absorption of light in material:

a light ray striking a solid can undergo three optical events:

*Reflection* the light bounces off the surface of the object,

1. *transmission*: the light passes through the object,
2. *absorption*: the light penetrates the object and remains within it, its energy converted to another form.

#### Optical absorption of some photovoltaic materials:

*Table 2 Optical absorption of some photovoltaic materials*

<table>
<thead>
<tr>
<th>Material</th>
<th>$a$ (cm$^{-1}$)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Crystalline silicon</td>
<td>4.5 x 10$^3$</td>
</tr>
<tr>
<td>Amorphous silicon</td>
<td>2.4 x 10$^4$</td>
</tr>
<tr>
<td>Gallium arsenide</td>
<td>5.4 x 10$^4$</td>
</tr>
</tbody>
</table>

#### 2.5.1.2 The transfer of energy from protons into electric current:

The charges that produce the electric current under illumination are electrons, elementary negative charges, contained in the semiconductor matter.
The absorbed photons simply transfer their energy to the peripheral electrons of the atom, enabling them to liberate themselves from the attraction of their nucleus. These liberated electrons produce an electric current if they are attracted to the exterior, this physical phenomenon, called photoconductivity. The energy absorbed by electron is obtained by the next equation:

\[ E = h\nu = \frac{hc}{\lambda} \]

2.5.1.3 Charge collecting:
For the charges liberated by illumination to generate energy, they must move. They therefore have to be ‘attracted’ out of the semiconductor material into an electrical circuit. This charge extraction is achieved by a junction created in the semiconductor. The aim is to generate an electrical field within the material, which will align the negative charges on one side and the positive charges on the other. This is possible through the doping of the semiconductor. The junction of a silicon photo cell is made up of at least one part doped with phosphorus, called type ‘n’, joined to a part doped with boron, called type ‘p’.

2.6 Efficiency of solar panel:
Most of the energy that reaches a cell in the form of sunlight is lost before it can be converted into electricity. Maximal sunlight-to-electricity conversion efficiencies for solar cells range up to 30% (and even higher for some highly complex cell designs), but typical efficiencies are 10%-15%.

-The major phenomena that limit cell efficiency are:

1. Reflection from the cell's surface.
2. Light that is not energetic enough to separate electrons from their atomic bonds.
3. Light that has extra energy beyond that needed to separate electrons from bonds.
4. Light-generated electrons and holes (empty bonds) that randomly encounter each other and recombine before they can contribute to cell performance.
5. Light-generated electrons and holes that are brought together by surface and material defects in the cell.
6. Resistance to current flow.
7. Self-shading resulting from top-surface electric contacts.
8. Performance degradation at nonoptimal (high or low) operating temperatures.

2.6.1 REFLECTION:
Some of the sunlight that strikes a solar cell is reflected. Normal, untreated silicon reflects 36% (or more) of the sunlight that strikes it. This would be a horrendous loss in terms of efficiency. Fortunately, there are several ways of treating cell surfaces to cut reflection drastically. Among them are chemically coating and texturing the surface.

2.6.2 Light with little or TOO MUCH ENERGY
Efficiency losses are associated with light that either is not energetic enough or too energetic,
-Light entering a solar cell can:
   a. Go right through it.
   b. Become absorbed, generating heat in the form of atomic vibrations.
   c. Separate an electron from its atomic bond, producing an electron-hole pair.
   d. Produce an electron-hole pair but have an excess of energy, which then becomes heat.

At an energy that is specific to the material and its atomic structure, light can free an electron from its atomic bond (c) rather than just cause that bond to vibrate. Different solar cell materials have a different characteristic energy at which electrons are freed (so called electron-hole generation).
For silicon, the energy is 1.1 electron volts.

2.6.3 RECOMBINATION OF ELECTRON HOLE PAIRS:
Recombination of electrons and holes before they can contribute to an electric current are two types:
2.6.3.1 **Direct Recombination.**

Direct recombination is relatively rare. It happens when an electron and a hole randomly encounter each other, and the electron falls back into the hole. Thus, the material's original bonds are reasserted and the electron's and hole's energies are lost as heat.

2.6.3.2 **Indirect Recombination.**

Indirect recombination can occur in many ways. ("Indirect" means that the electron and hole do not just run into each other and combine-the interaction is influenced by further circumstances.) Contrary to what one might expect, indirect recombination is much more of a problem in solar cells than direct recombination. Experiment has shown that electrons and holes are lost via recombination in about a hundredth of a second, on average.

2.6.4 **RESISTANCE:**

Resistance is ever-present in most electrical elements, where the flow of current is accompanied by collisions between charge carriers and the material the charges are flowing through. Electric resistance can be so great that it can be used to provide heat (stoves) or light (light bulbs). Thus, resistance losses in cells are equivalent to energy losses; whatever a solar cell loses because of resistance degrades its efficiency.

Resistance losses in solar cells occur predominantly in three places: in the bulk of the base material, in the narrow top-surface layer typical of many cells, and at the interface between the cell and the electric contacts leading to an external circuit.

2.6.5 **SELF-SHADING:**

It refers to losses engendered by the electrical grid on top of the cell, which reflects light that otherwise would enter the cell. Since resistance is maximal to lateral movement in the top-surface layer of the cell, there must be many charge removal points to minimize resistive effects. Thus, electric contacts are not placed far from the charge carriers. The result is a grid-like geometry narrow fingers of conductive material spread over the front surface of the cell. This electric grid shades a portion of the cell's top surface: A typical shading loss percentage is 8%, but some cells have losses as high as 20% and others as low as 3%. 
2.6.6 TEMPERATURES:

Solar cells work best at certain temperatures, according to their material properties: Some materials are more appropriate for use in orbit around the earth, some for terrestrial uses, and others for high temperature applications either under concentrated sunlight or in space near the sun.

Normal terrestrial temperatures, 25°C, silicon's efficiency compares favorably with other materials; but at high temperatures, 200°C for instance, silicon's efficiency has dropped to 5%, whereas the other materials are near 12%. Silicon is a good material for ambient temperature terrestrial uses; it fails in high temperature applications.

2.6.7 METHODS TO INCREASE THE EFFICIENCY OF PHOTOVOLTAIC SYSTEM:

2.6.7.1 The Maximum Power Point Tracker:

Maximum Power Point Tracker (MPPT) is often used to increase the energy conversion efficiency for a photovoltaic energy source. The maximum power is transferred to the load when the impedance source matches the load one. To accomplish this objective, a switching converter is placed between the PV source and the load.

Types of solar trackers and tracking technologies:

2.6.7.1.1 Active tracker:

Active trackers make use of motors and gear trains for direction of the tracker as commanded by the controller responding to the solar direction as tracked by sensors.

2.6.7.1.2 Passive tracker:

Passive trackers use a low boiling point compressed gas fluid driven to one side or the other to cause the tracker to move in response to an imbalance.
2.6.7.1.3 Chronological solar tracking

A chronological tracker counteracts the rotation of the earth by turning at the same speed as the earth relative to the sun around an axis that is parallel to the earth’s.

2.6.7.1.4 Single axis trackers

Single axis trackers have one degree of freedom that act as the axis of rotation. The axis of rotation of single axis trackers is aligned along the meridian of the true North.

2.6.7.1.5 Dual axis trackers

Dual axis trackers have two degrees of freedom that act as axes of rotation. These axes are typically, normal to each other.

Tracking angles

- The Zenith angle is the angle between the direction of the sun (direction of interest) and the zenith (straight up or directly overhead).
- The Azimuth angle is measured clockwise from true north to the point on the horizon directly below the object.
- The sun's elevation or altitude is the angle from the horizontal plane and the Sun's central ray or just the compliment of the Zenith angle (90 - Zenith angle).

2.6.8 Efficient of solar panels

The efficiency is the parameter most commonly used to compare performance of one solar cells to another. It is the ratio of energy output from the solar panel to
input energy from the sun. In addition to reflecting on the performance of solar cells, it will depend on the spectrum and intensity of the incident sunlight and the temperature of the solar cell. As a result, conditions under which efficiency is to be measured must be controlled carefully to compare performance of the various devices.

The efficiency of solar cells is determined as the fraction of incident power that is converted to electricity. It is defined as:

\[
\eta = \frac{V*I*FF}{P}
\]

\[
P = V*I*FF
\]

Where: V is the open-circuit voltage;
I is the short-circuit current
FF is the fill factor
\( \eta \) is the efficiency.

2.7 Modeling of a PV Generator:

The PV generator current and, consequently, the power vary with the cells’ operation temperature T and irradiance Es. A photovoltaic array can be represented by an equivalent circuit composed of a current generator, a sensitive diode D to the light, a series resistor Rs and a shunt resistance.

Equivalent circuit of a PV cell

Where:

Iph is the photocurrent source equal to the short-circuit current Icc,
Id is the generated current,
Io is the saturation current of a solar array,
q is the electron charge,
KB is the Boltzmann’s constant,
V and P-V characteristics of a solar module under varied solar irradiance

V and P-V characteristics of a solar module under varied temperatures

Influence of the series resistance Rs on the I-V and P-V characteristics of a PV module
3 Methodology

3.1 Introduction:

In this chapter, the design and working mechanism of TEST RIG components device will be presented.

The device changes the rotation angle of the solar panel and increasing or decreasing light from power supply on the solar panel and reading the output voltage by an analog read pin (ADC).

Arduino Uno which is an open-source electronics platform based on easy-to-use hardware and software will be used to control a DC light with Arduino using relay module. Also it will be building DC motor controller using relay module.

To read the output voltage from solar panel we will Read the value from the specified analog pin called ADC.

We can say that the device consists of these main components:

1- Arduino Uno
2- Window lifting motor
3- Amplifier:LM358n
4- 3 Channel relay module
5- IC: (ULN2803-SMD)
6- IR Obstacle Detector

3.2 Arduino Uno:

- Arduino microcontroller module with USB connection
  - Based on the ATmega328 (removable DIP IC)
  - Variety of I/O pins including analog, digital, PWM and more

3.2.1 Overview:

The Arduino Uno is a microcontroller board based on the ATmega328 microchip. It has 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.

The main reason to go for Arduino Uno is that the UNO in programming this device that it is the best board to get started with electronics and coding.

### 3.2.2 SCHEMATICS:

![Figure 10 arduino uno](image)

Each of the 14 digital pins on the Uno can be used as an input or output, using pin Mode (), digital Write (), and digital Read () functions. They operate at 5 volts. Each pin can provide or receive 20 mA as recommended operating condition and has an internal pull-up resistor (disconnected by default) of 20-50k ohm. A maximum of 40mA is the
value that must not be exceeded on any I/O pin to avoid permanent damage to the microcontroller.

3.2.3 PROGRAMMING:

To send command directly from computer to our ARDUINO UNO, computer command prompt is used. The ATmega328 on the Arduino/Genuine Uno comes preprogrammed with a bootloader that allows you to upload new code to it without the use of an external hardware programmer. It communicates using the original STK500 protocol.

3.2.4 Power and memory:
The Arduino Uno board will be powered via the USB connection or with an external power supply no problem. The power source is selected automatically. External (non-USB) power can come either from an AC-to-DC adapter (wall-wart) or battery. The adapter can be connected by plugging a 2.1mm center-positive plug into the board's power jack. Leads from a battery can be inserted in the GND and VIN pin headers of the POWER connector.

The input voltage to the Arduino UNO board when it's using an external power source (as opposed to 5 volts from the USB connection or other regulated power source). Supplying voltage through this pin. This pin outputs a regulated 5V from the regulator on the board.

If supplied with less than 7V, however, the 5V pin may supply less than five volts and the board may become unstable. If using more than 12V, the voltage regulator may overheat and damage the board. The recommended range is 7 to 12 volts.

3.2.5 Differences with other boards:-
The Uno differs from all preceding boards in that it does not use the FTDI USB-to-serial driver chip. Instead, it features the Atmega16U2 (Atmega8U2 up to version R2) programmed as a USB-to-serial converter.
3.2.6 Technical specification

<table>
<thead>
<tr>
<th>Technical specs</th>
<th>ATmega328P</th>
</tr>
</thead>
<tbody>
<tr>
<td>Microcontroller</td>
<td>ATmega328P</td>
</tr>
<tr>
<td>Operating Voltage</td>
<td>5V</td>
</tr>
<tr>
<td>Input Voltage (recommended)</td>
<td>7-12V</td>
</tr>
<tr>
<td>Input Voltage (limit)</td>
<td>6-20V</td>
</tr>
<tr>
<td>Digital I/O Pins</td>
<td>14 (of which 6 provide PWM output)</td>
</tr>
<tr>
<td>PWM Digital I/O Pins</td>
<td>6</td>
</tr>
<tr>
<td>Analog Input Pins</td>
<td>6</td>
</tr>
<tr>
<td>DC Current per I/O Pin</td>
<td>20 mA</td>
</tr>
<tr>
<td>DC Current for 3.3V Pin</td>
<td>50 mA</td>
</tr>
<tr>
<td>Flash Memory</td>
<td>32 KB (ATmega328P)</td>
</tr>
<tr>
<td>SRAM</td>
<td>2 KB (ATmega328P)</td>
</tr>
<tr>
<td>EEPROM</td>
<td>1 KB (ATmega328P)</td>
</tr>
<tr>
<td>Clock Speed</td>
<td>16 MHz</td>
</tr>
<tr>
<td>LED_BUILTIN</td>
<td>13</td>
</tr>
<tr>
<td>Length</td>
<td>68.6 mm</td>
</tr>
<tr>
<td>Width</td>
<td>53.4 mm</td>
</tr>
<tr>
<td>Weight</td>
<td>25 g</td>
</tr>
</tbody>
</table>

3.3 Controlling windows lifting motor by Arduino Uno:

Thanks to its simple and accessible user experience, Arduino has been used in controlling our dc motor by using

1- IR Obstacle Detector: to stop the solar panel when reaching the determined angle that is interred by the computer through:

2- Computer command prompt is used which is an interface between computer and Arduino Uno (H bridge).
However for power supplied it is found that the control motor will be needed. Furthermore control the motor movement directly from the code will be given by the previous interface. Organizing rotating to increase or decrease the angle is done by relays modules. Next will be explaining about the role and mechanism of each part has been presented.

3.3.1 3 Channel relay module:
A Relay is an electrically operated switch. Many relays use an electromagnet to mechanically operate the switch and provide electrical isolation between two circuits. In this project there is no real need to isolate one circuit from the other, but we will use an Arduino UNO to control the relay.

Controlling of dc motor by 2 relays and the third one will be for protection. The motor either rotates the solar panel up or down in our device changing the rotating angle.

The Relay no 1 in board turns on when power is applied (via the V CC pin). When power is applied to one of the Channel pins, the respective green light goes on, plus the relevant relay will switch from NC to NO. When power is removed from the channel pin, the relay will switch back to NC from NO. When there is no power applied to the CH1 pin, the CH2 will be on, and the Green CH1 will be off.

In our code we also show what happens when you apply power to a channel (CH3) when there is nothing connected to the relay terminals. This is useful for troubleshooting the relays, and knowing what state the relay is in (NC or NO). NC stands for normally closed (or normally connected) NO stands for normally open (or normally disconnected)

<table>
<thead>
<tr>
<th>Relay 1</th>
<th>Relay 2</th>
<th>Possibility</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>0</td>
<td>Enable</td>
</tr>
<tr>
<td>0</td>
<td>1</td>
<td>enable</td>
</tr>
<tr>
<td>1</td>
<td>1</td>
<td>disable</td>
</tr>
<tr>
<td>0</td>
<td>0</td>
<td>Disable</td>
</tr>
</tbody>
</table>
The last two cases will give short circuit so the third relay is added with delay to avoid that as it is written in code.

### 3.3.2 Connecting the relays to control the motor through these steps:

**Step 1: Connecting the Motor & Power Supply:**

Motor positive - Relay switch 1 COM input

Motor negative - Relay switch 2 COM input

In this project, both wires from the motor will connect to both of the COM (middle) inputs of the relay switches.

External power supply will be used to power the motor. This can be changed to control the speed of the motor.

**Step 2: Connecting the Arduino:**

**Connection:**

*Arduino* 5v pin - Relay module VCC pin

*Arduino* GND pin - Relay module GND pin

*Arduino* pin#7 - Relay module IN1

*Arduino* pin#8 - Relay module IN2

*Arduino* pin#9 - Relay module IN2

After we finish connecting the motor, all we need to do is power the relay switch module itself. Using the Arduino, we can connect the wires and send signals to activate the relay switches.
Step 3: Uploading the Code:

For controlling the rotation direction, we inverse the direction of the current flow through the motor and the most common method has been done in our device of doing that is by using an H-Bridge. An H-Bridge circuit contains four switching elements, transistors, with the motor at the center forming an H-like configuration. By activating two particular switches at the same time we can change the direction of the current flow, thus change the rotation direction of the motor.

Step 4: Done!

3.3.3 IR Obstacle detector:

The device consists of an Infrared Transmitter, an Infrared Detector, and support circuitry. It only requires three connections. When it detects an obstacle within range it will send an output low.

IR Obstacle Detection Module Pin Outs

The drawing and table below identify the function of module pin outs, controls and indicators.

![Figure 11 IR obstacle detector](image)
Arduino Uno with IR Obstacle

Using the picture below. Connecting the circuit will be like this:

<table>
<thead>
<tr>
<th>Pin, Control Indicator</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Vcc</td>
<td>3.3 to 5 Vdc Supply Input</td>
</tr>
<tr>
<td>Gnd</td>
<td>Ground Input</td>
</tr>
<tr>
<td>Out</td>
<td>Output that goes low when obstacle is in range</td>
</tr>
<tr>
<td>Power LED</td>
<td>Illuminates when power is applied</td>
</tr>
<tr>
<td>Obstacle LED</td>
<td>Illuminates when obstacle is detected</td>
</tr>
<tr>
<td>Distance Adjust</td>
<td>Adjust detection distance. CCW decreases distance. CW increases distance.</td>
</tr>
<tr>
<td>IR Emitter</td>
<td>Infrared emitter LED</td>
</tr>
<tr>
<td>IR Receiver</td>
<td>Infrared receiver that receives signal transmitted by Infrared emitter.</td>
</tr>
</tbody>
</table>
3.4 Controlling dc light

3.4.1 PWM:

Pulse Width Modulation, or PWM, is a technique for getting analog results with digital means. Digital control is used to create a square wave, a signal switched between on and off. This on-off pattern can simulate voltages in between full on (external source Volts (30)) and off (0 Volts) by changing the portion of the time the signal spends on versus the time that the signal spends off. The duration of "on time" is called the pulse width. To get varying analog values, we will change pulse width. Repeating this on-off pattern fast enough with an LED for example, the result is as if the signal is a steady voltage between 0 and 30v controlling the brightness of the LED.
3.4.2 **Arduino LM358 Op Amp PWM to Voltage out Tutorial**

LM358 Pin Outs:

You’ll be using an LM358. If you use an eight pin DIP, the pins are as show below:

![LM358 Pin Diagram](image)

**Figure 13:arduino LM358**

Here we will use one output and we will control of gain by the value of r2.

3.4.3 **Connecting LM358 Circuit to our Arduino**

A common external supply 30V would work.
BY combining these two methods: pulse width modulation and H Bridge there was be able to control of the rotation angle of the solar panel and the brightness. To read the output voltage we will use:

### 3.4.3.1 Analog read pin (ADC):

Reads the value from the specified analog pin. The Arduino board contains a 6 channels (8 channels on the Mini and Nano, 16 on the Mega as here), Among those any one or all of them can be used as inputs for analog voltage. This means that it will map input voltages between 0 and 5 volts into integer
values between 0 and 1023.

Figure 153.4.3.1 Analog read pin (ADC)
4 Results

4.1 Introduction:

The main objective for designing this device is measuring the effects of the rotation angle of the solar panel and the brightness on the outage power that is generated from photovoltaic solar energy.

There have been done many experiments explain the relationship between the rotation angle and the brightness and the outage power.

Every once we fixed either the angle or brightness and changing the another factor

As well reading the outage power.

<table>
<thead>
<tr>
<th>ANGLE AND ROTATION VS VOC</th>
<th>0</th>
<th>10</th>
<th>20</th>
<th>30</th>
<th>40</th>
<th>50</th>
<th>60</th>
<th>70</th>
<th>80</th>
<th>90</th>
</tr>
</thead>
<tbody>
<tr>
<td>120</td>
<td>15</td>
<td>14.5</td>
<td>12</td>
<td>10</td>
<td>7</td>
<td>3</td>
<td>1</td>
<td>.5</td>
<td>.1</td>
<td>0</td>
</tr>
<tr>
<td>100</td>
<td>14.7</td>
<td>14</td>
<td>11.3</td>
<td>9</td>
<td>5.7</td>
<td>1.5</td>
<td>.7</td>
<td>.3</td>
<td>.1</td>
<td>0</td>
</tr>
<tr>
<td>80</td>
<td>13.5</td>
<td>13.2</td>
<td>10</td>
<td>7</td>
<td>3.3</td>
<td>1</td>
<td>.3</td>
<td>.2</td>
<td>.1</td>
<td>0</td>
</tr>
<tr>
<td>60</td>
<td>10</td>
<td>9</td>
<td>6</td>
<td>3</td>
<td>1</td>
<td>.1</td>
<td>.1</td>
<td>.1</td>
<td>.1</td>
<td>0</td>
</tr>
<tr>
<td>40</td>
<td>5</td>
<td>4</td>
<td>2</td>
<td>1</td>
<td>.1</td>
<td>.1</td>
<td>.1</td>
<td>.1</td>
<td>.1</td>
<td>0</td>
</tr>
<tr>
<td>20</td>
<td>.8</td>
<td>.5</td>
<td>.3</td>
<td>.1</td>
<td>.1</td>
<td>.1</td>
<td>.1</td>
<td>.1</td>
<td>.1</td>
<td>0</td>
</tr>
</tbody>
</table>

Table 3 the output data of the test
4.2 Discussion:

- Design of the test rig device has been developed and approved. The results obtained from reading the outage at every changing in angle or brightness as in the previous curves showed the effect of each other on the outage power.
- We have noticed that the outage increases when the panel rotates into horizontal level, and it was decrease when the panel rotates into vertical level.
Also we have noticed the effect of the amount of brightness on the outage power, when there is little amount of brightness, the outage power approximately equal zero regardless of the rotation angle of the panel.
5 Conclusions and further studies

5.1 Introduction:

The main aim of this project was investigation on the effect of dust on the solar panel. Dust reduces the amount of brightness which depends mainly on the rotation angle of the solar panel.

Because there was no any device to test this effect; a test rig was designed.

We used microcontroller (ARDUINO UNO) to generate signals in order to control the rotation angle of solar panel and brightness using external power supply through technique like pulse width modulation(PWM) and (H) bridge.

Many experiments have been done, by changing the angle of rotation and the amount of brightness we discovered the relationship between them and the amount of outage power which increases due to brightness and decreases when the angle of rotation approximately near the vertical level.

5.2 Further studies:

- Improving the device to be suitable for measuring all factors that affect the solar panel like dust by adding parts separate it according to its size.
- Computerize the device to do experiments outdoor on long time and saving data, analysis it and draw curves that explains the relationship between factors and outage power.
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APPENDIX A - SOFTWARE

//the H bridge takes two outputs from the Arduino to control the motor.
int motorPin0 = 2;
int motorPin1 = 3;
// there is one switch
//declare the state variable
int state = 0;
int lamp = 0;
int IR=4;
int IRvalue = HIGH;
// the setup routine runs once when you press reset:
void setup() {
  // initialize serial communication at 9600 bits per second:
  Serial.begin(9600);
  pinMode(IR,INPUT);
  pinMode(3,OUTPUT);
  pinMode(13,OUTPUT);
  pinMode(7,OUTPUT);
  pinMode(8, OUTPUT);
  digitalWrite(13,OUTPUT);
  digitalWrite(7,OUTPUT);
  digitalWrite(8,OUTPUT);
}
// the loop routine runs over and over again forever:
void loop() {
  // read the input on analog pin 0:
if (Serial.available() ) {
    int serinput = Serial.read()-'0';
    switch (serinput) {
      case 8:
        //do something when var equals 1
        digitalWrite(13,LOW);
        delay(20);
        digitalWrite(8,LOW);
        IRvalue = digitalRead(IR);
        delay(500);
        while(IRvalue == HIGH){
          IRvalue = digitalRead(IR);
        }
        digitalWrite(8,HIGH);
        delay(20);
        digitalWrite(13,HIGH);
        break;
      case 2:
        //do something when var equals 2
        digitalWrite(7,LOW);
        digitalWrite(13,HIGH);
        delay(20);
        digitalWrite(8,LOW);
        IRvalue = digitalRead(IR);
        delay(500);
        while(IRvalue == HIGH){
          IRvalue = digitalRead(IR);
        }
    }
}
digitalWrite(8,HIGH);
delay(20);
digitalWrite(7,HIGH);
break;
case 6:
if(lamp-102 >= 0){
lamp = lamp -102;
}
analogWrite(3,lamp);
Serial.print("Lamp value : ");
Serial.println(lamp);
break;
case 4:
if(lamp+102 < 1024){
lamp = lamp +102;
}
analogWrite(3,lamp);
Serial.print("Lamp value : ");
Serial.println(lamp);
break;
case 5:
int sensorValue = analogRead(A0);
// Convert the analog reading (which goes from 0 - 1023) to a voltage (0 - 5V):
float voltage = sensorValue * (30.0 / 1023.0);
// print out the value you read:
Serial.print(sensorValue);
Serial.print(" = ");
Serial.println(voltage); } 
} 
}