POSITION CONTROL OF SUN TRACKING SYSTEM

A. A. Khalil, *M. El -Singaby*

akhalil@aast.edu

Arab academy for science and technology and maritime transport

Abstract - *This paper presents the experimental investigation of a sun tracking system. The design and implementation of the overall system; mechanical setup and the positioning control circuits are carried out in the (AAST) lab. Tracking systems try to collect the largest amount of solar radiation and convert it into usable form of electrical energy (DC voltage) and store this energy into batteries for different types of applications. The sun tracking systems can collect up to 50% more energy than what a fixed panel system collects. Therefore, the proposed system is easy to implement and efficient.*

1. Introduction

One of the most important problems facing the world today is the energy problem. This problem is resulted from the increase of demand for electrical energy and high cost of fuel. The solution was in finding another renewable energy sources such as solar energy, wind energy, potential energy…etc.

Nowadays, solar energy has been widely used in our life, and it's expected to grow up in the next years. Solar energy has many advantages:

1- Need no fuel
2- Has no moving parts to wear out
3- Non-polluting & quick responding
4- Adaptable for on-site installation
5- Easy maintenance
6- Can be integrated with other renewable energy sources
7- Simple & efficient

This paper is organized as follows:

Section 2 is devoted to clarify the Suitability of solar cell photovoltaic power systems for Egypt, while in section 3 we get a flash on the function of photovoltaic cells. In section 4 the experimental setup is presented and the concluding remarks are found in section 5.

2. Suitability of solar cell photovoltaic power systems for Egypt

The plan of Egyptian government aims at installing many projects. Industry of food processing, new societies in the remote desert and lighting the villages are some of these projects. These projects need an electric energy. The water supply in the new cultivated land is either from an extension of the canal network or from the development of ground water services especially in the land where the water level seams to be not very deep. In both cases lifting of water using pumps is required. These pumps need an electric energy too. At present; Egypt has not a sufficient energy to supply the previous projects. Moreover, the foregoing projects must be installed in the Egyptian deserts, which represent a remote region. On the other hand, The average annual supply of solar energy in Egypt between 5.5 and 5.73 Kwh/m^2/Day. Therefore, it is appropriate to think of solar energy as a means of electrification for these projects and to be a viable solution of the energy problem in Egypt. This paper provides the implementation of a Sun Tracking System and how to control it. The proposed system consists of *timer circuit, positioning circuit*, *charging circuit*, *and inverter circuit.* The block diagram of the overall system is shown in figure(1).

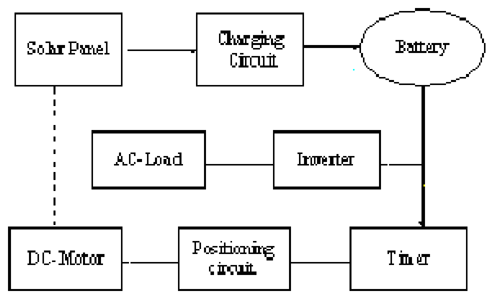


Figure (1) Block diagram of sun tracking system.

3. Photovoltaic cells

Photovoltaic cells are devices that convert light into electricity. Because the source of light (or radiation) is usually the sun, they are often referred to as solar cells. A solar cell is made by placing a thin layer of phosphorous – doped silicon in intimate contact with a layer of boron-doped silicon. When light falls on the cell, photons are absorbed and electrons are set free. The excess electrons accumulate in the phosphorous–doped silicon, which is called n-silicon because electrons have negative charge. If one end of a wire is attached to this top layer and the other end connected to the layer beneath, electrons will leave the upper layer, flow through the wire, and absorbed by the boron-doped silicon, which is called p-silicon meaning positive as shown in figure (2).

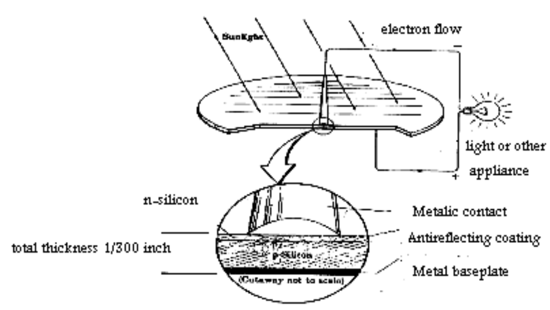


Figure (2) Schematic diagram of single crystal silicon solar cell

When the cell is made, a peculiar phenomenon occurs at the plane of contact between the two silicon layers. Immediately, some of the excess electrons in the n-layer diffuse a short distance across the interface into the p-layer just beneath. They are attached by the holes there, which they "want" to fill. This leaves the phosphorous atoms in the n-layer without enough electrons to balance fully the positive charge in their nuclei, while too many electrons are located in the p-layer around the boron atoms. A very thin layer of static electrical charge thus formed along the zone of contact, or junction, between the two layers of silicon as shown in figure (3).

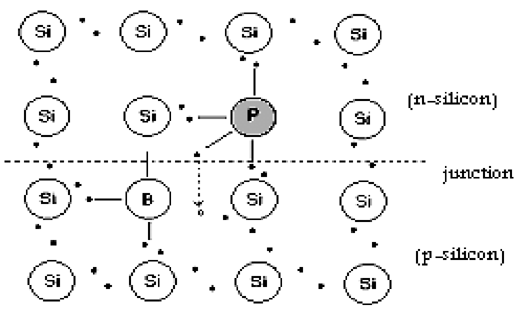


Figure (3) Establishing the cell barrier

Because electrons are charged particles, it is difficult for them to pass through the zone of static electric charge in a solar cell. For this reason, the charge region is called the cell barrier. When cell is fabricated, the barrier establishes itself instantly. It lasts for the life of the cell and it never wears out.

Due to the barrier resistance of the passage of electrons through it, only electrons with high energy (great speed) can penetrate it. As a result, the barrier acts as a filter that lets high-energy electrons through and stops low energy electrons. In a solar cell, the p-silicon has an excess of holes due to the boron doping and these holes tend to absorb electrons. As a result, there are not many free electrons in the p-silicon, but those that are free to move at high speeds (have high energy). The opposite is true in the n-silicon, where there are not enough holes and there are too many electrons, so that the average electrons have less energy (is moving slower) than those in p-silicon. Electrons in both layers are moving at random, some driving by chance into the barrier. The high energy one from the p-silicon penetrates the barrier into the n-silicon, while low energy electrons in the n-layer prevented from returning. Thus 'voltage is created between the two layers. From the standpoint of electrical theory, the electrons in the p-layer near the junction are the higher voltage than those in the n-layer just across the junction. Because, by definition, electric flows from higher voltage to a lower voltage, a current flows through the junction region from the p-layer to the n-layer. Finally, we can say that, the amount of current (amperage) produced by a photovoltaic cell is proportional to the amount of light falling on the cell (the number of photons entering it). For this reason, current increases with area of the cell as well as the intensity of the light and each silicon cell produce about 20-30 mA/cm^2. The voltage, on the other hand, depends on the material used and each silicon cell produces ½ volt regardless of cell area [1].

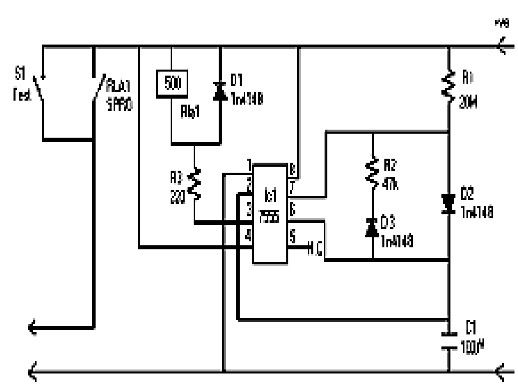
4.Experimental setup

The design and implementation of a small sun tracking system is carried out in the lab [2-3]. The mechanical setup of the implemented system with the solar panel is shown in figure (4).

Figure(4) System mechanical setup

4.1. Timer circuit

The timer circuit diagram is shown in figure (5) and is configured as a conventional astable. It is important that the timing capacitor, C_1, is of the tantalum variety. Such, capacitors have a very low current leakage, which is essential in this circuit; the use of an electrolytic capacitor is not recommended. The 20 mega ohm resistor, R1, results in a charging current to C_1 of between 0.5 to 1.0 micro amps. The timer output, IC_1 pin 3 has a high current-sink capability but acts as a poor source. Therefore the output from IC_1 is arranged to switch on the supply to the positioning circuit when its output is in the off-state (0V). The circuit includes two diodes, D2 and D3, which are normally associated with low duty cycle operation (output off for a long time and on for a short time). However, it was found that although the duty cycle was the reverse of this, the circuit was erratic without the diodes. With them included, though, repeatability was within a few seconds in thirty minutes. Switching of the supply voltage to the positioning circuit is by relay RLA1.Switch S_1 has been included to bypass the relay, to enable testing and initial positioning of the solar panel.



Figure(5) Timer Circuit

The timer circuit output response and its photo are shown in figure(6) and figure(7).

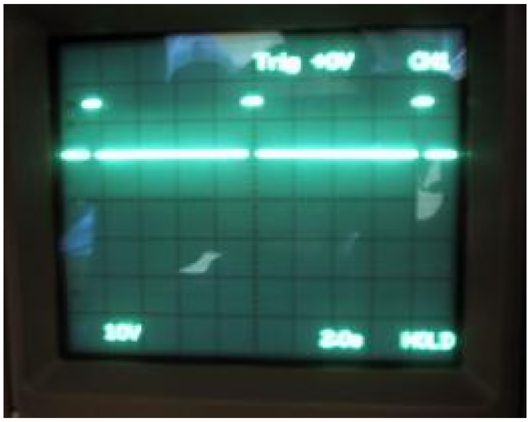
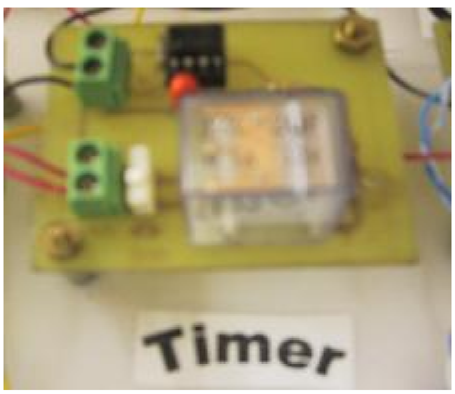


Figure (6) Timer Circuit response



Figure(7) Timer Circuit photo

4.2. Positioning System

The proposed positioning system is composed of three-main subsystems, a light dependent resistor (LDR), as a bridge, a permanent magnet DC-motor (12 volts) and a driving circuit (Darlington configuration [4]. The LDR's are both attached to the mechanical setup using a shutter so as to ensure that the light falls perpendicularly on the panel at static or non-moving state. The positioning circuit that performs this job is shown in figure (8). The LDR's when each of them faces light, it's resistance will decrease. As for the LDR's we have here when exposed to light rays, they measure1.5M OHMS, and during the absence of light they measure both 25 OHMS, we will be talking about the LDR's shortly. The difference between the voltage drops between the two LDR's is about 30 mV, which will be input to the LM324 (quad OP-AMP), which will amplify the difference to about 5 to 6 volts both positive and negative, however this system is a low power system, therefore, we will be needing a driving motor circuit. To achieve both clock-wise and anti-clock-wise directions, the unity gain buffer is put so as to facilitate the (-) terminal to take place in the circuit, nevertheless we will need a dual supply with both (+) and (-) terminals, accordingly the system is a bi-directional one. Since the motor has a very high inductance, then the diodes that are put in the circuit to prevent the IC324 from being damaged or burnt by the strong spikes of the motor during transient states.

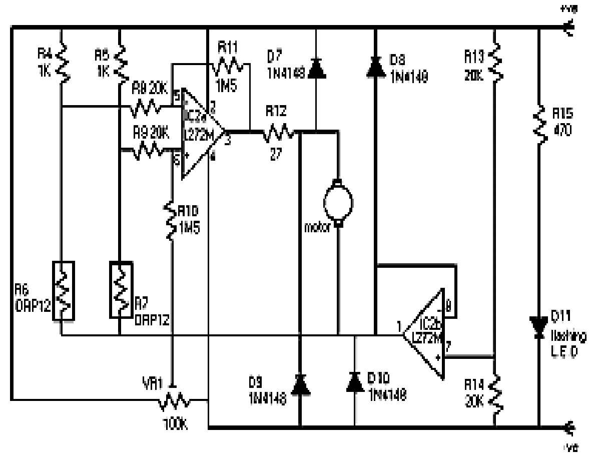


Figure (8) Solar panel positioning circuit.

The solar panel positioning circuit photo is shown in figure (9).

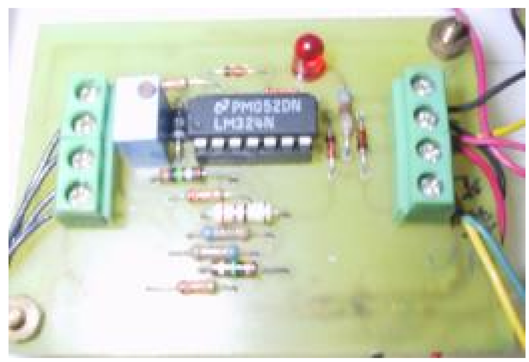


Figure (9) Solar panel positioning circuit. Photo.

4.3. Charging Circuit

Two purposes are served by the circuit: prevention of excessive charging currents and illumination of an light emitting diode (LED) as an approximate indication of charge completion. Basically, the circuit consists of two shunt regulators. It has been designed on the principle that all energy should pass unimpeded to the battery unless it is unsafe to do so. Safe charging current is regulated by transistor TR3, and is set by the value of resistor R19. As the current through R19 approaches the safe charging current (Ic) the voltage between the base (b) and emitter (e) of TR3 rises to 0.6V and the transistor stars to turn on. This shunts current away from the charging circuit and dissipates the surplus energy in R18. The value of R19 is calculated from: R19 = 0.6 / Ic. The circuit around transistors TR1 and TR2 serves to warn the user and reduce the charge current as the NiCad voltage rises. The battery voltage is sensed by Zener diode D12, resistor R16 and preset VR2. The circuit values were chosen to minimize current drain. Preset VR2 is adjusted so that resistor R17 and the LED. D6 shunt the required current when the battery reaches its full charge. This can be arranged to either terminate charging or to reduce charging so that the solar panel can continue safely charging the NiCad at its standard rate. In this circuit, the current is dumped through the LED., which glows at its brightest when the battery is fully charged. Note that the current to this part of the circuit is ultimately limited by TR3 and if all the available current is dumped through the LED. then no current will pass to the battery. The circuit diagram and its photo are shown in figure (10) and figure (11).

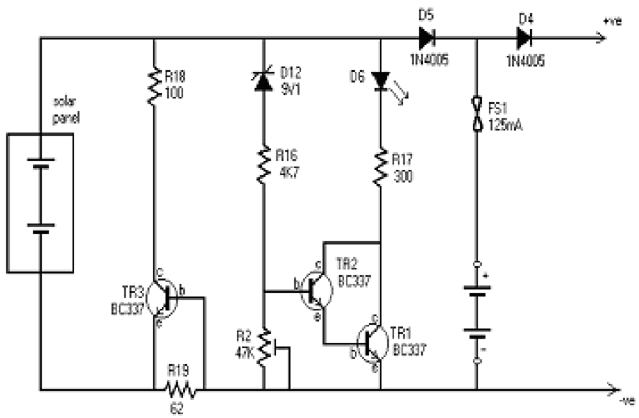


Figure (10) Shunt regulator battery charging circuit.

Figure (11) shunt regulator battery charging circuit photo.

4.4. INVERTER

Dc-to-ac converters are known as inverters. The function of an inverter is to change a dc input voltage to a symmetrical ac output voltage of desired magnitude and frequency [5]. The output voltage could be fixed or variable at a fixed or variable frequency. A variable output voltage can be obtained by varying the input dc voltage and maintaining the gain of the inverter constant. On the other hand, if the dc input voltage is fixed and it is not controllable, a variable output voltage can be obtained by varying the gain of the inverter, which is normally accomplished by pulse-width-modulation control within the inverter. The inverter gain may be defined as the ratio of the ac output voltage to dc input voltage. The output voltage waveforms of ideal inverters should be sinusoidal. However, the waveforms of practical inverters are non-sinusoidal and contain certain harmonics. For low and medium power applications, square-wave or quasi-square-wave voltage may be acceptable; and for high-power applications, low distorted sinusoidal waveforms are required. With the availability of high-speed power semiconductor devices, the harmonic contents of output voltage can be minimized or reduced significantly by switching techniques. Figure (12) shows the inverter output voltage response of the implemented system.

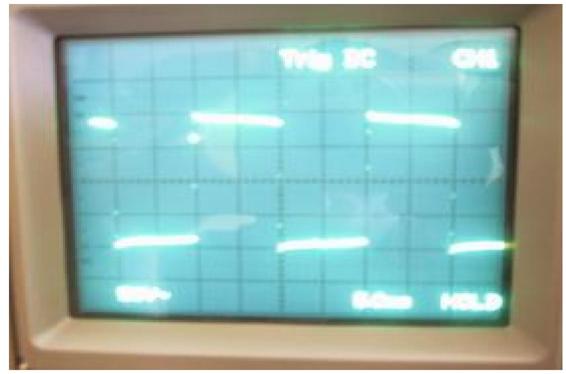


Figure (12) Inverter output voltage response.

The overall sun tracking control circuit is shown in figure (13).

Figure (12) Sun tracking control circuit.

5. Conclusions

In this paper the sun tracking system was implemented and tested in the AAST laboratory. The sun tracking system is an efficient system for solar energy collection. It has been poved that the sun tracking systems can collect up to 50% more energy than what a fixed panel system collects.

6. References

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