Implementation of Low Cost Motion Controller with Input of Passive Sun-position Data for PV- Solar Tracking in Gaza strip

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ABSTRACT--- ***Certainly, if one efficient solar panel can provide as much energy as two less-efficient panels, then the cost of that energy will be reduced also the issue of uncertainty to other solar components need to be investigated by the utilization of robust control. To minimize these losses and improve the efficiency of solar modules is the goal of this research.***

The idea of this research is the development of a low-cost system which tracks the sun on both axes and which be controlled via a programmable logic control (PLC) with the aid of Sun Position-Data regarding Gaza strip.

An analog module was designed and implemented. After the mechanical control unit of the designed system was started, the performance measurements of the solar panel were carried out first when the solar panel was in a fixed position and then the solar panel was controlled while tracking the sun on azimuth and solar altitude angles and the necessary measurements were performed.

Furthermore, when the data obtained from the measurements were compared, it was seen that 41.6% more energy was obtained in the two-axis sun-tracking system compared to the fixed system.

Keywords----Renewable Energy, PV-Solar Energy, Sun Tracking, Gaza Strip

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1. INTRODUCTION

With the rapid growth of development in alternative and renewable energies, technologies, solution, and huge Investment, the electricity consumption rate has global increased. That means, increasing negative effects of CO2 emission on the environment in addition to limited reserves of fossil fuel are also major concerns, which influence the adoption of the renewable energy sources. At the same time, renewable energy is expected to play a vital role to mitigate the impact of global warming and scarcity of energy demand [1].

The Solar power has a relatively lower cost, easy to install and maintain, and for underprivileged countries near the equator, ideal for the location. However, the problem with solar power is that it is directly dependent on light intensity. To produce the maximum amount of energy, a solar panel must be perpendicular to the light source. Because the sun moves both throughout the day as well as throughout the year, a solar panel must be able to follow the sun's movement to produce the maximum possible power. The solution is to use a tracking system that maintains the panel's orthogonal position with the light source. There are many tracking system designs available including passive and active systems with one or two axes of freedom.

The goal of this study was to design an active, dual axis, solar tracker that will be economically feasible to market towards Gaza strip/Palestine. We started by examining the prior work done in solar tracking methods to determine our course of action. From there we designed and tested mechanical and electrical systems.

Different power applications require different tracking systems. For certain applications a tracking system is too costly and will decrease the max power that is gained from the solar panel. Due to the fact that the earth rotates on its axis and orbits around the sun, if a PV cell/panel is immobile, the absorption efficiency will be significantly less at certain times of the day and year. The use of a tracking system to keep the PV cell/panel perpendicular to the sun can boost the collected energy by 10 - 100% depending on the circumstances.

If a tracking system is not used, the solar panel should still be oriented in the optimum position. The panel needs to be placed where no shadow will fall on it at any time of the day. Additionally, the best tilt angle should be determined based on the geographical location of the panel. As a general guideline for the northern hemisphere, the PV panel should be placed at a tilt angle equal to the latitude of the site and facing south. However, for a more accurate position and tilt angel a theoretical model of the suns iridescence for the duration of a year is created and the angel and position is matched to the model. So the using one axis of tracking can provide a significant power gain to the system. One article did mention that a TSAT at a tilt angle of 5° increases the annual collection radiation by 10% compared to a HSAT, a HSAT increases the annual collection radiation by 15% to a VSAT, and finally a PASAT increases the annual collection radiation by 10% over a HSAT. Thus for one axis a PASAT or TSAT configuration would collect the most solar radiation. A few of these tracker types are shown in Figure 1.1

Figure 1.1: Different One Axis Trackers from Left to Right: HSAT and PASAT

For an additional power gain a dual-axis tracking system can be used. The percent gain from going from a PSAT to a dual-axis system is small, but as long as the system doesn't use more power than gained, it still helps. Again Wikipedia mentions two classifications for dual axis trackers: Tip-Tilt Dual Axis Tracker (TTDAT) and Azimuth-Altitude Dual Axis Tracker (AADAT). The difference between the two types is the orientation of the primary axis in relation to the ground. TTDAT's have the primary axis horizontal to the ground and AADAT's have theirs vertical. The azimuth/altitude method seems to be largely used, based on its reference in multiple research articles on tracking. In the article by Sefa et al. the following was stated; "The results indicated that increases of electrical power gains up to 43.87% for the two axes, 37.53% for the east–west, 34.43% for the vertical and 15.69% for the north–south tracking, as compared with the fixed surface inclined 32 to the south in Amman" [2,3].

2. GAZA STRIP AND ITS SUITABILITY FOR CONSTRUCTING PHOTOVOLTAIC SYSTEMS

Palestine is located within the solar belt countries and considered as one of the highest solar potential energy; the climate conditions of the Palestinian Territories are predominantly very sunny with an average solar radiation on a horizontal surface about 5.4 kWh/m2 day.

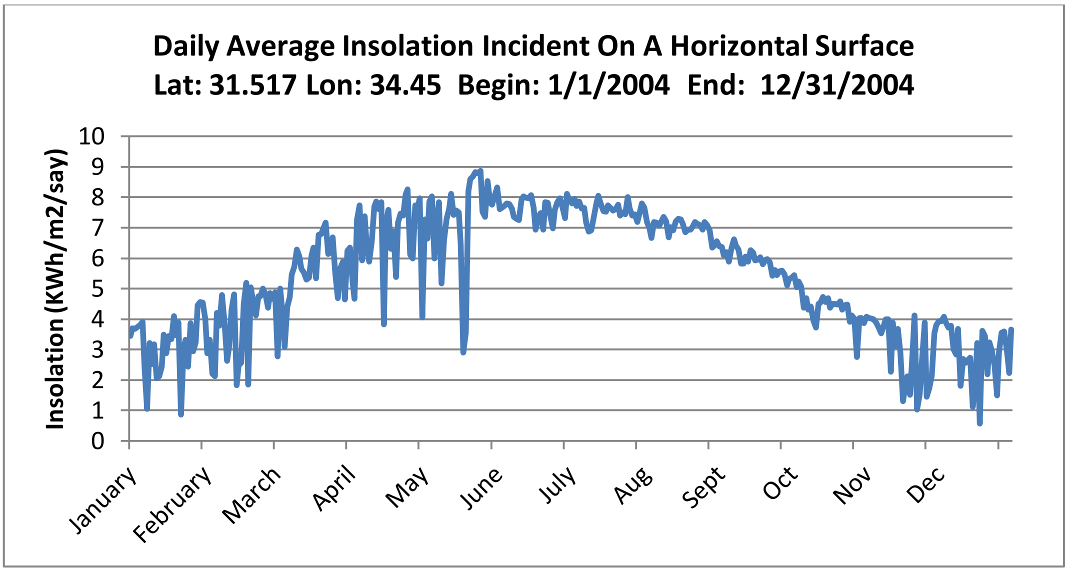

Figure 2.1: Average month radiation for Gaza [4]

Gaza Strip is 360km^2 with a high-density population of about 4,118 persons/km2, so Gaza Strip represents one of the most densely populated areas in The Middle East. As the population in Gaza Strip increases (population growth rate 3.349%/year), the consumption of water and energy will increase; leading to significant rise in unacceptable levels of air pollution, and the defect in water supply and energy sources will increase; leading to severe economical crisis that will result in a significant rise in the probability of an outbreak of warfare [5].

So, the need for renewable energy sources such as solar energy becomes essential trend especially in the political situation of Gaza Strip. The coastal climate of Gaza Strip is hot, humid in summer and mild in winter the mean average air temperature is 31 degree in summer and 6 degree in winter. Solar insulation is 5.4 KWh/m2 a day. From previous data, it is clear that the climate of Gaza Strip is very suitable for constructing photovoltaic system, hence it is enjoy with high global radiation degree and suitable energy.

3. SYSTEM DESIGN

The purpose of a solar tracker is to accurately determine the position of the sun. This enables solar panels interfaced to the tracker to obtain the maximum solar radiation. With this particular solar tracker a closed-loop system was made consisting of an electrical system and a mechanical system.

In the present study, PV panel produced was used for conducting the experiments. The characteristics of the panel are nominal power P max 150 Wp, nominal current 7.91 A, nominal voltage 18.97 V, short circuit current 8.54 A, AM 1.5, 1000 W/m2 ,25C. In order to move the panel on both axes, pins which were fixed to the panel which were connected to the motors were used. The supply voltage of these motors was 12 V DC and the control voltage was 2–10 V DC. For the control unit, PIC 16f877a is used, which has the ability to control this complex system and could store passive data for sun locations in its memory for ever, in addition to high ability for control its able to communicate with real time clock (RTC) which is very important in this system to get the specific location from memory regards to real time, and it's very recommended in previewing all data and time in 4*20 LCD.

3.1. Electromechanical system design and components

This solar tracking system has multiple functions and uses two motors as the drive source, conducting an approximate hemispheroidal 3-D rotation on the solar array. The two drive motors are decoupled, i.e., the rotation angle of one motor does not influence that of the other motor, reducing control problems. Additionally, the tracker does not have the problems common to two axis mechanical mechanisms (that one motor has to bear the weight of the other motor). This implementation minimizes the system's power consumption during operation and increases efficiency and the total amount of electricity generated. Figure 3.1 shows the solar tracking system we designed based on the considerations described previously.

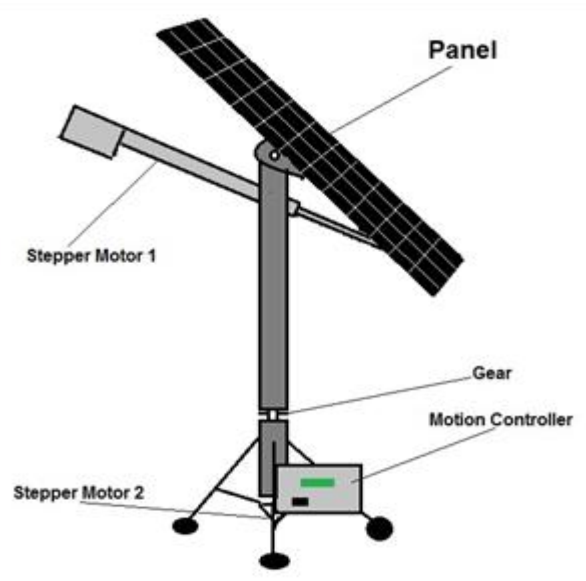

Figure 3.1: Mechanical structure.

The mechanism must support the solar panel and allow the panel to conduct 3-D rotation within a certain amount of space. The mechanism has two advantages:

- High photoelectric conversion efficiency—because the flexible panel of the solar tracker can conduct 3-D rotation, tracking the sun in real time, the system efficiently performs photoelectric conversion and production.
- Simple, energy-saving controls—the two rotational dimensions of the solar tracker are controlled by two independent drive sources. The rotation angles are decoupled and neither one has to bear the weight of the other one. Additionally, the overall movement inertia is dramatically reduced.

Table 3.1: Sun position data for Gaza Strip

Date:		**02/12/2013**
coordinates:	31.5232394, 34.4561291	
location:		
hour	Elevation	Azimuth
06:24:30	-0.833	115.47
06:30:00	0.22	116.18
07:00:00	5.85	120.27
07:30:00	11.24	124.71
08:00:00	16.33	129.59
08:30:00	21.06	134.97
09:00:00	25.34	140.93
09:30:00	29.08	147.53
10:00:00	32.16	154.77
10:30:00	34.48	162.61
11:00:00	35.94	170.93
11:30:00	36.47	179.53
12:00:00	36.04	188.13
12:30:00	34.67	196.49
13:00:00	32.44	204.39
13:30:00	29.42	211.7
14:00:00	25.75	218.36
14:30:00	21.52	224.38
15:00:00	16.84	229.82
15:30:00	11.78	234.74
16:00:00	6.42	239.22
16:30:00	0.81	243.34
16:38:35	-0.833	244.46

Two Dc motors with pulses feedback were used to get accurate position for every motion these motors were supplied with 12 v dc. One is used for azimuth angle motion and the other is used for elevation.

To produce a useful solar tracker the electrical system needs to give accurate control signals to the mechanical system, be reliable, and have low power consumption. The electrical system consisted of driver circuit and control circuit is fed by sun position data for each day in the year and with change in position every 30 minutes, a sample for these data is shown in table 3.1 below.

3.2. Driver circuit

Due to the high power needed to move the motors PWM method used in controlling the motors, we have to use driver circuit that enables these motors to move in two directions with variable velocity as the control circuit need. The circuit schematic is shown below in Figure 3.2. The components of driver circuit are 8 IRF 3502 transistors, 4 opt couplers PC187, 8 2n2222 transistors, Resistors and the PCB.

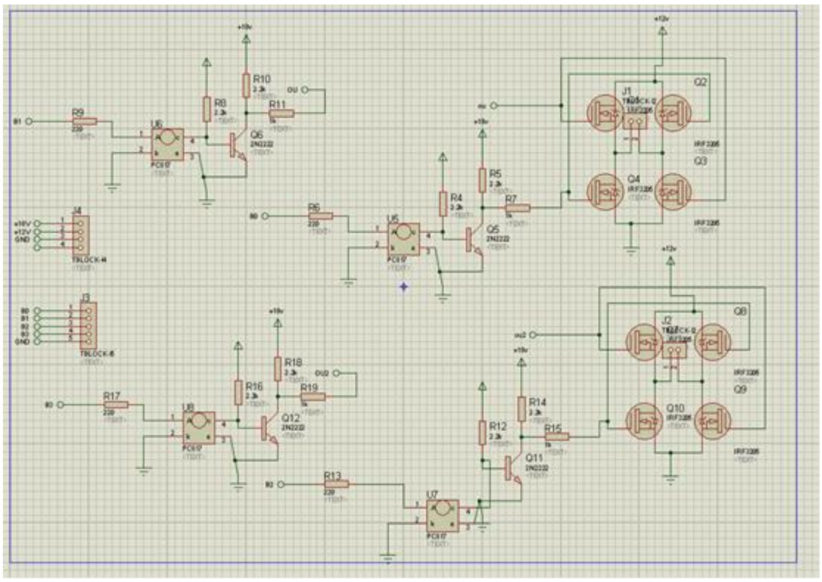

Figure 3.2: Circuit schematic of the driver

3.3. Control Circuit

The main control used in this circuit was PIC 16f877a, which have the ability to control this complex system and could store passive data for sun locations in its memory for ever, in addition to high ability for control its able to communicate with real time clock (RTC) which is very important in this system to get the specific location from memory regards to real time, and it's very recommended in previewing all data and time in 4*20 LCD. The circuit schematic is shown below in Figure 3.3. The components of control circuit are PIC 16f877a, LCD 4*20, RTC DS1307, Battery, Power Regulator, Resistors and the PCB**.**

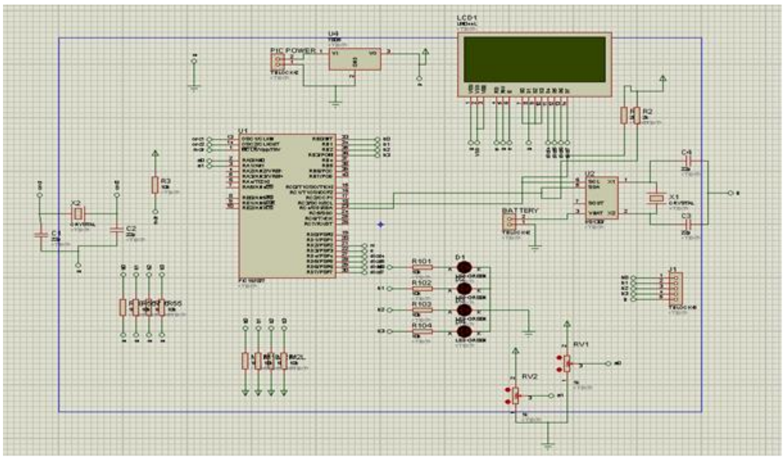

Figure 3.3: Circuit schematic of the control

3.4. The final prototype

The final system design consisted of a mechanical assembly made of steel parts for the axle, and motor mount assemblies and the electrical control system which was composed of the microcontroller development board and two custom-made printed circuit boards (PCBs) for the driver circuit and control circuit. Figure 3..4 show the final module:

Figure 3.4: The final prototype

After connecting the system to a 12V battery source the motion controller will mount the system to the right position according to the real time, then each 30 minutes the motion controller send signals to the driver circuit to move each motor to the new angle according to the sun position data stored in the microcontroller, LCD (4*20) screen display the date and the real time also the current position of the system as shown in figure 3.13. At the end of the day (sunset time) the system will go back to the position of the next day sunrise and still in standby till the next day.

After the prototype was built, it was put through several tests of functionality to ensure that it met the original design requirements. The tracker's power consumption was measured to calculate the tracker's power generation in comparison to other solar panel systems. The sun position data stored in the microcontroller. To ensure that the tracking system actually produced more power than it used, measurements were taken for the power consumption of each individual component of the system. A single 0.49Ω (measured value) resistor was used as a power shunt to measure the current going from the battery to the tracker system. The voltage measured by the voltmeter, VR1, divided by the resistance gives the current to the tracker. Multiplying the current by the supply voltage, 12 V, the power consumption can be calculated. Several measurements were taken to find the individual current draws to each section of the system. The first measurements were to the total system, with the shunt between the battery and the rest of the system. The currents were measured when the system was stationary, one axis was moving, the other axis was moving and both axes moving at the same time. From these results, the following can be deduced. The microcontroller, all four indicator LEDs and the LCD screen consumes 0.48 W when the system is stationary. The elevation axis consumes 2.40 - 0.48 = 1.92W. The azimuth axis consumes 3.60 - 0.48 = 3.12W at its maximum load point as determined by the friction in the mechanical part. The total power consumption at the maximum load point is equal to 0.48+1.92+3.12 = 5.52W. The difference between this amount and the measured amount is due to the tracker not moving through both maximum load points at the same time. These measurements conclusively show that the power consumption when the system is not moving to be just less than half a Watt and when the system is moving both axes in a worst-case scenario, it consumes 5.52 W. The final part of the functionality testing of the tracking system is to compare its performance to other types of panel orientations and tracking systems.

4. CONCLUSIONS

The Azimuth-Altitude Dual-Axis Solar tracker designed and built in this project show a clear benefit over both immobile and single-axis tracking systems. This value corresponds to a 41.63% energy gain over an immobile solar panel setup assuming the solar panels mounted on the tracker and the immobile system are identical 150W panels. Furthermore, testing showed that the power used by the tracking system built was much less than the power gained by tracking the sun accurately. This means that if the tracking system were to charge its own batteries, it would be entirely self-sufficient except for maintenance.

Perhaps the most important conclusion to be made from this study project is the total cost for this tracking system is very low, less than $800 in parts for each tracker in mass quantities. This means that the system can be built for a very low cost and most importantly; this system would be within the financial reach of many developing country communities. Based on the test results and cost analysis this project has met its original goals. To improve the efficiency of this tracking system, however, this project has several future recommendations for future study in solar trackers.

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