Automatic Irrigation System with PV Solar Tracking

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***Abstract*— In remote rural areas in Palestine, direct access to an electric grid is almost impossible especially where utility grids are either not available or its further extension is not feasible. The availability of abundant solar irradiance, makes solar energy the most promising one. In particular, the utilization of Photovoltaic (PV) off-grid solar systems could be the solution for pumping and irrigation system. The objective of this paper is to design and construct an automatic irrigation system powered by PV panels on a laboratory level. A humidity sensor in the soil and temperature sensors in the air are used to check the need for irrigation in order to operate a pump powered by the PV system. This PV system is a two axis solar tracking one. Sensors are installed on PV panels to check the position of the sun so that PV panels are always perpendicular to the sun. This control is made by means of a microcontroller. The whole system is first simulated by ISIS simulation software to validate the final control algorithm to be implemented. A particular attention has been given to the solar tracking system. Experimental study is carried out to evaluate the performance of the tracking system in laboratory by using a light source to simulate the sun.These results show the validity of the control of the irrigation system and the PV panels are always normal to the light source**.

***Keywords*—** *Solar Tracking, Microcontrollers, Stepper motors, Sensors, Simulation, Automatic Irrigation.*

1. Introduction

Like many other countries the energy situation in Palestine is becoming critical. In order to solve this problem, the government has taken initiatives for utilization of renewable energy sources for electricity generation. One of these renewable energy sources is the photovoltaic systems because of the high daily average of solar radiation (about 5.4 KWh/m^2-day) [5],[13,[16]. Photovoltaic systems have different applications. One of these applications is irrigation and pumping water in remote areas and far from electrical grid using PV DC water pumps [2]. DC pumps can be run by the electricity generated by PV systems while AC pumps need an inverter [10], [13].

Solar tracking keeps PV panels in an optimum position perpendicularly to the solar radiation during daylight hours so as to increase the collected energy [3]. Efficient collection of maximum solar radiation on a flat panel requires adjustment of two parameters of the energy collecting surface namely the angle of the azimuth and the angle of tilt [1],[9],[11].This paper deals with an automatic irrigation system powered by PV panels with tow axis solar tracking. Figure 1 shows the block diagram of the proposed system. It consists of Humidity sensor in the soil and temperature sensors in the air are used to control the DC water pump operation. Four light dependent resistances (LDRs) sensors are used to detect the sun position, this information is read and processed by a 16F877A PIC microcontroller to move two stepper motors, used as actuators for the two axes PV solar tracking system, in order to control the azimuth and tilt angles. The system has been simulated using PROTEUS-ISIS simulation software first as shown in figure 2, and then it is constructed as shown in figure 3.

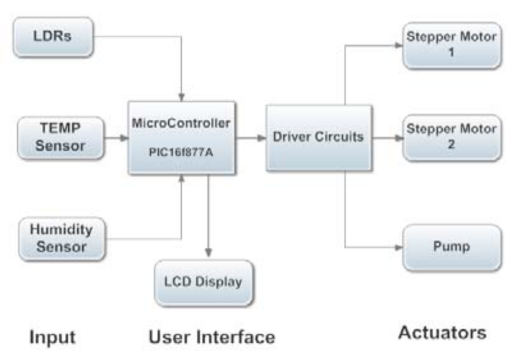

Figure 1. Block diagram of the automatic Irrigation system with PV solar tracking

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2. System Simulation

The complete system has been simulated by using Proteus ISIS professional package in order to verify the validity of the control algorithm of the irrigation system before its construction. The simulation includes the microcontroller PIC 16F877A, LDR sensors, temperature sensor LM35, humidity sensor, LEDs, relays, UNL2003 ICs, L298 ICs and stepper motors all connected as the block diagram in figure 2 [8]. Different situations has been simulated with very good results for solar tracking and for the pump function.

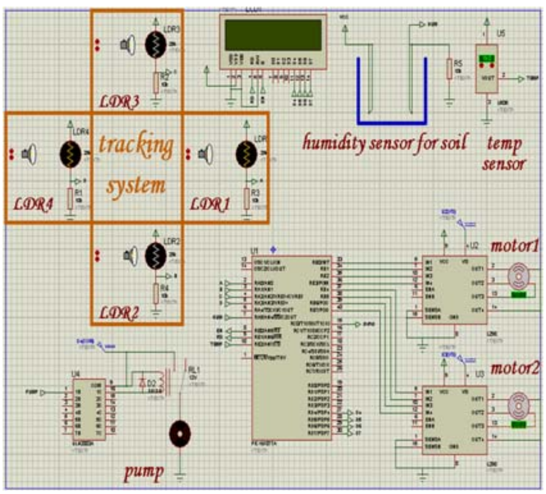

Figure 2. Simulation of the system by PROTEUS-ISIS simulation software

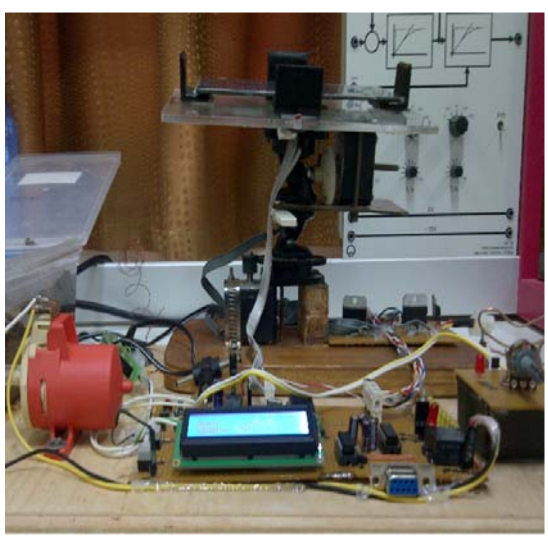

Figure 3. The constructed system

3. Circuits and Components

3.1 Solar Tracking System Circuits

Solar tracking is the most appropriate technology to enhance the electricity production of a PV system. To achieve a high degree of tracking accuracy, several approaches have been widely investigated. Generally, they can be classified as either open-loop tracking types based on solar movement mathematical models or closed-loop tracking types using sensor-based feedback controllers. In the open-loop tracking approach, a tracking formula or control algorithm is used. Referring to the literature, the azimuth and the elevation angles of the Sun were determined by solar movement models or algorithms at the given date, time and geographical information. The control algorithms were executed in a microprocessor or a microcontroller. In the closed-loop tracking approach, various active sensor devices, such as light dependent resistors (LDRs) are utilized to sense the Sun's position and a feedback error signal was then generated to the control system to continuously receive the maximum solar radiation on the PV panel. [7][12],[14]. Solar tracking can be achieved by using single-axis structure dual-axis structures for higher accuracy systems. In general, the single-axis tracker follows the Sun's movement from the east to west during a day while a dual-axis tracker also follows the elevation angle of the Sun. [7],[15].

This paper uses the two axis solar tracking whose block diagram is shown in figure 4 [3].The control strategy of two axis solar tracking is done using four light-dependent resistors (LDRs) as sensors. Two of them (LDR1 and LDR4) are used to control the azimuth angle and the other two (LDR2 and LDR3) are used to control the tilt angle.[1],[3],[5].

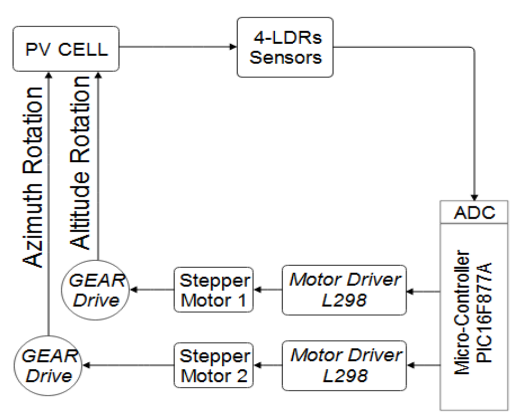

Figure 4. The block diagram of the two axis solar tracking system.

The LDRs are fixed on to the flat solar panel. The whole system constructed in laboratory is shown in figure 3 [1].

3.2 Light Dependent Resistor (LDR)

The LDR sensor is a resistor whose resistance decreases with the increase of light intensity. It can also be referred to as a photo conductor. A photo resistor is made of high resistance semiconductor. If light, falling on the device is of high enough frequency, photons absorbed by the semiconductor give bound electrons enough energy to jump to the conduction band. The resulting free electron and its hole partner conducts electricity, thereby lowering resistance. The reverse is the case when darkness falls on the LDR, for this will increase its resistance. This characteristic of the LDR is used to vary the input voltage as the sun moves over it.The LDR is connected in series with a resistor , a voltage divider is thus formed, which will split the voltage Vcc into two voltages V1 and V2. The equations of V1 and V2 are shown below in equation (1) and equation (2). As darkness sets in, the resistance of the LDR increases. Following the OHM,s law V=IR, if R increases when the current I is constant, then V is increased. Therefore V2 increases while V1 reduces obeying the Kirchoff voltage law [6]. In figure 5 is shown the component LDR used in this project and its connection circuit. The analog outputs of the LDR1,LDR2, LDR3 and LDR4 are connected to AN0, AN1, AN2 and AN3 inputs of the microcontroller respectively and there values are calculated as shown in equation (3).

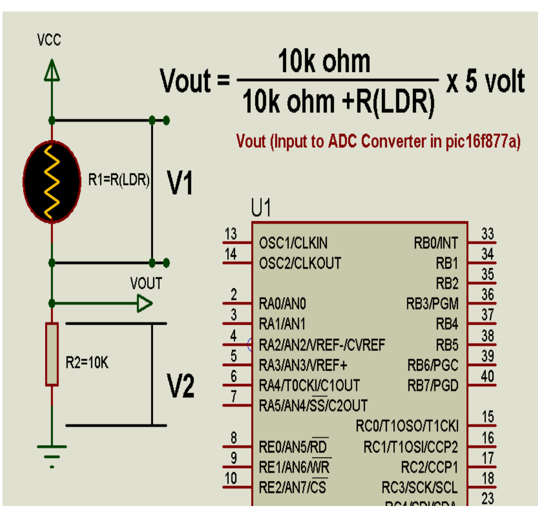

Figure 5. The LDR circuit

$$V1 = \frac{R1}{R1+R2} \times VCC \quad (1)$$

$$V2 = \frac{R2}{R1+R2} \times VCC \quad (2)$$

$$Vout = \frac{10K\Omega}{10K\Omega + R(LDR)} \times 5volt \quad (3)$$

3.3 Stepper Motor Circuits

Stepper motors are commonly used in precision position control applications. This is because of the different advantages they have such as they are brushless, load independent, has open loop position control capability, good holding torque and excellent response characteristics. For these reasons two identical bipolar, permanent magnet 2 phase, 12V, 1.5^0 step stepper motors shown in figure 6 are used in this application in order to control the azimuth and tilt angle. Motor 1 is used to control the azimuth angle and motor 2 is used to control the tilt angle. Two L298 IC shown in figure 7 have been used to drive the two stepper motors.

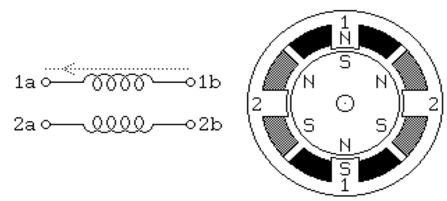

Figure 6. Stepper motors

The sequence of alimentation of the motors and pins connections between the microcontroller via portB and L298 ICs are shown in table 1, and table 2.

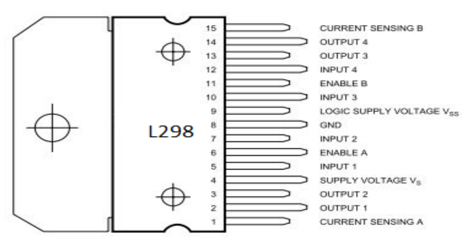

Figure 7. L298 IC driver

Table 1. Sequence of Azimuth angle motor (motor 1)

Step	**Bit3 (RB3)**	**Bit2 (RB2)**	**Bit1 (RB1)**	**Bit0 (RB0)**
1	1	0	0	0

2	0	0	0	1
3	0	1	0	0
4	0	0	1	0

Table 2. Sequence of tilt angle motor (motor 2)

Step	**Bit3 (RB7)**	**Bit2 (RB6)**	**Bit1 (RB5)**	**Bit0 (RB4)**
1	1	0	0	0
2	0	0	0	1
3	0	1	0	0
4	0	0	1	0

3.4 Humidity and Temperature Sensors Circuits

Humidity and temperature sensors have been used to decide the operation of the pump. The main idea is when the humidity is low (less than 4V) there is a need for irrigation, we measure the temperature so as to make the pump operate and so irrigate during low temperature (less than 20 C°) so as to avoid water evaporation. The temperature sensor used is the LM35 shown in figure 8 with its connection circuit. The analog output of this sensor is linearly proportional to the Celsius (Centigrade) temperature, 10 mV/C°. The output of this sensor is connected to the analog input (AN7) of the microcontroller.

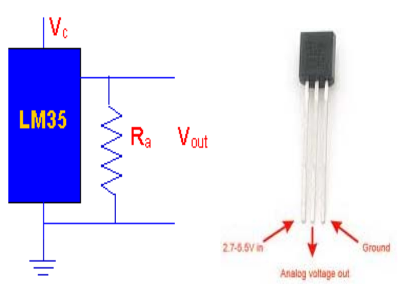

Figure 8. Temperature sensor circuit.

The humidity sensor is a home made one. It consists of two electrodes, one of them is connected to a resistance as shown in figure 2 to form a voltage divider. The output voltage value depends on the resistance between the two electrodes which depends in turn on the humidity of the soil. The output of this sensor is connected to the analog input (AN4) of the microcontroller.

3.5 PV and Pump Circuits

The PV module used has an output voltage of 12V dc capable of supplying a dc current of 300mA which is enough to switch on the pump. The connection circuit of the pump with the microcontroller is shown in figure 2. Here the control signal of the microcontroller to switch on the pump is sent from RC0 output to driver UNL2003 IC to drive the coil of the relay.

3.6 LCD Circuit

The LCD used is shown in figure 9. Table 3 shows the function of each pin of the LCD. The connections of the pins with the microcontroller are shown in fig. 2. The LCD is used to show the values of the LDRs, temperature sensor, humidity sensor, state of motor1, motor2 and the pump.

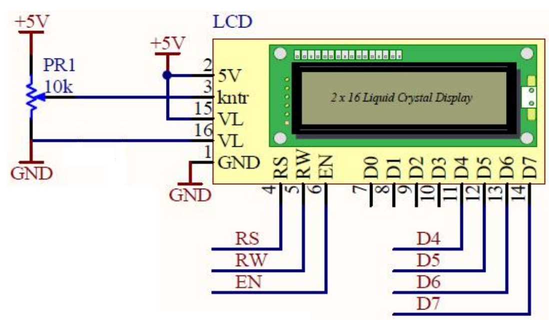

Figure 9. LCD

Table 3. Description of the LCD's pin function

Pin	Symbol	I/O	Descriptions
1	VSS	--	Ground
2	VCC	--	+5V power supply
3	VEE	--	Power supply to control contrast
4	RS	I	RS=0 to select command register, RS=1 to select data register
5	R/W	I	R/W=0 for write, R/W=1 for read
6	E	I/O	Enable
7	DB0	I/O	The 8-bit data bus
8	DB1	I/O	The 8-bit data bus
9	DB2	I/O	The 8-bit data bus
10	DB3	I/O	The 8-bit data bus
11	DB4	I/O	The 8-bit data bus
12	DB5	I/O	The 8-bit data bus
13	DB6	I/O	The 8-bit data bus
14	DB7	I/O	The 8-bit data bus

4. Flow Chart of the Control System

In figure 9 the flow chart of the control system is shown. When the humidity is less than 4V and the temperature is more than 20 C^0, the pump operates. If the difference between the value of LDR1 and LDR4 is less than a certain value (e), the microcontroller generates no control signals because that means that the PV panels are perpendicular to the source light. When the difference between LDR1 and LDR4 is more than (e), the microcontroller generates control signals to drive stepper motor 1 to the left. When the difference between LDR4 and LDR1 is more than e, the microcontroller generates control signals to drive stepper motor 1 to the right [1][4]. The same test is done for LDR2 and LDR3 in order to control stepper motor 2 up and down. The system is programmed so that after sunset the PV panels are directed to east waiting the sunrise. The microcontroller has been programmed using Flowcode software.

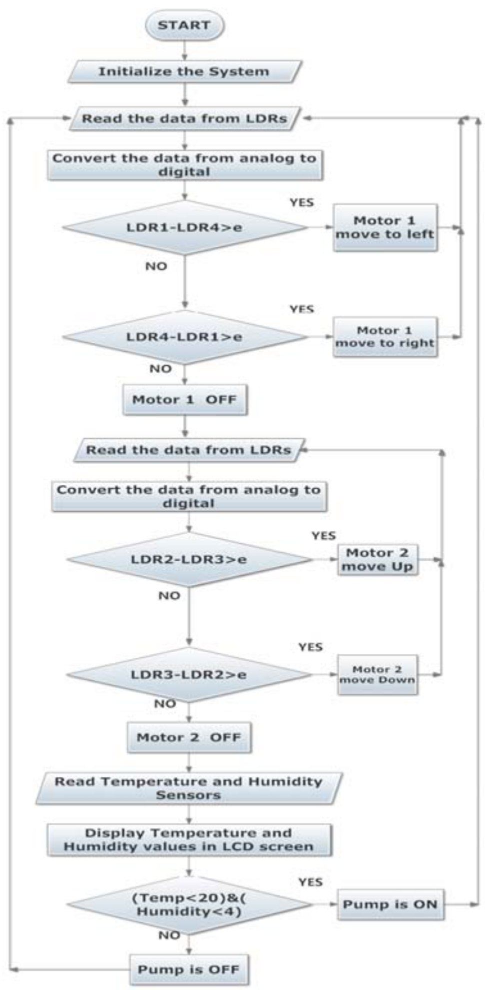

Figure 9. Flow chart of the control system

5. Conclusion

An automatic irrigation system based on a microcontroller with two axis PV solar tracking is first simulated, then it is designed and constructed on a laboratory level. The simulation and the experimental results show the validity of the hardware design and the validity of the control algorithm concerning the operation of the pump under predetermined conditions and the exact solar tracking.

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References

[1] Okam Bingol, Ahmet Altintas, Yunus Oner, “Microcontroller based solar-tracking system and its implementation”, Journal of Engineering Sciences, Vol 2, No. 12, pp. 243-248, 2006.

[2] M. Sharath Kumaar, J. Sridhar, “Renewable irrigation system using dual axis solar tracker with microcontroller and regeneration of electricity from irrigated Water”.

[3] M.R.I. Sarker, Md. Riaz Pervez and R.A. Beg, “Design, fabrication and experimental study of a novel two-axis sun tracker”, International Journal of Mechanical and Mechatronics Engineering IJMME-IJENS , Vol. 10, No. 01, 2010.

[4] Nasir Ahmed Filfil, Deia Halboot Mohussen and Dr. Khamis A. Zidan, “Microcontroller-based sun path tracking system”, Eng. And Tech. Journal , Vol. 29, No. 07, 2011.

[5] Ahmad Abu Hanieh, “Solar photovoltaic panels tracking System”, Proceedings of the 6th WSEAS international conference on dynamical systems and control, Sousse, Tunisia, 3-6 May 2010, pp 30-37.

[6] S. Zubair, A Suleiman, H. T. Abdulazzez, B. A. Salihu, “Design and construction of a microcontroller based single axis tracker”, Innovations in Science and Engineering,1(4), pp. 41-47, 2011.

[7] Jing-Min Wang and Chia-Liang Lu, “Design and implementation of a sun tracker with adDual-axis single motor for an optical sensor-based photovoltaic system”, Sensors, pp. 3157-3168, 2013.

[8] Mohammad Shoaib, V.Nagaraj, “Proteus based simulation of PV inverter for rural electrical Service”, International Journal of Modern

Engineering Research (IJMER), Vol 3,Issue 2 No. --, pp. 1212-1219, 2013.

[9] A. Kassem and M. Hamad, "A microcontroller-based multi-function solar tracking system, IEEE, International System Conference (SysCon), 4-7 April, 2011.

[10] M. D. Goudar, B. P. Patil, and V.Kumar, "Adaptive MPPT algorithm for a distributed Photovoltaic based irrigation system", International conference on devices and communication, IEEE, India, 24-25 feb. 2011.

[11] Xiaodong Zhang, Xiujuan Li, Ke Lu, "Research on an intelligent solar tracking system based on LPC2131", 3rd international conference on network infrastructure and digital content, IEEE, pp 429-432 , 2012.

[12] M. Anish John Paul, "Design and performance analysis of automated two axis solar tracking system for steam generation", international conference on energy efficient technologies for sustainability, IEEE, Vol--,Issue -- No. --, pp 432-437. , 2013.

[13] Rajib Baran Roy, "Design and performance analysis of the solar PV DC water pumping system", Canadian Journal on Electrical and Electronics Engineering , Vol 3, No. 7, pp. 403-412 , 2012.

[14] Md. Tanvir Arafat Khan, S. M. Shahrear Rifat Rahman, S. M. Shafiul Alam, "Design and construction of an automatic solar tracking system", 6th International Conference on Electrical and Computer Engineering (ICECE) Dhaka, Bangladesh, 2010.

[15] Farhan A. Salem, "Mechatronics Design of Solar Tracking System", International Journal of Current Engineering and Technology, 2013.

[16] Marwan Mahmud, "Solar electric powered RO-Brackish water desalination system in Palestine", Proceedings of the 3th international conference on energy and environmental protection in sustainable development, Hebron, Palestine, 9-10 October2013, pp 124-132.