

MICROCONTROLLER BASED SOLAR-TRACKING SYSTEM AND ITS IMPLEMENTATION

Okan BİNGÖL*, Ahmet ALTINTAŞ**, Yusuf ÖNER***

*Süleyman Demirel Univ., Faculty of Tec. Education, Department of Elec. and Computer Education, Isparta

**Dumlupınar Univ., Faculty of Tec. Education, Department of Elec. Education, Simav/Kütahya

***Pamukkale Univ., Faculty of Eng., Dep., of Elec. & Elec. Engineering, Kınıklı/Denizli

Geliş Tarihi : 23.06.2005

ABSTRACT

In this paper, a new micro-controller based solar-tracking system is proposed, implemented and tested. The scheme presented here can be operated as independent of the geographical location of the site of setting up. The system checks the position of the sun and controls the movement of a solar panel so that radiation of the sun comes normally to the surface of the solar panel. The developed-tracking system tracks the sun both in the azimuth as well as in the elevation plane. PC based system monitoring facility is also included in the design.

Key Words : Solar energy, solar-tracking system, Solar collector

MIKRODENETLEYİCİ TABANLI GÜNEŞ TAKIP SİSTEMİ VE UYGULAMASI

ÖZET

Bu çalışmada, mikrodenetleyici tabanlı bir güneş takip sistemi önerilip gerçekleştirilmiş ve test edilmiştir. Sunulan tasarım, sistemin kurulmuş olduğu coğrafik bölgeden bağımsız olarak çalışabilmektedir. Sistem, güneş ışığının güneş panelleri yüzeyine dik gelmesini sağlamak için güneşin konumunu test edip güneş panellerinin hareketini kontrol eder. Geliştirilen güneş takip sistemi güneşi, yükselti ve açıklık düzlemlerinin her ikisinde de izleyebilmektedir. Tasarıma, bilgisayar tabanlı sistem gözetleme birimi de ilave edilmiştir.

Anahtar Kelimeler : Güneş enerjisi, Güneş takip sistemi, Güneş kollektörü

1. INTRODUCTION

Currently, many alternative energy sources appear to be technically feasible. One of them is solar energy (Kreider and Kreith, 1981). The panels are the fundamental solar-energy conversion component. Conventional solar panels, fixed with a certain angle, limits their area of exposure from the sun during the course of the day. Therefore, the average solar energy is not always maximized. Solar-tracking systems are essential for many applications such as thermal energy storage systems and solar energy based power generation systems in order to

improve system performance (Saxena, and Dutta, 1990; Koyuncu and Balasubramanian, 1991; Harakawa and Tujimoto, 2001). The change in sun's position is monitored, and the system always keeps that the plane of the panel is normal to the direction of the sun. By doing so, maximum irradiation and thermal energy would be taken from the sun.

The elevation angle of the sun remains almost invariant in a month and varies little (latitude $\pm 10^\circ$) in a year. Therefore, a single axis position control scheme may be sufficient for the collection of solar energy in some applications (Konar and Mandal, 1991. Yeong-Chau, et al., 2001. Wilamowski and

Xiangli, 2002). Efficient collection of maximum solar irradiation on a flat panel requires adjustments of two parameters of the energy collecting surface namely the angle of azimuth, ψ and the angle of tilt, α , of the surface to be illuminated in Figure 1 (Davies, 1993; Macagnan, et al., 1994).

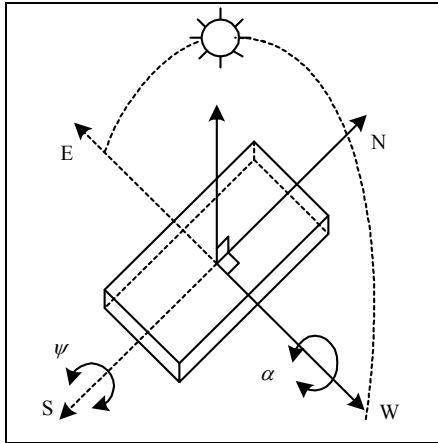


Figure 1. Two axis position control of the solar panel

This paper deals with controlling the solar panel at two axis (or two angles) by using LDRs as sensors, stepper motors as actuators (SM1, SM2) and micro-controller as a controller. In order to keep the design as simple and cheap we have chosen PIC16C71 as a micro-controller-unit (MCU). In addition to this, to observe position of the solar panel, PC based system monitoring facility is included in the design. Block diagram of the proposed solar-tracking system is given in Figure 2.

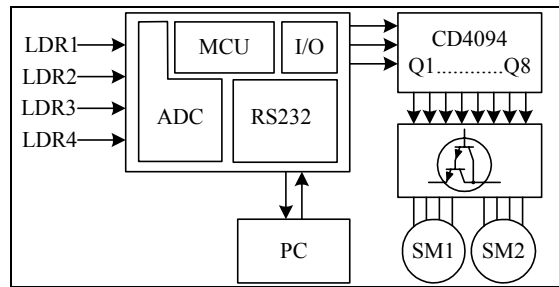


Figure 2. Block diagram of the proposed solar-tracking system

2. DESIGN OF THE SOLAR-TRACKING SYSTEM

The tracker control system contains a control board, a control program, a power supply board, one motor-interface board and a set of sensors. The main idea of design of the solar-tracking system is to sense the

sun light by using four light dependent resistors (LDRs). Each LDR is fixed inside the hollow cylindrical tubes. A pair of them, controlling the angle of azimuth, are positioned East-West direction and the two of them, controlling the angle of tilt, are positioned South-North direction. The LDR assembly is fixed onto the flat-solar panel, shown in Figure 3. The tubes are making a degree of 45° with the plane of panel; so, the angle between the tubes is 90° . The differential signals of each pair of LDRs representing the angular error of the solar panel are employed to re-position the panel in such a way that the angular errors are minimized.

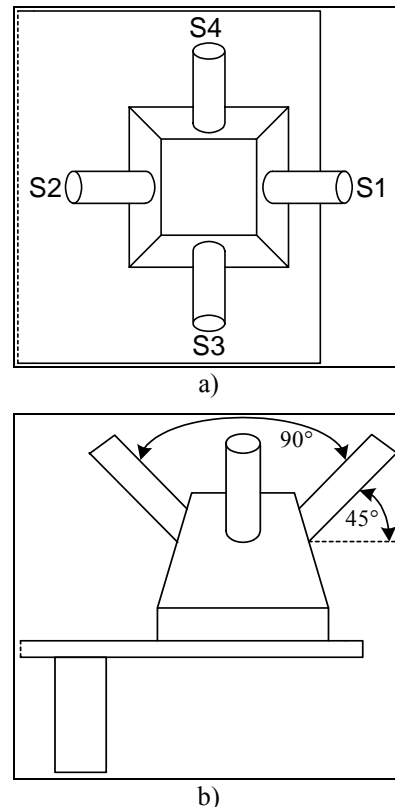


Figure 3. The LDRs assembly, a) Top view, b) Front view

A micro-controller system with PIC16C71 used as the controller of the position control scheme offers up to 10MHz clock frequency, four ADC channels with 8-bit, 1Kx14 EPROM memory and thirteen I/O ports (Anon., 1998a). Since the apparent speed of the sun is very slow, the panel will also move very slowly. Therefore, a crystal with a frequency of 4MHz is used as a clock signal generator for MCU. The signals, taken from voltage divider consisting of resistors and LDRs (S1, S2, S3, S4), are applied to I/O port lines of MCU (RA0, RA1, RA2, RA3) respectively. These analog signals are converted to digital signals and compared with each others (S1-S2, S3-S4).

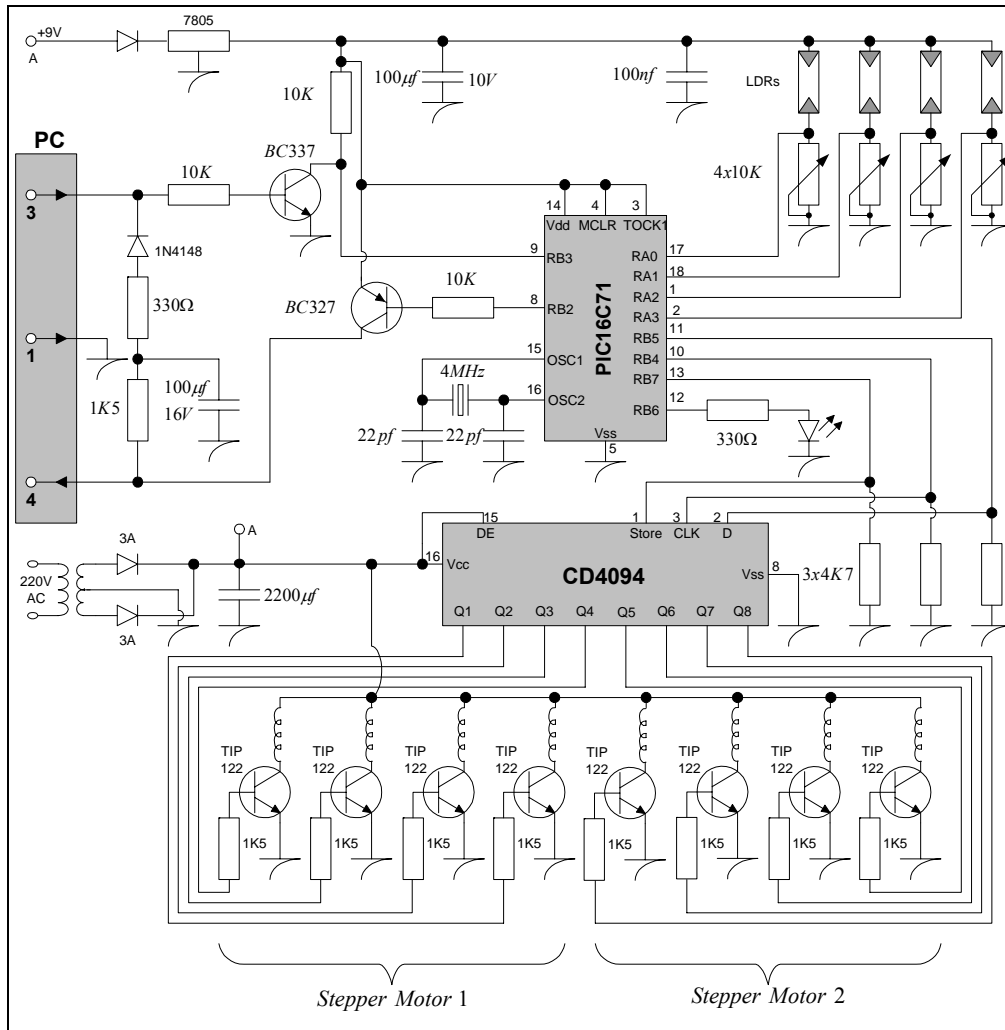


Figure 4. Schematic representation of the solar-tracking system

If the difference between S1 and S2 (or S3 and S4), error signal, is bigger than a certain value (tolerance), MCU generates driving signals for stepper motors. If the error signals are smaller than or equal to the value of tolerance, MCU generates no signal; which means that the solar panel is facing the sun and the light intensities falling on the four LDRs are equal or slightly different. Schematic representation of the solar-tracking system is given in Figure 4.

In order to drive two-stepper motors, an 8-bit shift register CD4094 is used (Anon., 1998b). Data is shifted serially through to shift register on positive transition of the clock signals generated by MCU. Four-output signals (Q1, Q2, Q3, Q4) drive the first-stepper motor and the rest of the signal (Q5, Q6, Q7, Q8) drive the second-stepper motor. In this system, eight darlington transistors (TIP122) are used to drive the SMs. The control commands generated by MCU for driving of SMs and positioning of the solar

panel are given in Table 1. As can be seen from the Table 1, when SM2 is driven, four-driving signals for SM1 is set (1111XXXX), and visa-versa.

The software is developed in an assembly programming language. It is compatible for PIC16C71 and is a machine level language. The software consists of a main module and a few subroutines. Simplified flowchart of the assembly program is given in Figure 5, where e denotes error (tolerance).

Table 1. The control Commands for Stepper Motors

STEPPER MOTOR 1		STEPPER MOTOR 2	
Q1-Q2-Q3-Q4-Q5-Q6-Q7-Q8			
Forward	Reverse	Forward	Reverse
0001-1111	1000-1111	1111-0001	1111-1000
0010-1111	0100-1111	1111-0010	1111-0100
0100-1111	0010-1111	1111-0100	1111-0010
1000-1111	0001-1111	1111-1000	1111-0001

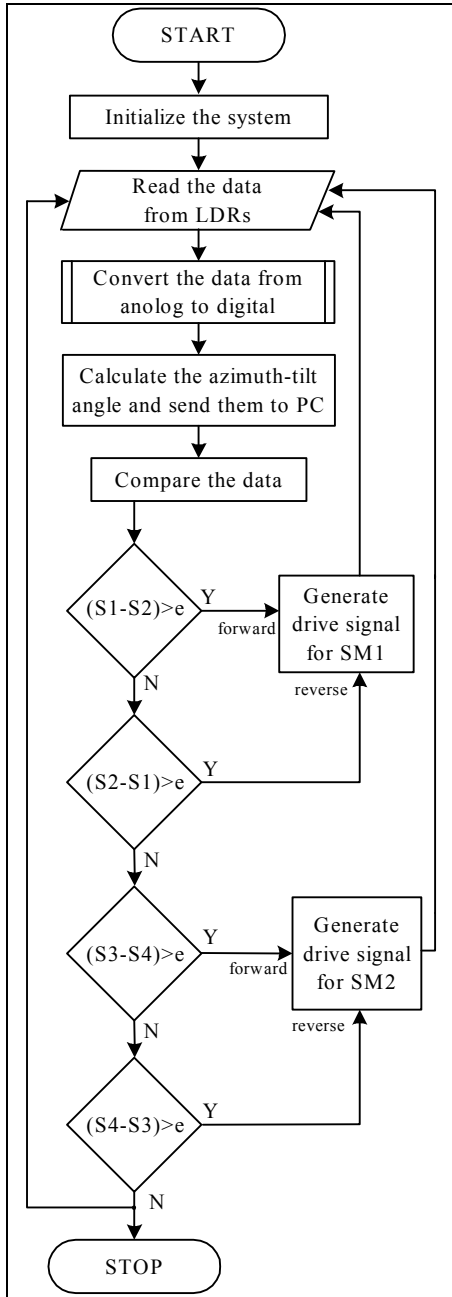


Figure 5. Simplified flowchart of the assembly program

The stepper motors requires a +9V supply and four control pulses at its terminals. One step angle of the motor is equal to 1.8°. If the difference between S1 and S2 is grater than the error, the first stepper motor should rotate forward; if the difference between S2 and S1 is grater than the error, it should rotate reverse direction. Same procedure is applied for the second stepper motor. In order to prevent the flat panel hitting to body, the panel is limited as vertically with a degree of 50° (Figure 6). Thus, the azimuthal drives can rotate on a total of degree of 260° during day times.

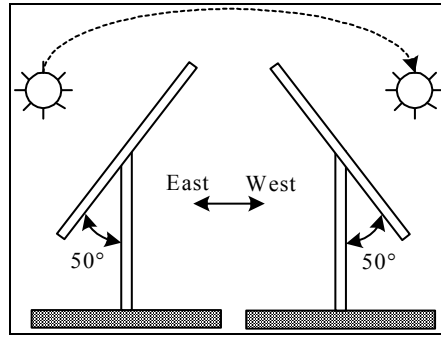


Figure 6. Limits for movement of the solar panel

In general applications, the panel should be rotated towards East direction in order to make it ready for operation on the next day. The proposed system sends no signals during night times by sensing low or none sunshine intensities and stays as pointing at west direction after the sun set. The micro-controller unit is also skipped to sleep mode and consumes low energy. During the sun rise, the LDR senses the sunlight automatically and the panel is moved towards East direction in a short time; so, there is no need any extra circuitry and software to do this. A photograph of the proposed solar-tracker-system body used in experimental studies is given in Figure 7.



Figure 7. A photograph of the proposed solar-tracker-system body

3. EXPERIMENTAL RESULTS

The solar tracking system presented here is tested experimentally. The experimental study is realized at Gazi University in Ankara, Turkey. Two solar collector panels, one of which is stationary and the other is rotary, are employed in the test. The stationary panel is tilted at a fixed elevation angle and is oriented in some azimuth angle. The LDRs assembly is mounted on the rotary one. Temperature of the panels versus time is measured with a minute-interval of 11.75' in the period 7:48 to 17 : 24. So, a total of measurement time is 9:36'. In this interval, a

total of 50 data were captured from the stationary panel and the rotary panel with approximately an angle interval of 5.2°. The measurement results are given in Figure 8. The differences between the temperature of rotary panel and that of stationary one are also given as graphically in Figure 8.

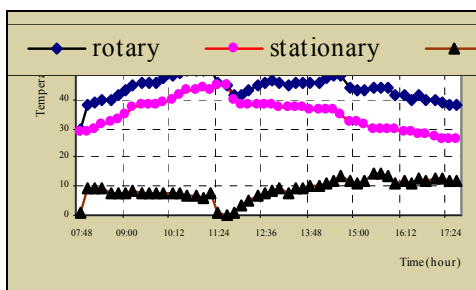


Figure 8. The measurement results

According to the results: while the sun rises in the morning, the temperature of each panel also increases linearly and the difference is almost constant until about 11 o'clock because of being illuminated from the sun with different azimuth and tilt angle (ψ, α). After this point, the temperature of panels decreases until about 11:30 due to weather condition. The temperature, then, increases to the normal condition again, and then keeps decreasing slightly afternoon. The temperature of average value of the stationary panel between the hours of 7 : 48 and 17 : 24 is measured as 34.9 °C and that of the rotary panel is 43.88 °C. It is very obvious that there is approximately a distinction of 9 °C between rotary and stationary panel. This result shows and verifies that the rotary panel containing solar tracking system takes more light density than the stationary panel.

System monitoring software in PC is developed in Pascal® program. Thus, LDRs' information depending on light intensities, the angles of azimuth and elevation, and position of the panel can be simultaneously monitored. The window screen of the system monitoring is given in Figure 9.

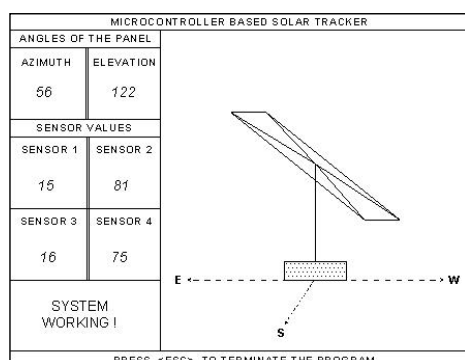


Figure 9. The window screen of the system monitoring

4. CONCLUSIONS

In order to collect the greatest amount of energy from the sun, solar panels must be aligned orthogonally to the sun. For this purpose, a new solar tracking technique based on micro-controller was implemented and tested in this study. The tracking system presented has the following advantages: The tracking system is not constrained by the geographical location of installation of the solar panel since it is designed for searching the maximum solar irradiance in the whole azimuth and tilt angle (except hardware limitations) during day times; namely, the angle of elevation does not need to be adjusted periodically. The operator interference is minimal because of not needing to be adjusted. The tracker provides also PC based system monitoring facility. Since the tracking system is controlled completely by MCU; the PC, used for monitoring the panel only, may not be employed. A drawback of the tracker is being effected by temporal variations in the atmospheric refractions caused by rain, cloud, fog, etc. Thus, the system may give an erroneous detection in the direction of the sun, and lead to wrong positioning of the solar panel.

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