Double Axis Solar Tracking System Design and Implementation

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Abstract— The designed system consists of mechanical system and electronic control circuit. Due to the large panel size of the system, the DC motors were used and the slowest motor speed settings were chosen. By applying a PWM signal, the speed of the motors is optimized. In addition, using the limit switches, the movement range of the panel is limited for undesired situations. The system was placed at Afyonkocatepe University ANS Campus after the design phase. The system follows the sun in a certain time period and generates energy at a constant angle by deactivating the control mechanism in a certain time period. In these two cases, the amount of energy obtained from the system is compared. It has been observed that when using the power system, it generates 25% more energy than the fixed system. In addition, the solar tracking system is compared with the fixed panel systems in terms of cost. As a result, energy and cost data were combined and the economic analysis of the system was carried out.

Index Terms—, Energy efficiency, Energy economy, H-Bridge motor control, Microcontroller, Solar tracking system

1 Introduction

In recent years, the need for clean energy sources has increased steadily due to global warming and climate changes, especially as fossil fuels have been suffering from environmental damage and the decline of such energy resources. For these reasons, clean energy is among the important issues that have been concentrated on the earth. As energy consumption increases day by day, there are searches for different energy sources and trying to find alternative energy sources. Solar panels that generate energy by using solar energy included in alternative energy sources are widely used. Solar panels have an average efficiency of 18-25%, and there are studies in the literature aiming at more efficient use. There are designs of mechanical systems based on axis motion for the panels to follow the sun in the applications for the efficient use of the solar panels. The efficiency of the existing systems can be increased mechanically by using the single tracking or dual axis moving solar tracking systems.

Vilsan and his colleagues used both wind energy and solar energy in order to use the energy continuously. As a result, it has been proved that for a telecommunication system which must be continuously operated, a hybrid wind and PV power system can be obtained by working together as a good alternative [1]. Erdoğan and his colleagues designed the Maximum Power Point Tracking (MPPT) for efficient use and storage of energy. They designed the MPPT to operate at maximum efficiency by using the soft-switching method in the design [2]. Esram and his colleagues researched the algorithms used from the past to the present for MPPT. In total 19 different algorithms have been used and these algorithms have been investigated [3]. In Demirtaş's study, the system can be controlled in two different ways as microcontroller and computer controlled. Computer controlled, solar tracking and energy storage allows instant data storage on the computer. In this way, the desired operations can be performed quickly with the instantaneous data [4]. Verachary and colleagues have designed a system that uses MPPT using fuzzy logic. The proportional (P) controller controlled system and the fuzzy logic controlled system were compared [5]. Karimov and colleagues designed and produced a simple photovoltaic (PV) monitoring system using a pyramidal stand (stand with four rotating modules). Cost analysis of the proposed PV solar monitoring system shows that it is cheaper for low power applications [6]. Azab has developed an algorithm that checks the power taken from the PV panel. The simple structure of the algorithm, the high convergence speed and the independent acquisition of the PV characteristics provide a great advantage. In the tests performed, the response time of the system is very fast. [7].In Gülşah's study, simulation of the network-related photovoltaic system with Matlab / Simulink was performed and the effects of the photovoltaic system on the network were investigated [8].Villalva and colleagues used a PV cell modeled as a function of maximum power point characteristics and analyzed the performance of the PV system in this study.They simulated according to the daily variation of solar radiation and simulated the effect of temperature on the system [9].In Aydoner's work, he wanted to reduce the installation costs of photovoltaic systems and build a building model of his own energy by applying integrated photovoltaic system to the building. It has also been found in sharing how to set up such a system [10]. Rubio and colleagues have designed a control application that follows the sun and aimed at high efficiency [11]. Öksüztepe designed a mechanical system that could follow the sun with a computer program in his work. The system can act spherical with motor control [12]. Okan and his colleagues used double-axis solar panel design using Ldr sensors. In this design, Ldr sensors and servomotor control have been provided with the help of a microcontroller [13]. In a study by Shugar and colleagues, a 2-axis solar tracking system was designed and observed as 9% more efficient than a uniaxial solar tracking system as a result of this design [14]. Bakos worked on a dual axis solar tracking system. The panel they designed had 46% higher efficiency than the fixed panels [15]. Alata and his colleagues used a fuzzy logic control algorithm for a dual axis solar tracking system [16]. Al-Naima and his colleagues have designed a high-efficiency, dual-axis solar tracker capable of handling complex equations, collecting the necessary data from the GPS card, and recording and managing them correct-

ly [17]. Beyoğlu has done a comparison between the 2-axis solar panel and the fixed axis PV system in Balikesir province. As a result of this study, the2-axissolar panel was found to work 39% more efficiently [18].

In this study, unlike the literature, a mechanical design has been carried out in such a way that the design is cheaper and the efficiency of the system is increased. Thanks to the designed system, daylight with solar panel can follow 360 degrees in vertical axis and 180 degrees in horizontal axis. Second-hand gearbox wiper motors are used for system motion control. With the use of these motors it is aimed to reduce the design cost.

2 METARIAL AND METHODS

The design phase of the project consists of two main parts. These are electric and mechanic parts. Also, electrical part can be divided in two subsections named as control system design and programming.

The mechanical system consists of two DC motors to provide horizontal-to-vertical and left-to-right motions and gears that will transfer their movements to the solar panel. According to the calculations made, a large and powerful system was designed to carry a solar panel of about 100W (Fig 1). The voltage information from the LDRs is given to the analog inputs of the microcontroller and DC motors are controlled according to this voltage information by the prepared software. Since the analog outputs of the PIC16F877 can not supply the current required to rotate the DC motors, a separate H Bridge driver circuits were designed within the two DC motors. In this system, the battery was used as a power source for supplying electronic system parts. The used solar panel is shown in Figure 1. The electrical properties of the solar panel are given in Table 1 and the physical properties are given in Table 2.

Figure 1: Solar panel used in the project

TABLE 1
ELECTRICAL PROPERTIES OF THE SOLAR PANEL

Nominal Power	100 W
Open Circuit Voltage:	21,60 V
Short Circuit Current:	6,03 A
Rated Voltage:	18 V
Rated current:	5,78 A

TABLE 2:
PHYSICAL PROPERTIES OF THE SOLAR PANEL

Number of solar cells in the module	48
Dimensions (inches) Length x Length x Thickness	1020 x 640 x 30 mm
Weight	9.5 kg
Area (square meters)	0,65 m2

2.1 Designed Main Control Circuit

The motherboard is mainly based on a microprocessor which is the brain of the system. Thanks to its built-in microprocessor, LDRs are used to detect ambient light level and send motor drive information to the drive circuit according to the light level. Analogue information from the light sensor is read through the microcontroller's ADC (Analog Digital Converter) connector. The read analogue information is converted to digital numbers and the information is transmitted to the motors according to the algorithm in the program. The information transmitted to the motors is both speed and direction information. Speed information is sent to the driver via PWM (Pulse Width Modification) signal while direction information is sent in digital (1-0). Control Part of the Solar Tracker System can be seen in Figure 2.

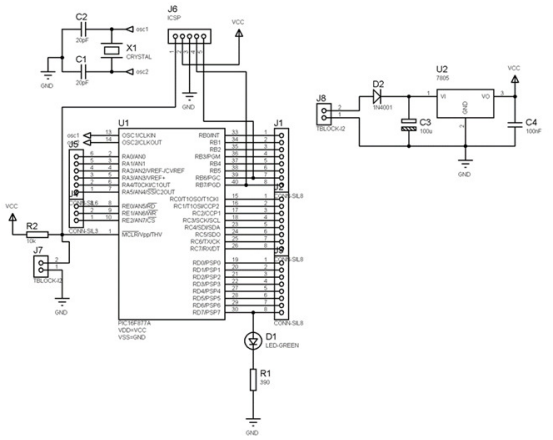

Figure 2: Control part of the solar tracker system project

2.2 DC Motor Driver Circuit Operation Logic

Two DC motors have been used to provide right-left and up-down movement so that the panel can follow the sun with minimum error. A microprocessor is used in determining the

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direction of motion of these motors and performing the switching process.

The motor drive circuit basically consists of two parts. The motor drive circuit is a semiconductor-controlled circuit with a main-power H-bridge connection. It comes from the logic circuit that combines the speed and direction information that the microprocessor receives and safely operates the transistors. The microprocessor sends speed and direction information at the same time and the panel is rotated in the correct direction at the desired speed. The 16F877A integrates two PWM outputs to send speed information. There are many logic outputs in direction information. Depending on the speed and direction information coming from the microprocessor, the decision of which transistors will work can be determined by logic gates. Logic circuit is designed with 7408 AND gate. The AND gate is basically an output in the case of logic 1 in both inputs, while output is logic 0 in any case. With this feature, eight transistors can be driven with two PWM outputs in used microprocessor. Solar tracer system DC motor driver circuit is seen in Figure 3.

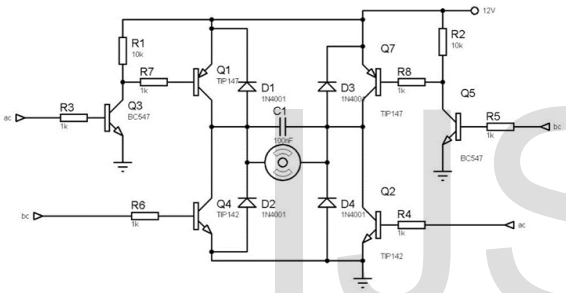

Figure 3. Solar tracker system DC motor driver circuit

If the transistors Q1 and Q2 conduct, the motor current flows from left to right, the transistors Q4 and Q7 conduct, the motor current will flow from right to left, and the motor will reverse the previous direction of rotation. Designed H-Bride motor drivers can be seen in Figure 4.

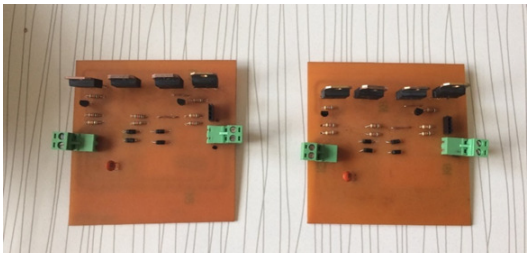

Figure 4. Designed H-Bridge DC motor drivers

2.3 Mechanics Part

The mechanical part consists of two motors to provide horizontal-vertical and right-left rotation movements and a gear and chain which will transfer the movements to the panes. In the calculations made, suitable motors with a torque of 9.5 kg are selected.

2.3.1 Potentiometer

The potentiometer used in the project is a linear potentiometer and the resistance is linear. The resistance value increases linearly from 0 with respect to the turning angle of the potentiometer shaft. With this increase, voltage control is provided linearly in an electronic circuit. The position of the panel was determined by the potentiometer connected to the upper motor shaft and the direction of the motors was determined according to the position.

2.3.2 Switches

There are two switches in our system. These are a kind of protection for our system. The switches are used to stop the DA motor when the panel is in the horizontal position, at the end point. This shows us that our panel has reached the end. Mounted limit switches can be seen in Figure 5.

Figure 5. Mounted limit switches at the solar tracker system

2.3.3 Gear System

The Gear Wheel is a power transferring element that is used to transfer the rotational movement that occurs in the machine to the other mile. The task of the gears is to perform the power transfer process while increasing or decreasing the rotation speed at the same time. The gear chain system used in the project is shown above. The gear system is used to slow the pivoting spindlesince the DC motors are turned at a high speed. At the same time, it made sure that the DC motor turned without any effort.

2.3.4 Roller

Rollers are used in many machines that work or operate with circular or axial movement. The main duty of rollers; to ensure that the movement is transmitted with as little friction as possible. Two rollers were used in this project. The rollerswere used to rotate the panel in the vertical axis so that the motor can rotate with maximum efficiency, with minimal friction. Mounted roller at the bottom of solar tracker system can be seen in Figure 6.

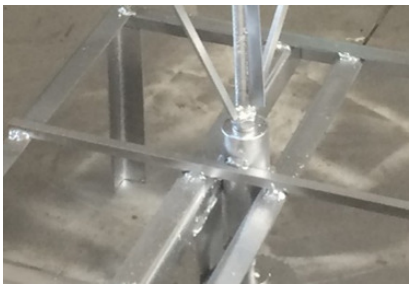

Figure 6. Mounted roller at the bottom of solar tracker system

2.3.5 Profile Iron Stand

It is used to place the solar panels at a certain angle to the ground plane. It is specially designed stainless steel or steel structure for the fixing process. The iron stand used in the project was made 50cm * 50cm wide. The height was 15 cm. The iron stand is designed so that the system can be easily balanced and the vibrations that can occur when the system is working can reduce the worst. The used iron stand table has the durability to carry the system easily. Designed profile iron stand is can be seen in Figure 7.

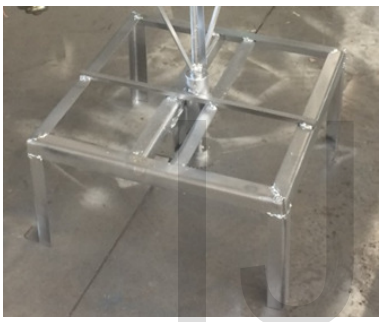

Figure 7. Profile iron stand of solar tracker system

2.4 Control Algorithm

The designed double axis solar panel control system is controlled by PIC16f877 microprocessor. The movement of the solar panel was carried out with two DC motors as horizontal and vertical axes. The position of the solar panel is controlled according to the information from the four LDR sensors placed on the panel. LDR sensors transmit the information of up, down, left and right directions to the system. First, when the system is started, the software controls for the control are performed. A few rounds of solar panels are turned to the right to prevent the cables from wrapping around the hull and to determine the initial starting position. After the initial starting position has been determined, light is emitted from the LDR sensors. According to the information obtained from the LDR sensors, the position of the solar panel is determined by the algorithm as up-down or left-right. Solar tracker system control algorithm is given in Figure 8.

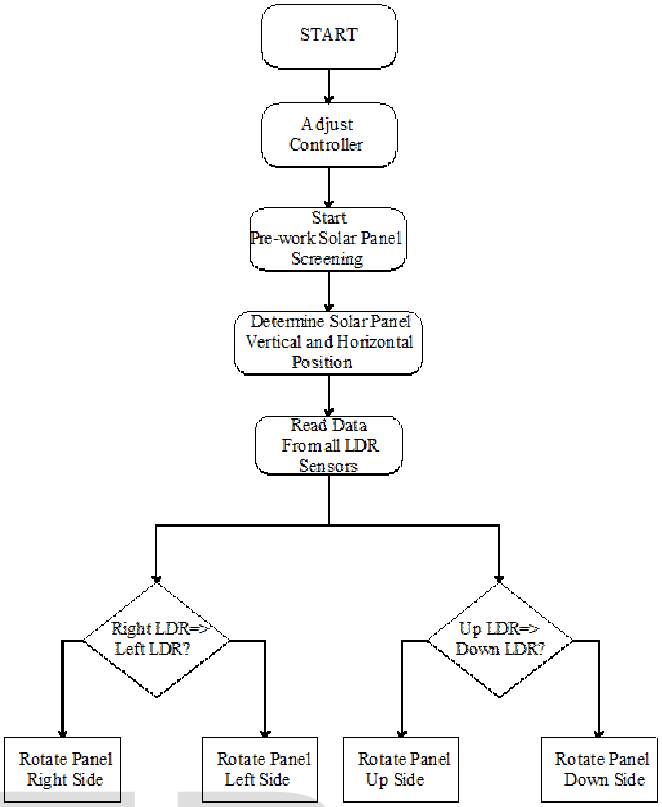

Figure 8. Solar tracker system control algorithm

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3 DESIGNED SOLAR TRACKER SYSTEM OVERVIEW

The general view of the designed system from the front and rear is given in Fig. The mechanical and electronic components of the system were designed and prototyped. The energy required for the control system is additionally supplied by the used battery. For the analysis of experimental results, an experimental setup was established, both fixed and mobile. Power values were taken at specific time intervals. The impact of the mobile system on energy efficiency has been researched. The values required for the fixed state are taken by mounting a solar panel to laboratory roof. Mounted solar panel is seen in Figure 3. Designed and implemented solar tracker system with solar panel can be seen in Figure 9. Also wall mounted fixed solar panel can be seen in Figure 10.

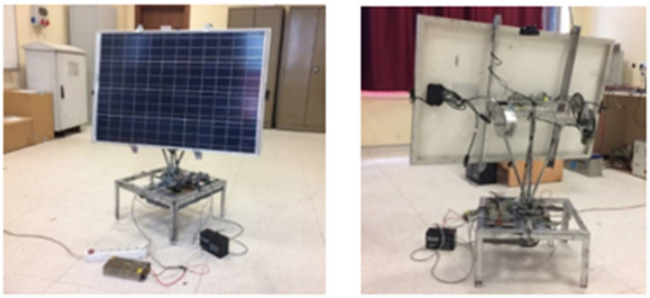

Figure 9. Solar tracker system with solar panel

Figure 10. Wall mounted fixed solar panel

4 EXPERIMENTAL RESULTS AND DISSCUSION

The data of the moving solar tracking system was taken at 25 June 2018 between 13.00 and 17.00 hours. DC lamps are used as load in the system. The amounts of generated power in the time intervals when the solar panel is moving and stationary are shown in Fig. 11 and Fig. 12, respectively.

An average of 60 W of energy was produced when the solar panel was stationary. When the solar system was followed by the moving system on the designed system, energy production was realized around 80W. Thanks to the designed system, it is possible to produce approximately 25% more energy. Table 3 gives the system cost and whole system was designed approximately 740 TL.

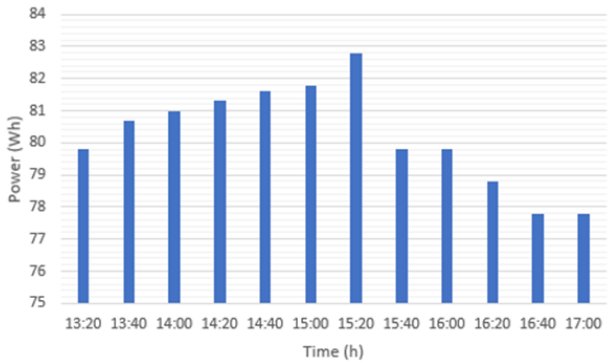

Figure 11. Wall mounted fixed solar panel Power Values

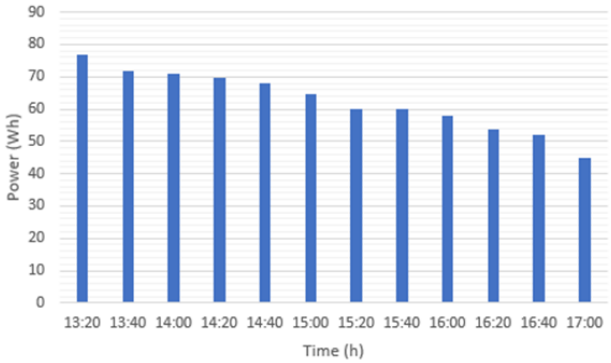

Figure 12. Solar Panel Power Values wirh Solar Tracer System

TABLE 3:
SOLAR TRACKER SYSTEM COMPONENTS PRICE AND TOTAL COST

COMPONENTS	UNIT PRICE	UNIT PRICE	UNIT PRICE
Solar Panel	300	1	300 TL
Reduction motor	50 TL	2	100 TL
Roller	10 TL	2	20 TL
Cooler + Switch	10 TL + 5 TL	1+2	20 TL
Gear Set	30 TL	2	60 TL
Chain (50cm)	10 TL	1	10 TL
Battery (12V 7Ah)	50 TL	1	50 TL
Electronic Materials	100 TL		100 TL
Copper Plate (10x15cm2)	3 TL	3	9 TL
Connection Wires	30 TL	1	30 TL
Used Iron	3 TL	20	60 TL
Toplam		739,0 TL	

5 CONCLUSION

In this study, a mechanical system design with double axis and following the sun has been realized. The system is basically made up of mechanical and electronic components. In the mechanical part, two motors have been used to allow the system to move with double axes. The system is designed to monitor the sun through the LDR sensors placed on the panel. An inexpensive microcontroller of the PIC16f877A type has been implemented to control the system according to the control of the motors and the sensors. The mechanical part is also designed so that the double axle can move smoothly. The power values of the solar panel are measured at a certain time interval so that the power values can be compared according to the moving and steady state of the system during operation. It has been determined that about 25% more power is obtained from the moving system than the standing system. Finally, cost analysis of the system has been done.

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