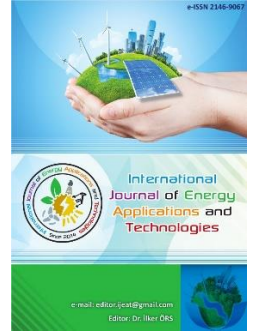




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Original Research Article

### Solar tracking system with PID control of solar energy panels using servo motor



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#### ABSTRACT

Parallel to the developing technology and the increasing population, the energy requirement is increasing day by day. Turkey's dependence on foreign sources of energy constitutes a significant budget in terms of energy costs. In this context, in Turkey, renewable energy sources with high potential are gaining importance. Fossil energy sources cause environmental pollution and threaten human health more and more every day. For this reason, the use of renewable energy sources should be encouraged and widespread. With a good energy needs analysis, producer costs will be reduced and efficiency will be increased.

Solar energy is an efficient resource in electricity generation. Increase the efficiency of the solar panels used, increases the amount of electricity produced. However, the change in the angle of the sun's rays has an adverse effect on energy production.

In this study, it was aimed to increase the efficiency of the solar panels by moving according to angle of sunlight. For this purpose, solar panel was driven by the servo motor and it was directed to the sunlight. Servo motor's PID control was implemented using the MATLAB program. The energy analysis made is given in the results.

*Keywords:* Solar Panel, Servo Motor, PID control

#### 1. Introduction

The increasingly depletion of fossil fuels has led scientists to clean and renewable energy sources. In addition, environmental pollution and high costs have increased the speed of renewable energy research. Especially in recent years energy production with renewable and environmentally friendly new energy sources have gained great importance [1].

The most common sources of renewable energy are wind and solar energy. These two energy sources are readily available in many parts of the earth. For reasons of simplicity of control and low investment cost, studies have been carried out on the production and use of solar or wind energy independent of each other. Despite these developments, the need for a diesel

generator for recipients who cannot feed from the network arises because the energy generated by the independent use of each system does not enough when the daylight or wind is not available [2,3]. In such applications, solar analysis is the most important criterion at the beginning of the system. In Turkey, wind and solar power analyzes have been done according to the regions and systems have been independently investigated or applied [4,5]. The performance of systems designed using solar energy was compared with the help of computer simulations by creating mathematical models in various applications made with solar panels [1, 6-8].

Bingöl et al. (2006) conducted a study to follow the sun by using stepper motor and light sensor in microprocessor based

solar tracking system. Sefa et al. (2009), the study they have done in Turkey, RS-485 communication interface and microcontroller-controlled single-axis solar tracking systems were designed. Due to the simplicity of the system, it will provide easy installation and less maintenance. Sungur (2009), the work that it has done in Turkey has calculated the sun's azimuth and elevation angles relative to the movement of the sun and the solar tracking system has been checked by the PLC. It has determined that with mobile system, it produces 42.6% more electric energy than the fixed system. Eke and Şentürk (2012) have compared production of two-axis solar tracking system established on the campus of Muğla University with the production of the fixed system. As a result of the study, according to an annual production data measured between April 2010 and March 2011, the production of the movable system is 30.79% higher than the production of the fixed system [11].

In the studies, usually microprocessor or PLC processors are used and DC or stepper motors are used as actuators.

In this study, the servo motor is used as an actuator because the start and stop settings are easily controlled by PID (Proportional- Integral- Derivative) control. The Data Acquisition (DAQ) card is used as the controller for ease of direct control and data collection. The solar panel is driven by the servo motor. The system is operated by computer control and the data of energy production is recorded instantaneously. By tracking the sun with the designed system, it is aimed to produce more electric energy than the fixed position models. The structure of the servomotor and the PID control method are examined and the applied solar tracking system is explained. In the conclusion part, the system which is designed with the help of the obtained data is compared with the fixed system.

## 2. Material and Methods

The azimuth and elevation angle of the sun at noon are two basic angles for positioning PV panels. In order to calculate the change of the position of the sun throughout the day, both the elevation angle and the azimuth angle changes within the day should be calculated. To calculate the position of the sun, first find the local sun time, then calculate the height and azimuth angles [11]. In a day, the angle of the sun according to the hours is shown in Fig. 1.

Solar radiation data is usually in the form of spherical radiation falling on a horizontal plane. For this reason, the solar panels are positioned at a certain angle with the horizontal plane. The sun moves in the sky during the day. For a solar collector and / or panel in the steady state shown in Fig. 2, the projection of the respective receiver region onto the plane is determined as the cosine of the incoming light. As the sunshine angle " $\theta$ " increases, the power received from the panel decreases [9].

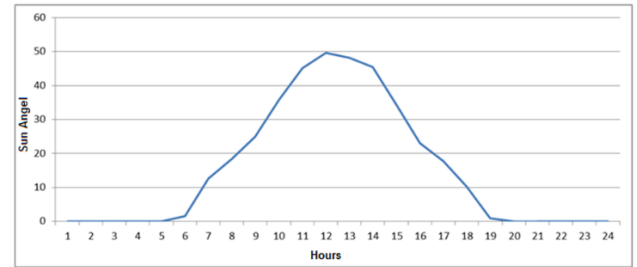


Figure 1. Hour - sun angel graphic

Solar tracking systems aim to maximize the energy to be obtained by trying to keep the solar panels according to the sun in the perpendicular position to get the best possible radiation from the sun. However, there is no need for very high resolution, even at a 10-degree deflection from the proper right angle, the efficiency is over 98% [10]. In this study, considering productivity and price/performance criterions, polycrystalline solar panel was used.

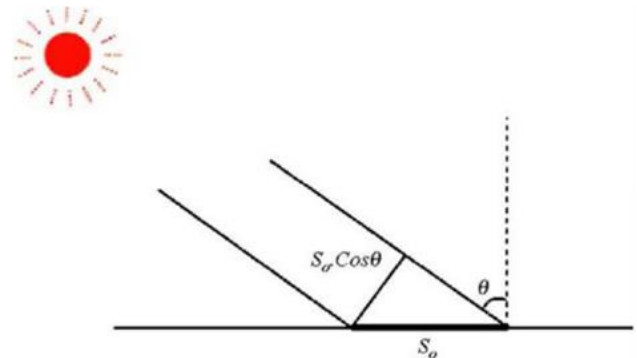


Figure 2. Sunshine angle,  $\theta$  [9]

The study of Orkun (2013) shows that there is no significant difference between 10 and 15 hours between moving and fixed systems. Following the sun between these hours will cause unnecessary energy consumption [11]. For this reason, it is enough to take the sun panels to the appropriate positions with minimum movement during the day instead of following the sun constantly. For this purpose, two analog Light Dependent Resistor (LDR) sensors are placed in the east-west direction and the movement is made according to the light intensity difference. The light level detected by the LDR is converted to a digital value between 0 and 1023 and used as the input value of the controller. The panel is moved when the voltage difference between the mutual LDRs exceeds 0.1 volts. When this difference drops below 0.1 volts, the rotation of the panel is stopped. Thus the maximum amount of light falling on the panel is ensured. The output value of the controller is the servo motor control signal. In this study, DAQ card was used as a controller to drive servo motor with developed MATLAB code. "MATLAB® Simulink" simulation platform is used to generate code [12].

### 2.1. Servo motor

The servo is defined as the drive system that makes the

angular-linear position, speed and acceleration control in the mechanisms error-free. Servos are designed to get the desired position and not change the position as long as there is no new command. There are one DC motor, encoder and motor drive circuit in the body of servo motors (Fig. 3). There is an external drive in industrial servo systems. The encoder measures the amount of rotation of the motor shaft and the control circuit performs the motor drive operation by comparing the desired position with the position of the motor. Servos are controlled by sending an electrical pulse of variable width, or pulse width modulation (PWM), through the control wire. There is a minimum pulse, a maximum pulse, and a repetition rate. The PWM sent to the motor determines position of the shaft, and based on the duration of the pulse sent via the control wire; the rotor will turn to the desired position. The servo motor expects to see a pulse every 20 milliseconds (ms) and the length of the pulse will determine how far the motor turns [13].

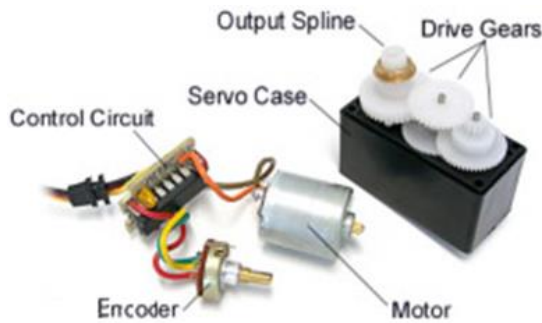


Figure 3. Servo motor and components [13]

The position of the designed system and servo motor is shown in Fig. 4. The panel was moved only in the east-west direction and the angle in the north-south direction was kept constant at 35°.



Figure 4. Designed solar system

### 2.2. PID control of system

A PID controller compares the signal from the output to the input (reference) signal by feedback and an error occurs.

According to this fault, the PID controller makes an effect by reducing the fault to the minimum and sends it to the output. In this way, errors are determined by continuous feedback from the output to the input until the error is minimized, and the error is reduced by sending the controller effect to the output. The PID control method includes three parameters; P (proportional), I (integral) and D (derivative).

- Proportional Term (Kp): The proportional term is your primary term for controlling the error.
- Integral Term (Ki): The integral term lets the controller handle errors that are accumulating over time.
- Derivative Term (Kd): The derivative term is looking at how your system is behaving between time intervals. This helps dampen your system to improve stability.

What is important here is to determine the Kp, Ki and Kd gains. Kp, Ki and Kd gains should be selected to meet the criteria such as minimum and zero error for the most suitable setting, minimum overrun, short time error resolution and stability in the system [14]. The controller block diagram of the designed system is shown in Fig. 5.

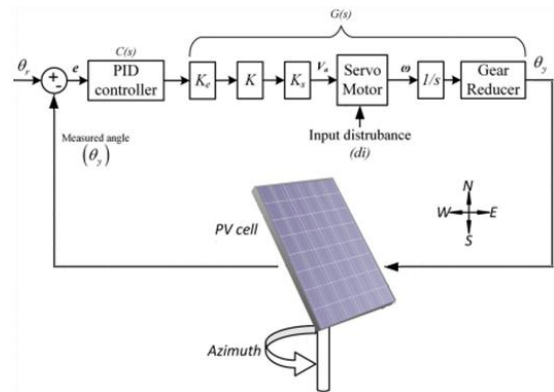


Figure 5. PID Controller [15]

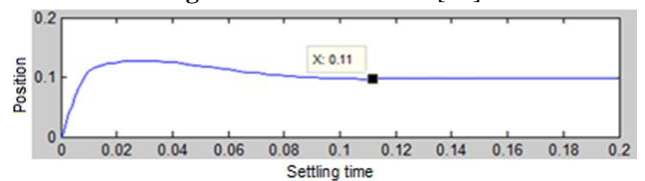


Figure 6. Settling time – Position graphics for motor

The graphs of the control signals (U) for the system are shown in Fig. 7.

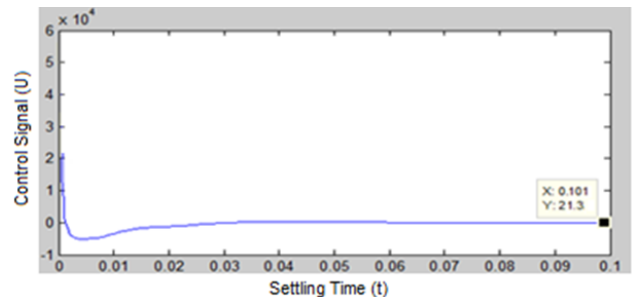


Figure 7. Settling time – Control signal graphics for servo motor

The system is controlled by the PID control method created in the MATLAB program. The  $K_p$ ,  $K_i$  and  $K_d$  gains are 0.0428, 0.0014 and 3.0126 respectively ( $1.0e+04$ ). Obtained values are optimized by genetic algorithm method. Position-settling time graphics for servo motor is shown in Fig. 6. As can be seen from the graphs, the longest settling time is about 0.11 seconds.

### 3. Conclusion

In this study, the polycrystalline solar panels were rotated to the sun through the servo motor according to the information received from the LDR sensors, and production was continuously tried to be maximum. Servo Motor is controlled and data acquisition realized by DAQ card, PID control algorithm written in MATLAB Simulink simulation platform. PID control is applied to reduce the energy consumption of the motor at the starting and stopping.

The system was tested on sunny days for 1 week in September and the production data in Table 1 was reached as the result of the application.

**Table 1.** Solar energy production data

	Mobile	Fixed
Total Production (Wh)	216.72	188.26
Average Surface Temperature (°C)	24.43	22.17
Average Ambient temperature (°C)	21.65	
Total Radiation Intensity (W/m <sup>2</sup> )	6980	

Shown in Table 1 that by following the sun the electricity generation from solar energy by the mobile system is higher than fixed system. With the mobile system 28.46Wh more energy generated according to fixed system.

Investment costs in energy production systems are expected to be low. At the applied system, a single panel is controlled by a servomotor and therefore the investment cost is high. However, the fact that more than one panel is controlled by a single engine with the aid of a mechanism and directed to the sun will reduce the investment costs considerably and the cost will be amortized in the short-term with the difference of the production.

One of the important parameters here is to ensure that the energy consumed to drive the panel is less than the energy generated. Otherwise, the system will waste more than it produces. For this reason, it is important to optimize the orientation and avoid unnecessary energy consumption.

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