

Design of a Solar Tracking System by Using Arduino

Oguzhan Timur (Corresponding Author)
Department of Information Technologies, Cukurova University
Saricam, 01330, Adana, Turkey
E-mail: otimur@cu.edu.tr

Ahmet Teke
Department of Electrical and Electronics Engineering, Cukurova University
Saricam, 01330, Adana, Turkey
E-mail: ahmetteke@cu.edu.tr

Abstract
Recently, renewable energy resources have gained importance as a result of increasing energy demand and rapid depletion of fossil fuels. Most of renewable energy resources depend on sunlight in one way or another. Since the solar energy is sustainable, the sun can be considered as an abundant energy source. Photovoltaic (PV) modules are used to convert sunlight into electrical energy. The amount of produced energy may change according to efficiency of the type of PV module. In other respects, proper positioning of PV modules directly affects the yield of solar energy system. Solar tracking systems (STSs) are designed to track the sun in order to position the PV modules and to provide the highest efficiency. In this study, an Arduino microcontroller based vertical axis STS was implemented to obtain the maximum power by rotating the PV modules either left or right.

Keywords: Solar tracking system, Arduino, Renewable energy.

1. Introduction

Fossil fuels have been exhausted too fast with respect to increasing energy demand. Therefore, renewable energy resources have been preferred to traditional fossil fuels. Furthermore, if renewable energy resources are compared to fossil fuels, they are cleaner, sustainable and more environmentally friendly.

In the Horizon 2020, the European Council outlined clear objectives for the European Union's strategy named as 20-20-20. 20% reduction of the total energy consumption, 20% contribution of renewable energy resources to total energy production and 20% reduction of greenhouse gases are aimed below the level of the year 1990 emissions before the year 2020 [1, 2].

As in many developing countries, Turkey has also been struggling with energy problems. In order to solve those problems and compensate for energy needs, Turkey has been purchasing energy from other countries, but recently it tends to utilize renewable energy resources. What is more, Turkey is trying to find available domestic natural resources. By the end of 2016, Turkey supplied 35% of the total energy production from renewable energy resources. In addition, Turkey's total installed capacity based on renewable energy was about 35 GW by the year 2017 [3].

By the end of May, 2018, the total installed electric power capacity of Turkey was 87,040.9 MW which includes both licensed and unlicensed electric power plants. The total capacity contains 46,819 MW from fossil fuels, 27,722 MW from hydraulic, 1,129 MW from geothermal, 6,667 MW from wind, and 4,703 MW from solar respectively. The percentile distribution is shown in Figure 1 [4].

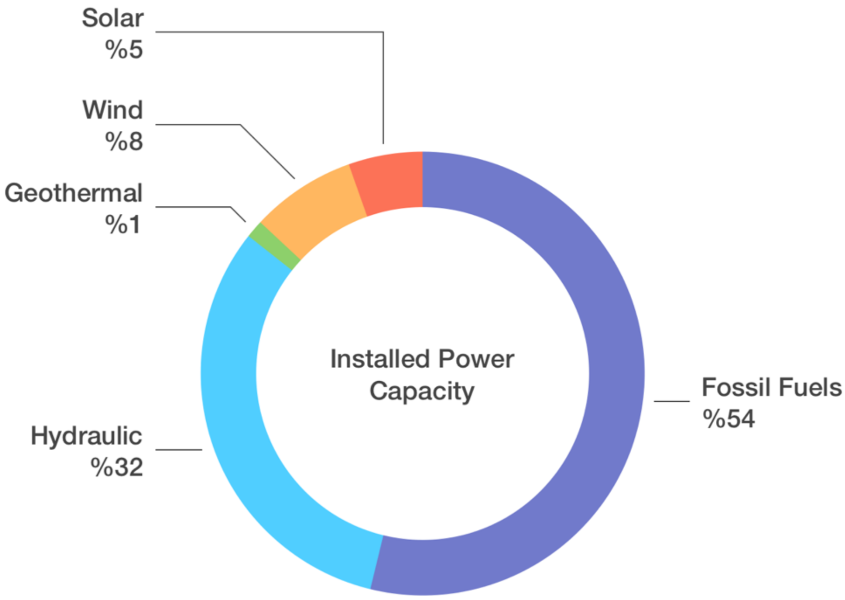

Figure 1. Installed electric power capacity of Turkey by the end of May 2018 [4]

PV modules produce variable energy at different times of a day. Depending on the angle and the amount of the sunlight, obtained energy may change. In order to achieve the maximum power point, the movement of the sun should be tracked and the best suitable position should be found.

Solar tracking systems (STSs) can be realized either single axis solar tracking system or dual axis solar tracking system. The STS drive systems existing in literature can be classified under five different categories, namely active tracking, passive tracking, semi-passive tracking, manual tracking, and chronological tracking [5].

In the studies carried out so far, active tracking system (ATS) and passive tracking system (PTS) have been used frequently. PTS presents a single option for tracking with a chemical material. This system works on the basis of the heating elements expanding. The chemical material is placed on the both sides of the PV module. When the sun is perpendicular to the PV module, both sides will be at balance. When the sun starts to move, one side is heated which causes one side to expand and the other to narrow, causing the PV module to rotate. Passive systems have the potential to increase efficiency up to 23% [6]. PTSs are cheaper than ATSs. ATSs have different control types such as microprocessor-based, electric-optical sensor-based, date and time methods, and auxiliary PV cells [5]. The daily energy amount of the PV module can be increased from 12% to 20% with a photo sensor based ATS [7].

Herein, ATS has been chosen to implement. ATS has input sensors, gear, motor and a controller. Controller manages the tracking system according to values received from input sensors. Read values are evaluated and then output values are calculated. According to the output values, the direction of the rotation is determined and motor rotates the PV module either left or right. When the sunlight starts to be perpendicular to the PV module, motor movement will stop.

The main contribution of this study is to express the steps of designing a STS by using an embedded card from its circuit design to coding obviously. The study is considered to assist prospective researchers in the field in adapting microcontrollers for enhancing energy efficiency of PV system. The prominent difference that distinguishes this study from studies having similar content in the literature is to share programming codes and flowchart which describes the methodology of the research and the application of STS mechanism as well.

In this study, an Arduino microcontroller based vertical axis STS was implemented to obtain the maximum power by rotating the PV modules either left or right. After this introductory section, design of a STS is summarized in Section II, the methodology of STS is presented in Section III, programming codes are given in Section IV, and the highlights of the study are discussed in the conclusions respectively.

2. Design of Solar Tracking System

In the design of STS, Arduino Mega ADK was preferred as a microcontroller. Technical specifications of PV module are given in Table 1 [8] and picture of the system is illustrated in Figure 2.

Table 1. Technical specifications of PV module [8]

Manufacturer	LCS Solarstrom AG
Product Code	LCS-M250-JA/SI
Dimensions / Weight	1650x991x40 mm / 19.5 kg
Cell Number	60 (Monocrystalline)
Maximum Power	250 W_p (±5 W_p)
Voltage / Current at P_{max}	30.96 V / 8.07 A
Short Circuit Current / Open Circuit Voltage	8.62 A / 37.92 V
Maximum System Voltage	1,000 V
Fuse Rating	15 A
Module Application / Working Degree	+45°

Figure 2. Vertical axis STS with PV module and step motor

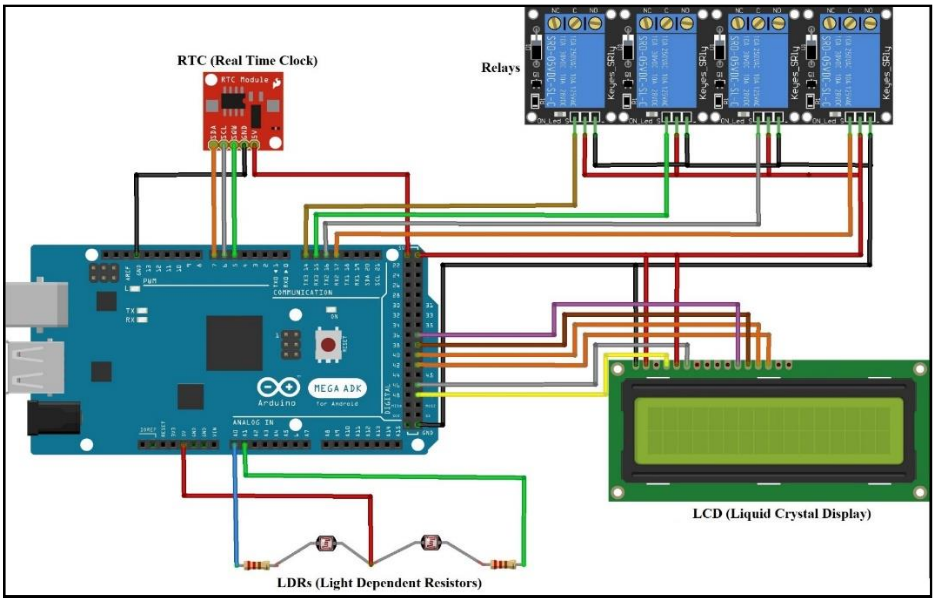

Figure 3. Circuit diagram of STS

Step motor is operating with 24 V_{dc}. When the step motor is connected to DC voltage directly, it will rotate in one direction. If the motor direction is desired to change, the polarity of DC voltage must be changed. In order to manage step motor and motor direction, quadruple relay card has been used. Besides, light dependent resistor (LDR) has been used for measuring the amount of sunlight. According to measured sunlight amount, step motor will rotate either left or right. Thanks to real time card (RTC), operation time of the system will be determined. After the sun sets, it is unnecessary to operate the system, and that's why RTC is used. In addition to all devices, 16x2 liquid crystal display (LCD) is used for time and LDR light amounts. The circuit diagram of STS is shown in Figure 3.

3. Methodology of Solar Tracking System

The working principle of STS can be explained by helping of flowchart in Figure 4. In order to measure sunlight intensity, two units of LDR are used. One of them is installed at the up-left corner of PV module and the other is also mounted at the up-right corner of the PV module. When the sun rises in the morning from the east, LDR sensor at left will take more light than LDR sensor at right side. In this situation, step motor will rotate the PV module to left. As time progresses, the sun will act to west. In this case, light intensity of right sensor will be bigger than light intensity of left sensor. Because of this, step motor will rotate the PV module to right. When the light intensities are close to each other, the PV module will remain motionless.

Embedded codes can be operated by ATMEL microprocessor. As a result, the following circuit shown in Figure 5 has been realized.

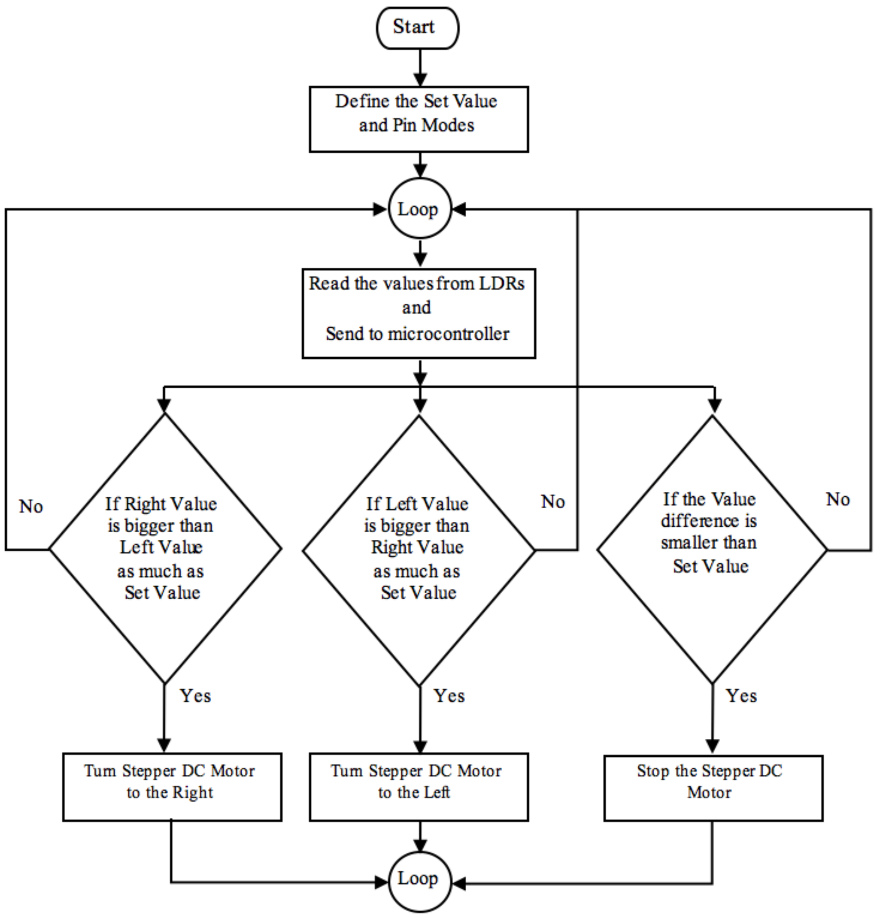

Figure 4. Methodology of STS

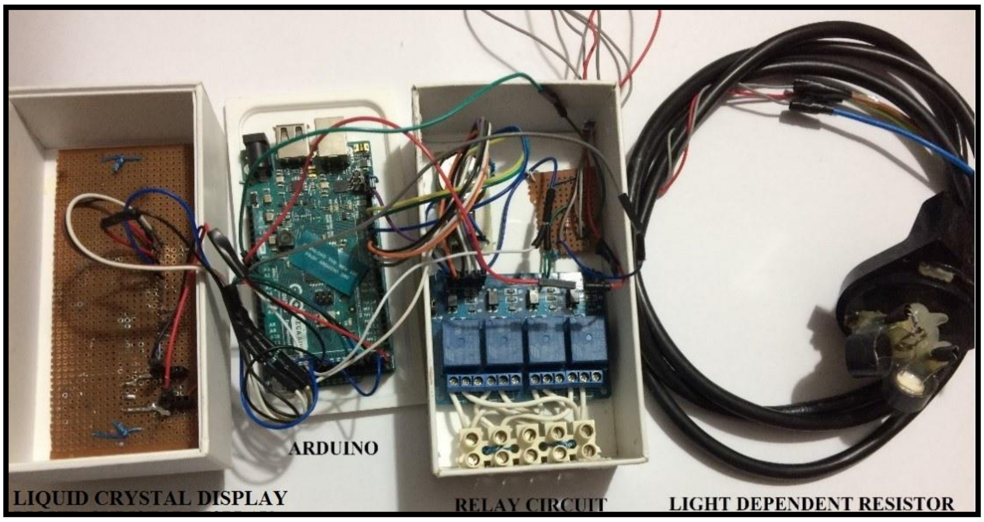

Figure 5. Application of STS

4. Programming Codes of Solar Tracking System

Programming codes of STS are written in C programming language by using Arduino IDE software and are given in below lines in detail. In these codes, only tracking system codes are given. The codes of LCD, RTC and the others are not given in order to prevent distraction.

```
////////////// SOLAR PANEL TRACKING SYSTEM ///////////////
Serial.print("Right "); // Print a message "Right " to the Serial Monitor.
sensorValueR = analogRead(sensorPinR); // Define sensorValueR as analog value of PinA0
Serial.print(sensorValueR); // Print the value of sensor Right to the Serial Monitor.
Serial.print("\tLeft: "); // Print a message "Right " to the Serial Monitor.
sensorValueL = analogRead(sensorPinL); // Define sensorValueL as analog value of PinA1
Serial.println(sensorValueL); // Print the value of sensor "Left" to the Serial Monitor.
if((sensorValueR-sensorValueL)> 100 || (sensorValueR-sensorValueL)< -100)
 // Compare Value of Right Sensor and value of Left sensor if the difference is bigger or smaller then
apply this
    {if (sensorValueL<sensorValueR)
            {
            digitalWrite (2, LOW); // Relay 2 is on
            digitalWrite (3, LOW); // Relay 3 is on
            digitalWrite (4, HIGH); // Relay 4 is off
            digitalWrite (5, HIGH); // Relay 5 is off
            }
          if (sensorValueL>sensorValueR)
            {
            digitalWrite (2, HIGH); // Relay 2 is off
            digitalWrite (3, HIGH); // Relay 3 is off
            digitalWrite (4, LOW); // Relay 4 is on
            digitalWrite (5, LOW); // Relay 5 is on
            }}
else
             {
            digitalWrite (2, HIGH); // Relay 2 is off
            digitalWrite (3, HIGH); // Relay 3 is off
            digitalWrite (4, HIGH); // Relay 4 is off
            digitalWrite (5, HIGH); // Relay 5 is off
             }
delay (1000);
/////////////////////////////////////////////////////////////////////////////////////////////////////////
```


5. Conclusions

In this paper, single axis active STS was designed and implemented. The Arduino embedded microcontroller system has been used to control, monitor and audit the system. LDR sensors have been used as input and DC step motor has been also used to output. PV module has been adjusted to move vertically for tracking the sun and producing the maximum power. Consequently, ATS is much more efficient than the fixed PV module.

Acknowledgments

The author would like to acknowledge the Scientific Project Unit of Çukurova University for the financial support for project named as "Design and Implementation of a Wireless Sensor Network for Energy Monitoring, Analysis and Management in Smart Buildings" and numbered as "FDK-2016-5772".

References

[1] Settino, J., Sant, T., Micallef, C., Farrugia, M., Staines, C. S., Licari, J., Micallef, A. (2018). Overview of solar technologies for electricity, heating and cooling production. *Renewable and Sustainable Energy Reviews*, 90, 892-909.

[2] Gokce, H. U., Gokce, K. U. (2014). Multidimensional energy monitoring, analysis and optimization system for energy efficient building operation. *Sustainable Cities and Society*, 10, 161-173.

[3] Karagöl, E. T., Kavaz, İ. (2017). *Renewable energy in the world and in Turkey*. SETAS, 197, 1-32.

[4] TEİAŞ (2018). Installed electric power capacity of Turkey by the end of May, 2018. [Online] Available: https://www.teias.gov.tr/sites/default/files/2018-06/kurulu_guc_mayis_2018.pdf (June 27, 2018)

[5] Hafez, A. Z., Yousef, A. M., Harag, N. M. (2018). Solar tracking systems: Technologies and trackers drive types – A review. *Renewable and Sustainable Energy Reviews*, 91, 754-782.

[6] Abdelghani-Idrissi, M. A., Khalfallaoui, S., Seguin, D., Vernieres-Hassimi, A., Leveneur, S. (2018). Solar tracker for enhancement of the thermal efficiency of solar water heating system. *Renewable Energy*, 119, 79-94.

[7] Kumar, N. K., Subramaniam, V., Murugan, E. (2018). Power analysis of non-tracking PV system with low power RTC based sensor independent solar tracking (SIST) PV system. *Materials-Today: Proceedings*, 5, 1076-1081.

[8] LCS (2012). *LCS Solarstrom AG Technical Datasheet*, 1-2.