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Araştırma Makalesi - Research Article

Realization of a Dual Axis Solar Tracking System

Çift Eksen Güneş Takip Sistemi Geliştirilmesi

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ABSTRACT

The effective use of renewable energy sources is very important today. Energy resources are limited and it is necessary to make maximum use of renewable energy. In this study, a dual-axis solar tracking system was implemented in the photovoltaic system in order to obtain the maximum possible energy from solar energy. In the solar tracking system, chestnut material is used as the vertical holder in the mechanical arrangement, and iron is used as the solar panel holder. By using a total of 4 LDRs at 4 corners of the solar panel, Arduino-based solar tracking on vertical and horizontal axis was carried out. The solar panel power used in the system is 45W, a geared DC motor on the horizontal axis and a linear DC motor on the vertical axis. As a result of the implemented application, a system that performs sensitive sun tracking has been realized and higher efficiency has been obtained compared to a static PV system.

Keywords- Solar Energy, Dual Axis Solar Tracking System, Solar Tracker

ÖZ

Yenilenebilir enerji kaynakların efektif kullanımı günümüzde çok önemlidir. Çünkü enerji kaynakları sınırlıdır ve yenilenebilir enerjiden maksimum düzeyde istifade etmek gereklidir. Bu çalışmada güneş enerjisinden olabilecek maksimum enerjiyi elde etmek için fotovoltaik sistemde çift eksenli güneş takip sistemi uygulaması gerçekleştirilmiştir. Güneş takip sisteminde mekanik düzende dikey tutucu olarak kestamit malzemesi, güneş paneli tutucu ise demir kullanılmıştır. Güneş panelinin 4 köşesinde toplam 4 adet LDR kullanılarak Arduino tabanlı dikey ve yatay eksende güneş takibi gerçekleştirilmiştir. Sistemde kullanılan güneş paneli gücü 45W olup, yatay eksende redüktörlü DC motor, dikey eksende lineer DC motor kullanılmıştır. Gerçekleştirilen uygulama sonucunda hassas güneş takibi yapan bir sistem gerçekleştirilmiş ve statik bir PV sisteme göre daha yüksek verim elde edilmiştir.

Anahtar Kelimeler- Güneş Enerjisi, Çift Eksen Güneş Takip Sistemi, Güneş Takipçisi

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I. INTRODUCTION

Today, electrical energy is used effectively in many areas of our lives. Electrical energy, which is in such high demand, can be produced in many different ways as well as being used in many different ways. Until recently, the main mode of production was based on fossil fuels. Since fossil fuels harm both nature and people, the interest in alternative energy sources has constantly increased. The effort to avoid this harm has led people to cleaner, more environmentally friendly and inexhaustible renewable energy sources [1].

Renewable energy sources are sources that are at different levels depending on the location (wind, hydraulic, solar, hydrogen, geothermal, current, wave, tides, etc.), have less CO_2 emissions and harmful effects compared to traditional energy sources. Examples of renewable energy sources are shown in Figure 1 [2].

Figure 1. Examples of renewable energy applications

Many examples of solar tracking systems have been given in the literature. When the examples of applied solar tracking systems are examined in the studies, it has been seen that the solar tracking system can be categorized as single and double axis, as well as active and passive tracking. In [3], it has been confirmed that the azimuth and altitude dual solar tracking approach produces results that are more efficient. On the other hand, from a financial point of view, a single axis solar tracking system is more convenient. In a different review paper [4]; it is mentioned that solar energy is an important renewable energy alternative, but following the sun is a difficult process in terms of efficiency. It has been stated that sun tracking is important especially in systems above a certain power. A review study examining solar tracking system techniques and presenting their advantages and disadvantages is given in [5]. As in other similar studies, it has been explained that solar tracking systems are classified as active, passive, single axis and double axis. In addition, the performance, construction, advantages and disadvantages of all this classification were evaluated. As a result, dual axis active solar tracking has come to the fore to obtain optimum energy. The performance of the dual axis solar tracking system and the fixed solar system was examined in Malaysia in terms of clearness index [6]. Dual axis solar tracking systems offer advantageous results especially in the morning and evening hours. A correlation was obtained with the clear index, which gives accurate results for the estimation of the energy produced. With this study, an important development has been achieved for the estimation of payback time for PV systems to be installed in Malaysia. The performances of static PV system, single axis and dual axis solar tracking systems in Qeshm island of Iran were investigated. The solar radiation data of 2011 were examined and the performances between the systems were compared. According to the results of the analysis, the single axis tracking system produced 35% more energy than the static system. On the other hand, the dual axis solar tracking system produced 4% more energy than the single axis tracking system. Thus, for the Iranian island of Qeshm, a single axis solar tracking system can be seen as a more suitable solution in terms of price/performance ratio [7]. In a study in which a microcontroller-based solar tracking system was carried out, LDRs were used to determine the position of the sun and to position the solar panel appropriately [8]. The motion of the solar panel in the appropriate direction is ensured by the geared DC motor controlled by the AT89S52 microcontroller. Compared to the static PV system, 17.45% more energy was obtained. A sensorless approach is proposed in the dual-axis solar tracking system. In the system with low mechanical construction, the parts of the system were determined according to multiple criteria and the boundary conditions of the system were determined

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according to the sun angles. Control process is provided with a programmable logic controller and vertical axis movement is provided with 1° precision [9]. The power that can be obtained from a solar panel depends on the position of the solar panel relative to the sun, and there is an angle of the solar panel that must be optimal for each moment of the day. In [10], a low-cost closed-loop controlled study was carried out with the sun position algorithm. With the sun position algorithm, the position of the sun is determined according to a mathematical formula or astronomical data. In this study, Astronomical Almanac's algorithm was used and according to the results obtained, 13.9% efficiency increase was achieved compared to the fixed PV system and 2.1% compared to optical tracking. In a study examining solar tracker systems [11], four different categorizations were made. The first of these categories is related to open loop or closed loop control operation. The second group is active or passive tracking. In the third category, an evaluation was made in terms of whether the sun tracking was done on a single axis or double axis, and in the last category, an evaluation was made in terms of tracking strategy. A dual-axis solar tracking system application for a 54W solar panel was implemented in Ramadi, Iraq [12]. With the help of microcontroller-based and LDRs, the position of the sun was tried to be estimated and Arduino Uno was used in the application of the sun tracking system realized on a dual axis. In another study, a soft-switched boost converter with maximum power point tracking is proposed [13]. The study in which the solar energy potential is examined for the province of Siirt can be considered as a theoretical study on solar energy [14].

Biaxial active sun tracking systems are the most important approach used to maximize the power to be obtained from the solar panel. In this study, a 45W dual axis solar tracking system was produced that predicts the position of the sun with Arduino Uno based LDR. The rest of the work continues as follows. In the second part, the fundamentals of solar energy are summarized. In the third part, the equipment used in a typical solar tracking system is mentioned. In the fourth chapter, the details of the solar tracking system produced are given. In the last section, the results of the study are presented.

II. SOLAR ENERGY

When the photons coming from the sun to the earth come into contact with the surface of the solar panel, direct current is produced in the panel and voltage is generated. In this way, clean energy is obtained without the emission of harmful gases. Photovoltaic cells are one of the most common ways to generate electrical energy by utilizing the sun. The p-n region in the photovoltaic cells causes separation, that is, a voltage difference, with the contact of the photons. In this way, the cell turns into a small battery. Cells connected in series or in parallel form solar panels. There are two different photovoltaic systems in which the solar panel is the main energy source. These are grid-connected and grid-isolated systems.

Grid-connected systems are based on the principle of using some of the electricity produced and transferring the remaining energy directly to the grid. The energy produced is transferred to the grid by inverters. Grid-connected systems can be installed at different powers for different needs. Off-grid systems are preferred where there is no transmission line or where it is more than 800 meters from the user [15].

III. COMPONENTS OF A TYPICAL SOLAR TRACKING SYSTEM

Solar tracking systems can be examined in two different categories in general. These are systems that move in a single axis and systems that move in a double axis. Dual axis tracking systems; it consists of 2 motors placed under the solar panel, driver circuit, 2 or more LDRs placed on the panel at different points and/or at different angles, battery, regulator and controller. When the necessary software is developed for the system after the necessary mechanical arrangement is established, the system generally works as follows. According to the position of the solar panel, LDRs have a resistance value. These resistance values are transmitted to the microcontroller. The controller sends the appropriate timed commands to the motor driver according to the LDR resistance information it receives, and the solar panel is provided to take the most suitable position according to the sun. Horizontal and vertical movement is performed to give the highest power. In single axis solar tracking systems, this control is performed in horizontal or vertical direction.

A. Solar Panel

The most basic part of the solar tracking system is the solar panel. Solar panels are formed by connecting a large number of cells in series. Solar panels produced based on different material technologies are produced in power levels ranging from 10W to 400W. They have different numbers of bypass diodes in their structures according to the power value.

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B. Geared DC Motor

DC motors are machines that work with the effect of electromagnetic field. They can be used in many areas of industry. In order to increase the torque by reducing the speed in DC motors, a gear set is added to the motor shaft and a geared DC motor is obtained. Low speed operation is provided in the geared DC motor and low speeds are obtained for solar tracking systems.

C. Microcontroller Platform - Arduino

Arduino is a platform with different models designed to be used in various electronic projects. Arduino boards have a microcontroller, various circuit elements, and input-output pins for connecting. Arduino provides the necessary signal to the driver ICs for the movement of the motors.

D. Light Dependent Resistor (LDR)

Photoresistors are electronic components whose resistance changes depending on the light intensity. The LDR is made of "cadmium sulfide" (CdS), a semiconductor material that can absorb photons of light. Although LDR is a type of resistor, it is also a passive sensor. LDRs provide an output with varying resistance values in the circuits they are in, but since they perform this process with a physical change they receive from the external environment, they act as a sensor [16].

E. Battery

Batteries are devices that chemically store electrical energy thanks to the electrolyte mixture in their structure. Batteries are needed to energize motors and other electronic equipment that provide motion in a solar tracking system. Since there is usually no space problem in solar tracking systems, types such as lead acid batteries and gel batteries are preferred instead of lithium-based batteries.

F. Battery Charge Controller

Charge controllers transfer the DC energy obtained from the solar panel to the batteries in a controlled manner. Negative effects, such as overheating, burning, explosion in the batteries that may occur during this process, charge regulator overcurrent, etc. prevented by systems such as protection. Charge controllers are generally produced as 12V-24V-48V as they will transfer the energy from solar panels to batteries. Solar panels and batteries, which are commonly used to meet needs such as lighting and television in vineyard houses, are installed as 12 volts, but solar energy systems are preferred at 24 or 48 volts to run more powerful loads such as washing machines and refrigerators [17].

IV. MATERIAL & METHOD

General information about a solar tracking system has been given in the previous sections. In this section, details about the mechanism design, the application steps of the methods followed and the electrical design will be given.

A. Mechanism Design

One of the most important parts of the solar tracking system is the mechanism. Because the electronic devices that make up the system are components that are already present in many fixed solar panel systems and have more or less similar features. It is physically the most important part of the vertical holder mechanism that will carry the necessary case and the motor that will move the panel in order to fix the solar panel securely. Elements such as the physical dimensions, material and length of the part to be placed here change its strength. These factors were taken into consideration while choosing the design and material. A mounting bracket is required to firmly fix the solar panel to the movable mechanism. This apparatus should hold the solar panel from all sides, be as light as possible and have high material strength, and should be capable of holding the photo resistors that must be present in the system. In the design given in Figure 2.a, the part where the LDRs will be placed is on the solar panel mounting apparatus. In addition, the shaft of the linear DC motor, which will move the mechanism on the horizontal axis, is connected to the back of this apparatus. The part that will perform the movement between the vertical holder and the panel mounting apparatus must be small, light and robust. In this context, a piece design was made that has the same dimensions as the main column, is short and can be mounted on the panel mounting apparatus. This design is given in Figure 2.b.

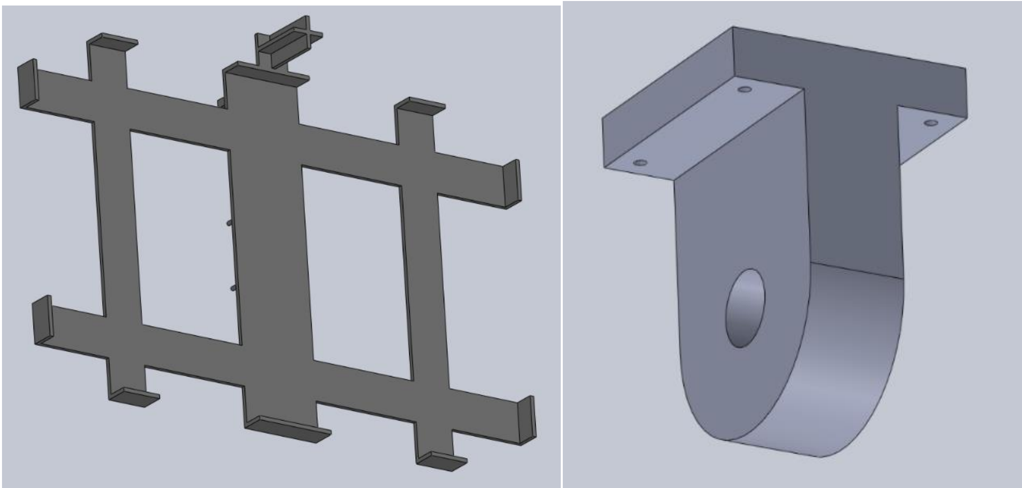

Figure 2. a) Solar panel mounting apparatus b) Movement part between vertical holder and mounting apparatus

After designing the main parts that make up the mechanism, the design was completed by bringing together the other parts (bearing, screw, motor, box, hinge, etc.) in a virtual environment through the Solid Works program. The front and back pictures of the design are given in Figure 3.

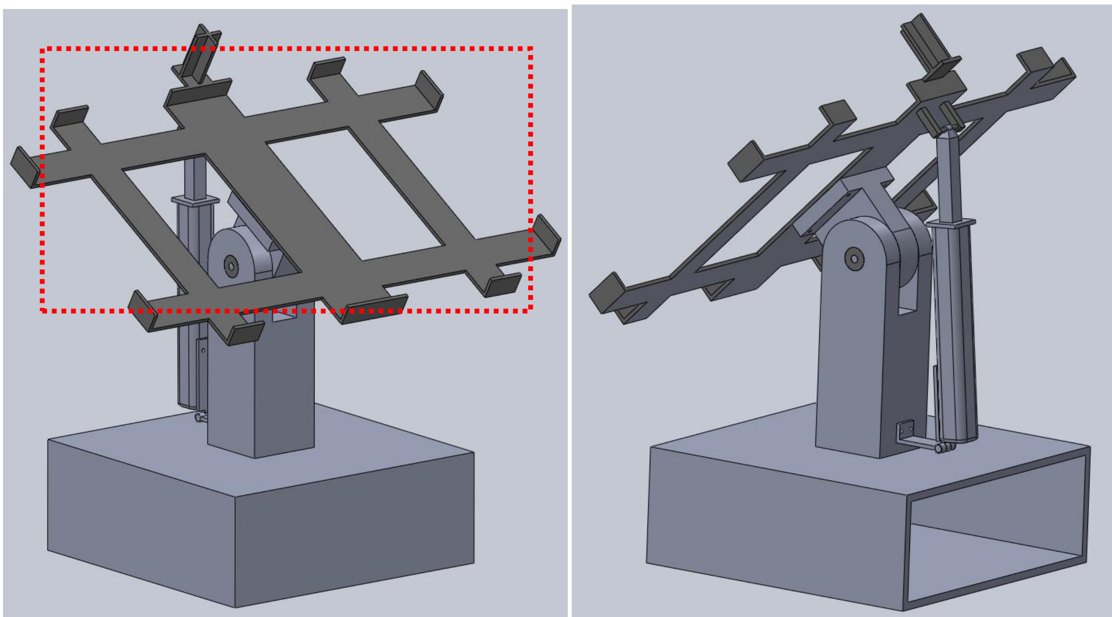

Figure 3. Front and back view of the solar tracking system design

B. Material Selection of the Mechanism

Different materials can be used for the vertical holder, which will carry the load of the mechanism directly. In this context, although aluminum is an important alternative, it has been determined that it is not a suitable material due to its unit price, processing cost and weight. Instead of aluminum, cestamite, which has a lower unit cost, easier to process and lighter material, was chosen for the vertical gripper mechanism. The vertical holder mechanism in the form of a cylinder was obtained by CNC application and is shown in Figure 4.a. Easy to process and good price/performance was decisive in the selection of chestnut. The picture of the part mounted on the vertical holder that provides the movement of the solar panel is given in Figure 4.b. This piece is similarly produced as a result of CNC machining of chestnut.

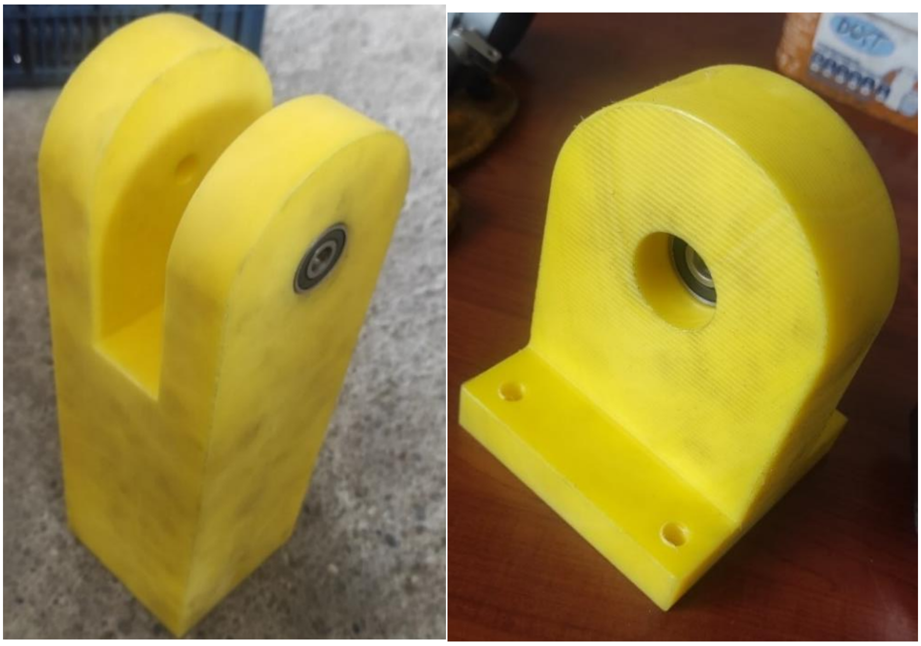

Figure 4. a) Vertical holder made by chestnut (left) b) Movement part of the tracking system (right)

Bearings are placed in the gaps seen in the parts given in Figure X to minimize friction losses. Iron sheet was chosen for the mechanism on which the solar panel will be mounted. While making this choice, it was decisive that the solar panel could show higher resistance to loads such as wind and snow that it could be exposed to. The panel casing produced using iron sheet is given in Figure 5.

Figure 5. Solar panel holder apparatus

C. Electronic Design and Components

After the material selection and design stages of the mechanical design are given, the selection of the electronic equipment that will provide the movement in the system and the remaining part of the production stages will be given in this section. In this study, a solar panel with 45W monocrystalline cell weighing 3.8kg was selected. With the choice of solar panel, two motors that can produce enough power are needed to move the mechanism. Although the use of servomotors is considered first, it has been observed that the servomotors, which have the capacity to produce the torque sufficient for the size of our system, are above the limits we want in terms of both cost and power. As a result of the researches, it has been determined that the desired torque can be obtained with minimum power values by using a geared DC motor. Although servomotors have advantages such as sensitivity and feedback compared to ordinary geared DC motors, the ideal location decision in the solar tracking system will be provided by the photo resistors on the top of the panel. Thanks to the gear reducer structure, the servo motor sensitivity is not needed since the rotation speed will be reduced considerably. In the solar tracking system, 12V 5-rpm L type Geared DC motor is selected for vertical movement. Many different solutions can be

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considered, including with a conventional Geared DC motor to provide motion in the horizontal axis. However, since it was determined that connecting the motor directly to the motion center greatly increased the cost and reduced the overall energy efficiency of the project, a 12V linear DC motor with a current of mA and a torque of 200 Nm was preferred. Selected motors are presented in Figure 6.

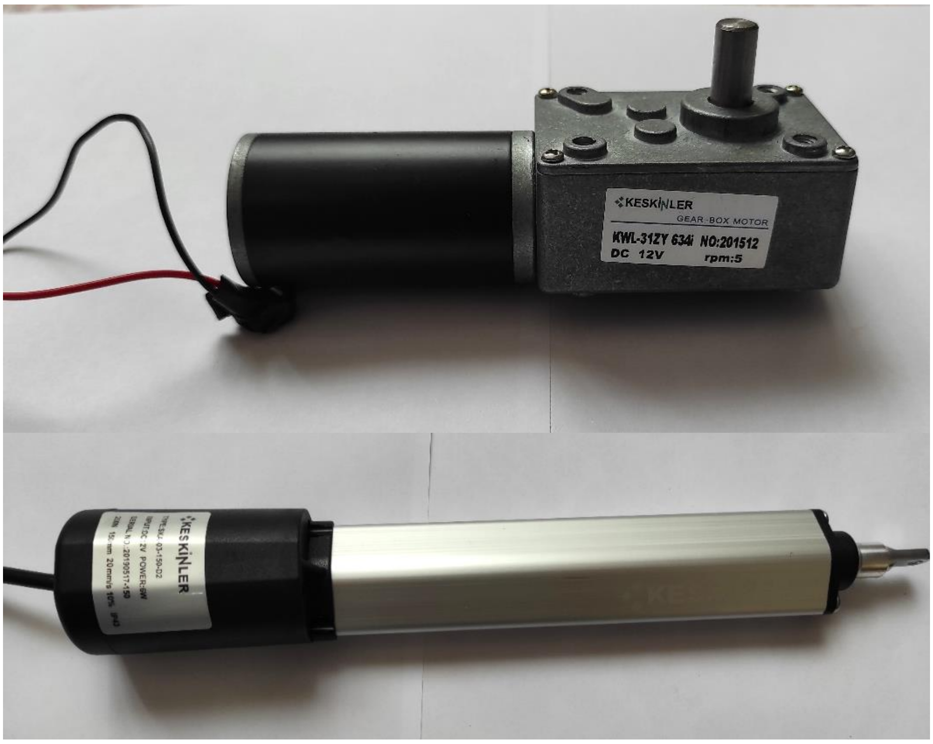

Figure 6. Geared DC motor (upper) and linear DC motor used in the solar tracking system

A motor driver should be used to control DC motors. With the selected L398N driver, motors can be controlled without damaging the outputs of the microcontroller. The L398N driver board can simultaneously power two different motors and control speed and direction. It has an internal cooler as additional equipment and has overheating and short circuit protections. With 24V/2A output data and related outputs that can feed the Arduino, it is very ideal for the application.

Since the solar tracking system is designed as an off-grid system, battery usage is required. While choosing the battery, the gel battery, which has a long service life and is frequently used in such studies, was preferred in addition to the system requirements. The preferred battery has 12V/24 Ah values. Adding a charge controller to the system, which ensures safe charging of the battery, cuts the power in case of full charge, and provides over-current and short-circuit protection, is an inevitable solution both for system safety and to prevent larger malfunctions that may occur.

Keeping the system active outside of certain hours causes unnecessary energy use. For this reason, it is necessary to follow the sun at a certain angle and then stop the system. Unlike servomotors, the DC motors we use do not have position control. For this reason, the limit button was included in the system. In this way, when the panel reaches the desired angle, it can be stopped and sent to the starting position. In the box included in the lower part of the system in order to ensure system safety, the equipment to be in order and the mechanism to remain in balance; There is a battery, regulator circuit, microcontroller and DC motor that provides vertical movement to the system.

Since the system will stay mostly in sunny places as a working place, the electronic circuit and components in the box are suitable for heating, so the air in this box is cooled by a fan. Of course, it is not logical to add a fan that will consume energy continuously in our project whose aim is efficiency. For this reason, temperature control was made with the LM35 temperature sensor placed in the box, and the fan was enabled to operate only when necessary. 2n2222 NPN type BJT transistor was used for fan motor control. As a result of the production, the final state of the dual axis solar tracking system is given in Figure 7. Block diagram of the electronic

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design is presented in Figure 8. Basic version of the control algorithm of the solar tracking system is presented in Figure 9.

Figure 7. Final state of the solar tracking system

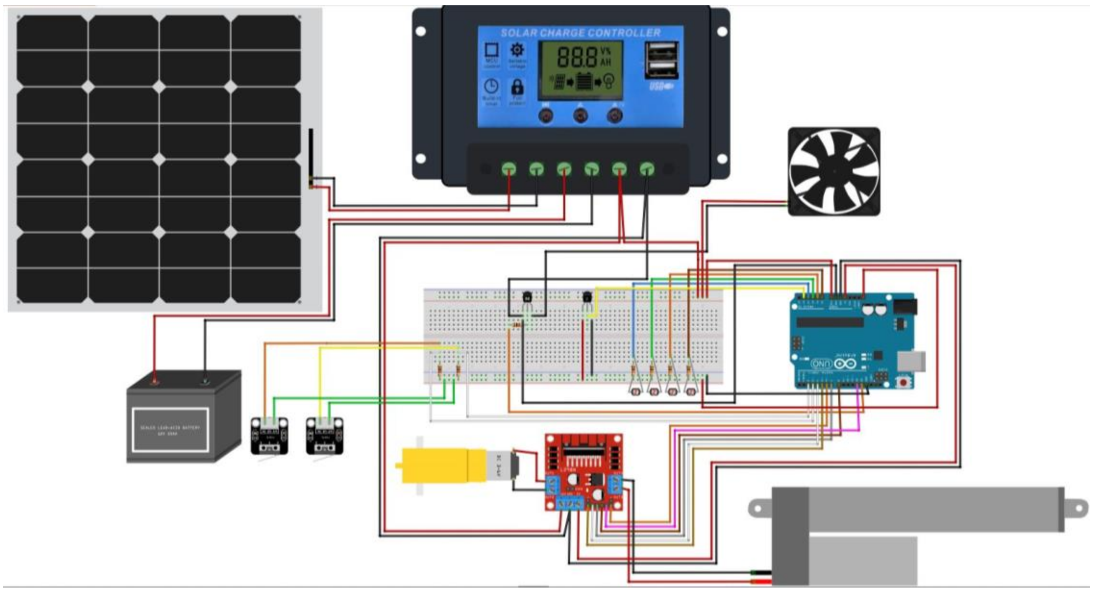

Figure 8. Basic electronic schematic of the solar tracking system

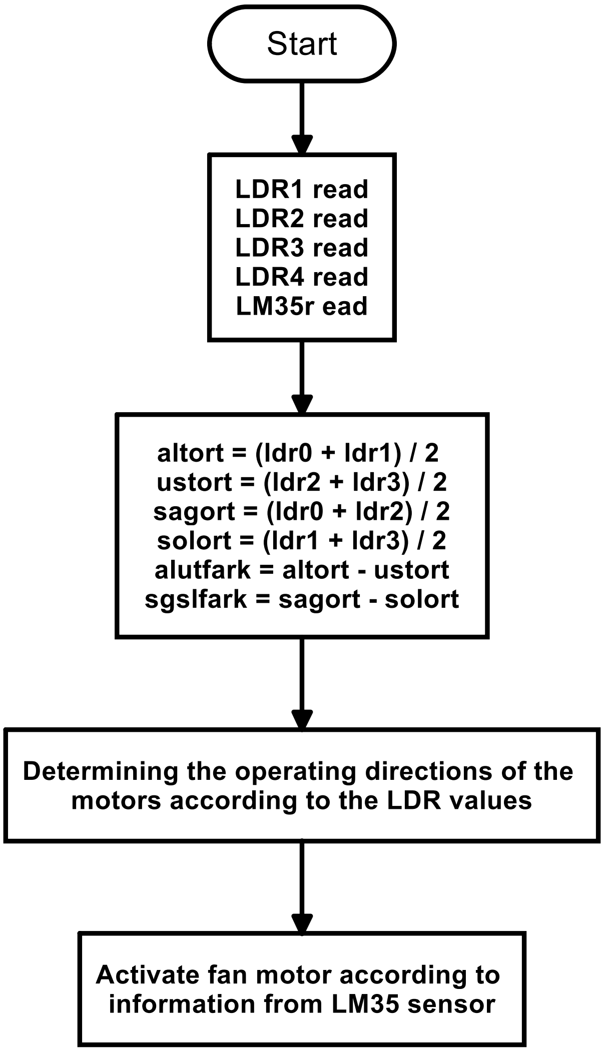

Figure 9. Basic version of the control algorithm

V. CONCLUSIONS

Solar energy is the cleanest, environmentally friendly and alternative energy source today. The working principle of solar tracking systems, which aim to produce electricity from solar energy more efficiently, has been a subject of interest for many years. In this study, Arduino based, dual axis solar tracking system application is presented. Chesttamide and iron were used in the mechanical arrangement of the system, and linear DC motor and geared DC motors were preferred for double-direction movement. In the system, 1° angle sensitivity tracking is provided and more energy is obtained than static PV systems. In further study, improvements in the mechanical construction and electronic tracking will be added to the current tracking system.

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