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Sun Following Solar Panel

Using Light Sensors to Implement Solar Tracking

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Sun Following Solar Panel

Bachelor's Thesis in Mechatronics

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Bachelor's Thesis at ITM
Supervisor: Nihad Subasic
Examiner: Nihad Subasic

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Abstract

The purpose of this project is to investigate if it is possible to get more energy out of a solar panel if the solar panel is always directed towards the sun. Furthermore, two questions surrounding the plausibility of building an efficient tracking system, and the level of complexity for the required software and mechanism will be investigated. To be able to answer these questions a prototype was built.

This project consists of three major parts, hardware, software and electronics. Stepper motors were used to rotate the solar panels and light dependent resistors (LDR) were used as light sensors.

With the tracking system, the solar panels outputted 48 % more energy.

Referat

Solföljande Solpanel

Syftet med detta projekt är att undersöka om det är möjligt att erhålla mer energi från en solpanel om solpanelen alltid är riktad mot solen. Vidare ska två frågor angående om det är möjligt att konstruera ett system som effektivt följer solen med ljussensorer och hur komplicerad den tillhörande mjukvaran blir besvaras. För att finna svar på dessa frågor har en prototyp skapats.

Detta projekt består av tre avgörande delar, hårdvara, mjukvara och elektronik. Stegmotorer används för att rotera solpanelerna och light dependent resistor (LDR)-motstånd används som ljussensorer.

Med det solspårande systemet erhölls 48 % mer energi från solpanelerna.

Acknowledgements

We would like to thank our examiner and supervisor Nihad Subasic for providing the support necessary to complete this project. We would also like to thank all of the assistants and other personnel that have provided invaluable knowledge and assistance. Thank you KTH for providing financial support and the materials needed for the build. Finally, we would like to thank the other students in the mechatronics lab who have been giving great feedback for both the design of the build and the report throughout the project.

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List of Abbreviations

CAD computer-aided design

DC direct current

IR infrared

LDR light dependent resistor

PLA polylactic acid

PWM pulse-width modulation

USB Universal Serial Bus

Chapter 1

Introduction

1.1 Background

Climate change is a subject that has been discussed profusely these recent years. The effects that fossil fuels, among other things, have had on the environment have led to many scientists trying to find alternatives, more environmentally friendly fuels and cleaner sources of energy. An example of a cleaner source of energy is the electricity generated by solar panels. The Swedish energy authority, Energimyndigheten, states that "*In two hours, the Earth receives as much energy from the sun as the whole world's population uses for a year. It is important to find ways to use the solar energy smartly, both in Sweden and other countries.*" [1]. This shows that there is great potential in solar energy and any improvements to solar panels could be of great help for society.

Solar panels work by absorbing the sunlight and converting it to electricity through the photovoltaic effect. The goal is to capture as much sun energy as possible. The amount of energy that can be collected is determined by the amount of light intercepted by the panel, or in other words, the area of the shadow from the solar panel on a perpendicular surface to the direct beam is equivalent to the energy intercepted [2]. Most solar panels are fixed and do not move. The angle and direction the solar panel should be pointing is determined by various calculations, and can vary depending on season and location of the panel. Solar panels with an automatic mechanism that can adjust the angle and the direction of the panel are able to capture more sunlight, but also require energy to move the solar panel.

1.2 Purpose

The purpose of this project is to examine how a system of light sensors can be used as a solar tracker for a solar panel. The light sensors will be mounted to the solar panel rig and be exposed to the sun. By examining which light sensor is exposed to the most sunlight, the solar panel will change both the direction it is pointing and its angle relative to the ground so that it is pointing towards the sun, and thereby capturing more of the sun's energy. The goal is to determine the efficiency and viability of this kind of system. This will be done by answering the following research questions:

1. Can you get a solar panel to efficiently follow a light source by using light sensors as a solar tracker?

2. How much more energy will be produced if solar tracking is implemented?

3. How complicated is the software for the mechanism?

1.3 Scope

This project focuses on constructing a model mechanism which allows a solar panel to be able to follow a light source. In this project, the scope has been reduced due to time and resource limitations. Because of this, only a small scale version of the tracking solar panel will be built as a basis for the data collection. Due to the smaller area of the solar panel, this will affect the amount of electricity that can be generated, which is something that has to be considered when discussing the results of the project. The small size of the solar panel and the other involved parts also means that the structure will not be subjected to big loads. Therefore, there will not be any major calculations for the strength of the structure. As a continuation for the project, a full-scale version could be built. For a full-scale version of the structure, strength calculations would have to be made. This project will only examine the amount of energy that is produced by the solar panels, and not how much energy is needed to power the mechanism. This is also something that can be examined in future work. Reliability and required maintenance are important issues, but this is also something that will not be examined during the project.

1.4 Method

The work process for the project began with a literature study. This included researching of solar panels, different kinds of servo motors, and light sensors among other things. This was done to give a better idea of what components would suit this project the best. After the literature study was complete, a first concept design was drafted. Solid Edge ST9 was used to create a computer-aided design (CAD) model of the solar panel structure. These models were then 3D printed and assembled together with the other components to form a first prototype. After testing the prototype and making sure that the software was working, necessary changes were made to the design and a final version of the construction was built. Various tests were then conducted in order to answer the research questions.

Chapter 2

Theory

2.1 Stepper Motor

A stepper motor is a type of direct current (DC) motor that moves in small, equally sized steps. The stepper motor can be told what step it should position itself, and hold that position without any form of feedback.

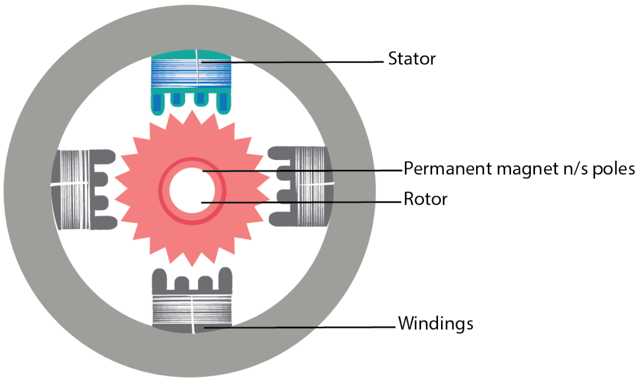

Figure 2.1. Components of a stepper motor [3].

The rotor of the motor contains permanent magnets, which can be seen in Figure 2.1. These magnets are divided into sections with alternating poles, like teeth on a gear wheel. The outer, stationary part of the motor (stator) contains sections of wire coils. The sections are energized in different phases, which makes the rotor containing the magnets rotate. How many poles and phases a stepper motor has can vary depending on the motor.

One of the advantages of using a stepper motor over other DC-motors are that it is easier to control how much the rotor should rotate, since the rotor moves in precise steps [4]. This makes stepper motors suitable for 3D printers and camera platforms, among other things. Other DC-motors also need to use commutators and brushes in order to rotate continuously. These are mechanical parts which require maintenance and also hinder the high speed operation of the motor [5]. Another advantage with stepper motors is that they allow for good control of the rotors rotational speed. The permanent magnets in the rotor also leads to high torque at low operating speeds and robust performance. The biggest drawback with stepper motors that is relevant for this project is that they have low efficiency since they draw a lot of current when they operate.

2.2 Solar Panel

A polycrystalline solar panel uses the difference in voltage between two layers of silicon panels with different polarity. When the suns rays detach electrons from the silicon atoms, the difference in voltage will push the electrons through the attached circuit [6]. The solar panel in this project gives an output of 5 V and 100 mA. The area of the solar panel is 50 x 100 mm.

2.3 Tracker Geometry

The mounting structure for the solar panel can be designed in a few different ways. The two major categories for these structures are dual axis and single axis. Both of these kind of structures have advantages and disadvantages. Dual axis trackers, see Figure 2.2, do a better job of keeping the sun's rays perpendicular to the solar panel, thereby allowing for a gain in energy absorption. However, these systems can be complex and expensive.

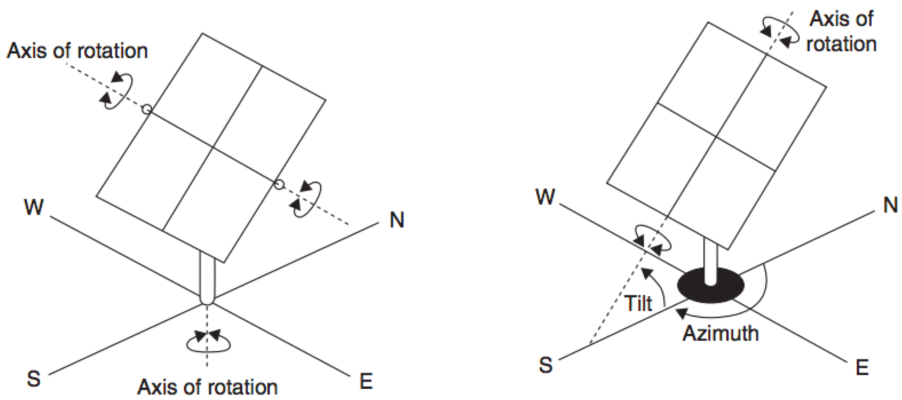

Figure 2.2. Different dual axis geometries [7].

Most single axis trackers are simpler than dual axis trackers, see Figure 2.3. They also require less area to deploy, but since they can only rotate around one axis, the solar panel will not be able to create as much energy.

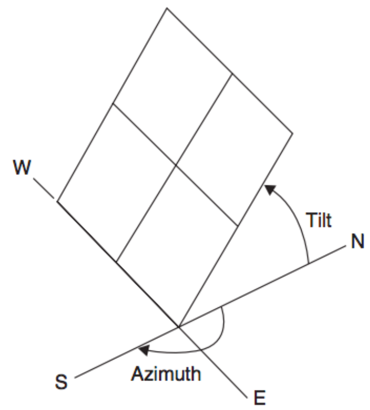

Figure 2.3. Single axis geometry [7].

With a dual axis tracking system studies have shown that the annual increase in solar performance ranges between 29-40 %, and the increase for single axis tracking systems range between 17-34 % depending on the system [7].

2.4 Light Sensor

The light sensor is made of a photoresistor which is a semiconductor just like the solar panel. When light of the right wavelength is absorbed by the photoresistor and the energy in the radiation is high enough, electrons are excited from the atom. The more radiation the photoresistor absorbs, the more free electrons in the material. Naturally the resistance decreases with the number of free electrons which leads to a lower resistance in sunlight and a higher resistance during the dark.

2.5 Theoretical Output

The efficiency of a solar panel depends on three major factors:

- Energy absorption limit due to excitation energy
- Spectra of absorption
- Narrow connections

First of all one photon can only set one electron free which means that when a photon contains more energy than needed, the efficiency decreases. The second factor is that the silicon can not absorb light with wavelengths greater than 1100 nm [8][9]. The major part of the infrared (IR) spectra is therefore useless. The third factor is that when solar cells are connected in series, the current has to flow through many narrow connections. Because of the inverse relationship between resistance and cross-sectional area, the resistance will be increased in these areas. Since the output of a resistor is proportional to the resistance, power will be lost in these connections. Typical value of the efficiency is 12-14 %.

For an example, the intensity at noon in May is 858 W per square meter in the radiations normal plane [10] which would lead to the output (meanvalue) 112 W per square meter.

Chapter 3

Demonstrator

This chapter will focus on how the different components of the build have been constructed and assembled. For the purchased components, product type and performance data will be reviewed. The two points of emphasis will be hardware and software.

3.1 Problem Formulation

The goal of the project is to design a model mechanism that allows a solar panel to follow a light source. In order to do this there are a number of problems that need to be solved, mainly:

- Getting the solar panel to know the position of the sun.
- Making the panels point in a specific direction.
- Measuring the results.

3.2 Hardware

A diagram showing the used components to create the model can be seen in Figure 3.1 below.

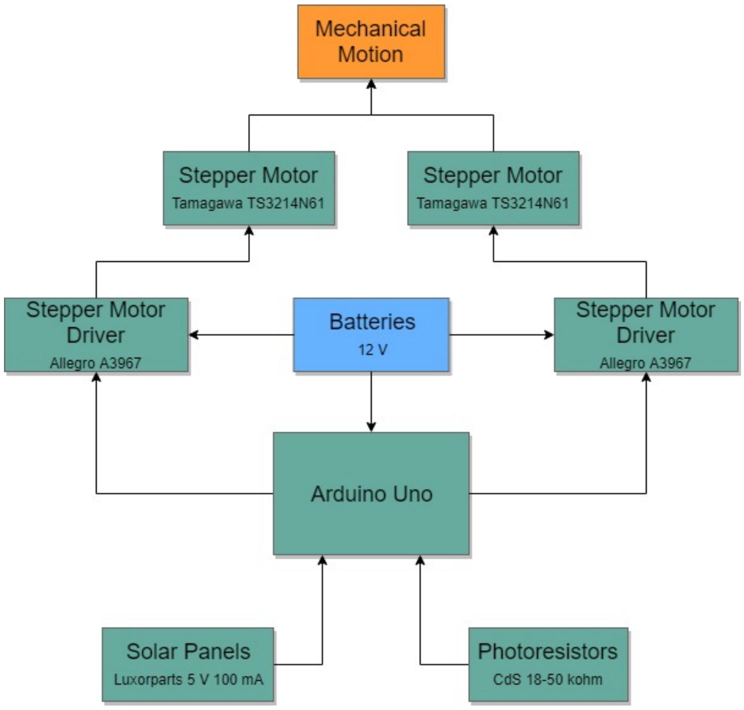

Figure 3.1. Diagram of hardware components, drawn in Draw.io.

Most of the models structures have been designed with the help of Solid Edge ST9 and then 3D printed with Ultimaker 3D-printers provided by the Royal Institute of Technology in Stockholm. The components were printed with a material called polylactic acid (PLA), which is commonly used during 3D printing due to its printability and rigidity [11]. A wiring diagram for the construction can be seen in Appendix B.

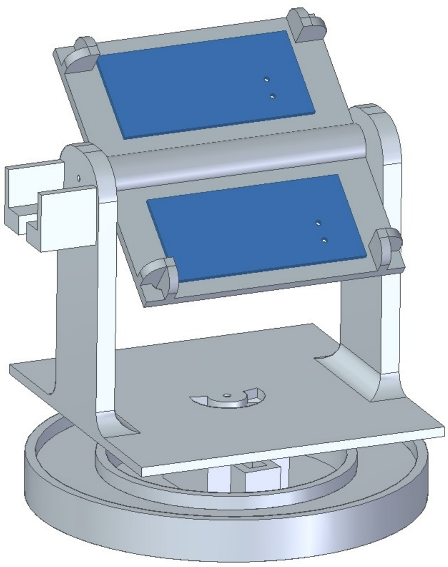

Figure 3.2. Overview of 3D printed components, image from Solid Edge ST9.

Figure 3.2 shows the components that have been designed with CAD and then 3D printed, along with the solar panel modules. The three major parts that have been 3D printed are:

- The bottom plate
- The Arduino platform with support arms
- The solar panel platform

The bottom plate has a slot in the middle where the first stepper motor fits. This stepper motor rotates the upper part of the model around a vertical axis. Around the outside of the bottom plate there is a track for the marbles. These marbles alleviate the strain on the stepper motor's axle by supporting the weight of the upper parts.

The axle of the stepper motor is attached to a hole in the middle of the Arduino platform. The top side of the platform is where the Arduino and stepper motor drivers are located. Wires go from the Arduino through a slot in the middle of the platform to the stepper motor. On two of the sides there are support arms that serve the purpose of holding up the solar panels. On one of these arms, there is a slot where the second stepper motor is positioned. This stepper motor rotates the solar panel platform around its horizontal axis. On the other support arm there is a hole for a removable pin which will help support the solar panels.

The solar panel plate has two holes on opposites sides of each other. One of these holes is for the axle of the second stepper motor, and the other is for the removable pin. On each of the corners there is a small hole surrounded by two walls. The LDRs are placed in these corners, and their wires pass through the holes to a circuit board underneath. The purpose of the walls is to block the LDR from the light unless the light is coming from a specific direction. The solar panels are placed on the top of the plate and the plate has two holes so that the wires of the solar panels can pass through to the other side.

3.2.1 Arduino

The Arduino Uno is an open source single-board microcontroller that is based on the ATMega328. It can be powered by a 5V Universal Serial Bus (USB) connection, or alternatively with an external power supply. The board has 14 digital input/output pins, among which 6 can be used as pulse-width modulation (PWM) outputs. There are also 6 analog input pins on the board, along with a reset button [12]. The programming of the board is done with the Arduino software, and the programming language is C with the Arduino library included. The capabilities of the Arduino Uno was deemed to be sufficient to control the solar panel mechanism.

3.2.2 Stepper Motor

In this project stepper motors were chosen to control the models movement. The main reason for this is that a stepper motor can be told exactly how many steps it should move, which makes it easy to control. The chosen stepper motors are made by Tamagawa with model number TS3214N61. It has 200 steps per revolution and can take a maximum of 12.5 V.

3.2.3 Stepper Motor Driver

Two stepper motor drivers are used to control the two stepper motors. The stepper motor drivers used are SchamlzHaus Easy Drivers, which are based on the Allegro A3967 driver chip. The stepper motor drivers add features to the stepper motor such as microstepping and over current protection. They also make the stepper motor run more precisely. A double H-bridge is also included in the stepper motor driver which makes it possible to rotate the stepper motor in both directions.

3.2.4 LDR Circuit

The LDRs used have a resistance of 18-50 kohm when there is light and more than 1 Mohm in the dark. The resistance in series with the LDR in the circuit has a value of 1.4 kohm which was chosen to make the sensors less sensitive of small differences in light. This low sensitivity makes it possible to detect where the sun is rather than weak light sources. See Appendix C for the LDR circuit diagram.

3.2.5 Solar Panel

The solar panels are polycrystalline with a max power of 0.5 W each. The panels are connected in series with a resistance of 1.4 kohm to be able to measure the voltage and calculate the current.

3.2.6 Power Sources

The Arduino and the stepper motor drivers are powered by a series of AA batteries which together create an output of 12 V. The Arduino's power regulator converts the 12 V to 5 V which is used to power the LDR-circuits.

3.3 Software

When started, the solar panels will be in their neutral state. Depending on the measured value over the LDRs, the stepper motors will rotate the panel so that the top side and the bottom side of the plate differ no more than the tolerance. If the top and bottom sides are not within the tolerance. The stepper motor will do 96 steps, where 6400 steps is equal to one revolution (due to the microstepping in the stepper motor drivers). The left and the right LDRs are then evaluated in the same way. Once left versus right and top versus bottom have been compared, the process restarts. Figure 3.3 below shows the flow chart of this algorithm.

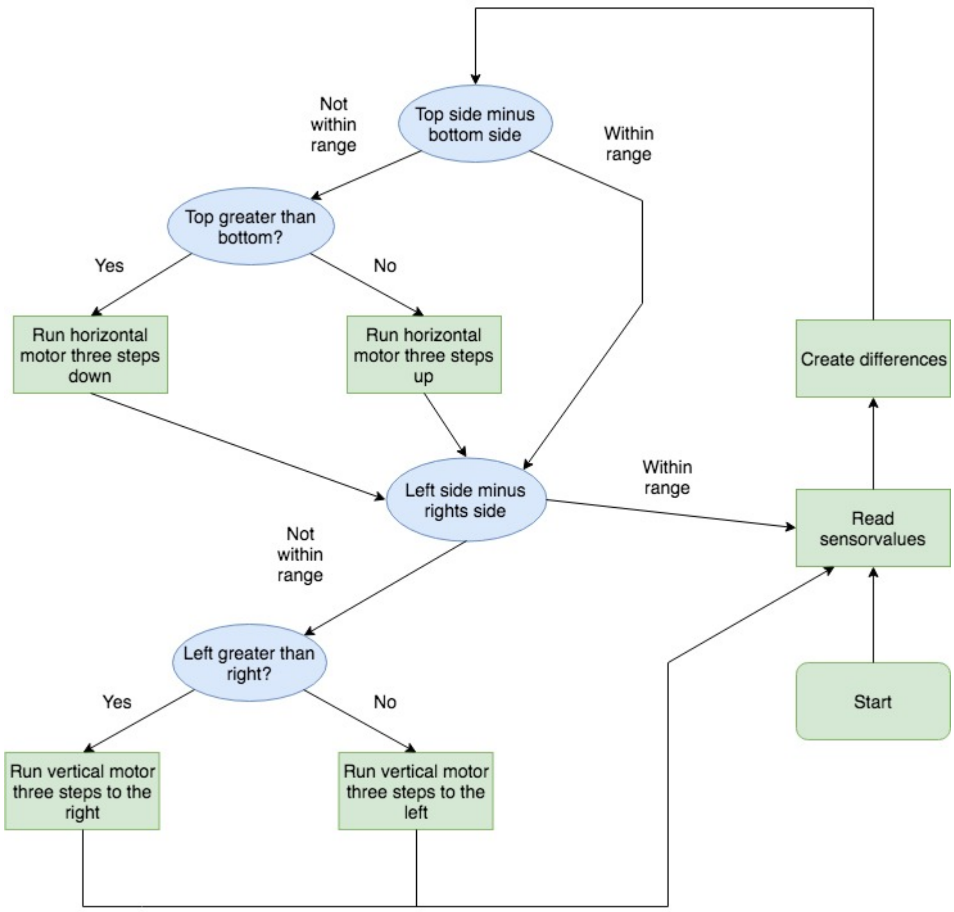

Figure 3.3. Diagram of software algorithm, drawn in Draw.io.

The full Arduino code can be found in Appendix A.

3.3.1 Movement

The two stepper motors are controlled with the Arduino built-in library ”Stepper”. In this library the function ”step” allows the user to make the stepper motor rotate the number of steps desired by just inputting the number of steps. The signal from the Arduino sent out by this function is however not enough to control the stepper motor. As mentioned earlier the signal goes to a stepper motor driver which in its turn controls the stepper motor.

3.3.2 LDR

The analog input pins are used to measure the voltage drop over the four resistors in the LDR circuit boards. These pins give, with help of the Arduino function analogRead(), a value between 0 and 1023 which represents a percentage of the reference value used. The reference value used is 5 V, meaning that when a pin measures 1023, the voltage measured by this pin is 5 V.

Chapter 4

Testing and Results

4.1 Testing

In order to limit the effect of external disturbances as much as possible, a full day of light was simulated in a dark room. A strong light source was moved along a fixed track with the solar panels in the tracks center. One simulation was 30 seconds long and 5 simulations were done for the case when the solar panels were stationary and 5 simulations were done for the case when the solar panels were tracking the light source's motion. Comparing the results of these two cases gives an indication of how much more energy the system picks up when the solar panels are directed towards the sun.

In order to measure how much energy was generated by the solar panels, the panels were connected to a resistor with a known resistance and the voltage was measured over this resistor with one seconds intervals. Since both the voltage and resistance were known, the power over the resistor could be calculated and graphed as a function of time. The generated energy, E, could be calculated with

$$E = \int_0^T P(t)\,dt, \tag{4.1}$$

where P is the power and T is 30 seconds. This is equivalent to the area under the power curve.

4.2 Results

The solar panel mechanism managed to follow light sources ranging from flash lights to the sun with good precision. It worked during lightly cloudy days, but had a bit of trouble finding the sun's position when it was very cloudy.

The power curve of one of the simulations with stationary solar panels can be seen in Figure 4.1 below. The area under the curve has been colored in and represents the amount of energy generated during the 30 seconds.

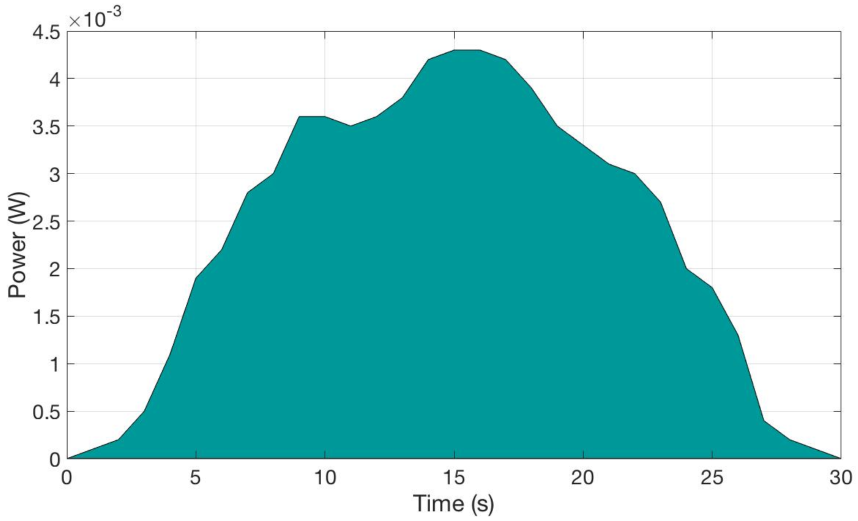

Figure 4.1. Power curve with stationary solar panels. Graph generated with MATLAB R2016b.

The same graph that was generated from one of the simulations with mobile solar panels and can be seen in Figure 4.2 below.

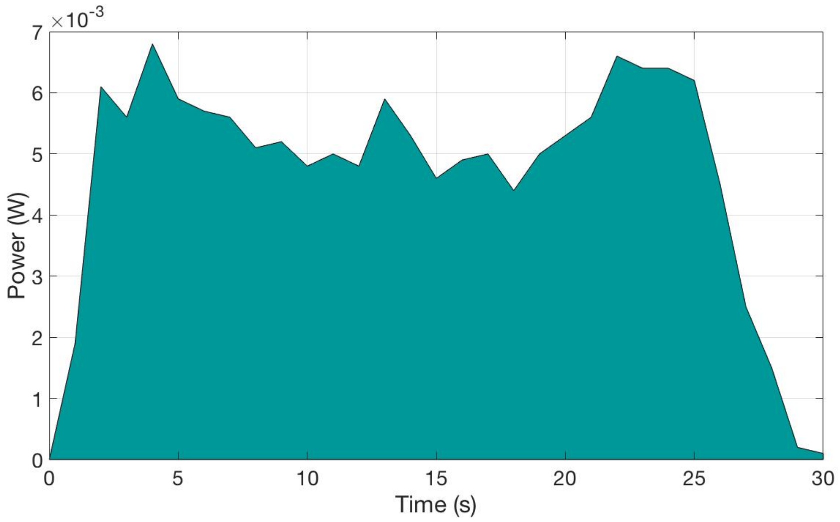

Figure 4.2. Power curve with mobile solar panels. Graph generated with MATLAB R2016b.

The amount of energy generated when the solar panels were stationary was approximately 0.081 J on average, while the solar tracking solar panels generated approximately 0.12 J. That means that the amount of energy generated increased by 48 %. Note that how much energy is being used by the stepper motors is not taken into consideration in this project.

Chapter 5

Discussion and Conclusion

5.1 Discussion

According to Solar Power World, an online resource for news regarding solar power, solar trackers can increase energy production by as much as 40 % [13]. That means that the result of 48 % is slightly bigger than expected. Possible reasons for this will be discussed in the next sections.

5.1.1 Simulation

The simulation is a major factor in the result. First of all the simulation track does not fulfill the purpose of simulating a day of light. One reason for this is that the increased distance to the solar panels in the beginning of the track compared to at the middle of the track does not fully represent the energy loss in the suns rays in the morning due to its passage through the air. This implies that the directed solar panels retrieves disproportionately much more energy in the beginning of the track compared to what it would retrieve by the sun.

Since the equation of energy loss in the suns rays due to the passage through the atmosphere is hard to take into account in the simulation track, it is also likely that the non directed solar panel would reach peak power sooner in reality than in the tests. This would thus have a negative impact on the 48% efficiency increase result.

5.1.2 Arduino

The Arduino Uno is single cored, meaning it can only do one thing at a time. This implies that when the solar panel is directed, the measurements will come at a slower pace. The stepping of the stepper motors take some time which over time adds up and is no longer negligible. This reduction of measurements leads to a decrease in the precision of these tests.

5.1.3 Power Used by the Mechanism

Since the power used by the solar tracking mechanism is not measured, no conclusions can be drawn as to whether the solar tracking improves the overall efficiency. Due to the relatively large size of the stepper motors in comparison with the solar panels, the motors more than likely use more than what is produced. In full-scale this could be different.

5.2 Conclusion

Since the solar panels worked as expected, the answer to the question if LDRs can be used to track a light source's motion is yes. Even though the testing experienced some lack of preciseness, the overall shape of the curves in Figure 4.1 and 4.2 were in accordance with the expectations. These graphs helped show that solar tracking improved energy production by approximately 48 %, which is the answer to the second research question.

On the third research question regarding software complexity, it seems the answer would be 'quite complex'. Since preprogrammed functions have been used for the measurements and to run the stepper motor, most parts of the software were prepared. However, if one considers the method of using preprogrammed functions satisfactory, combining them is not complicated.

As the testing showed the solar tracking worked fine. The slightly earlier reach of peak power and a higher general power in the less energetic span of the day due to this tracking was the expected result.

Chapter 6

Recommendations and Future Work

6.1 Recommendations

There are a few areas of the construction that could be improved. The stepper motors used were fairly weak and had low torque. This meant that a lot of focus went into making the mechanism as frictionless as possible. Even so, the stepper motors sometimes struggled rotating the structure and got caught a few times. With more powerful stepper motors this problem can be avoided.

Another thing that could be improved is the positioning of the lower stepper motor. The lower stepper motor was attached to the bottom plate, with its axle sticking up through a hole in the Arduino plate. If instead the motor would have been attached to the Arduino plate with its axle pointing down to the bottom plate, the solar panels would be able to spin an unlimited amount of degrees in either direction. The way the structure is right now, the panels can only rotate approximately 90 degrees in either direction due to the wires of the stepper motor stopping the structure from rotating more than that. The reason why the stepper motor was attached to the bottom was to put as little load as possible on the stepper motors due to its low torque, and if it was on the bottom it would not have to carry its own weight.

Finally, the electrical wires going from the solar panels and the LDRs down to the Arduino could have been placed differently. Right now they are going from the bottom of the solar panel plate down straight down to the Arduino, which means that they hinder the rotation of the plate sometimes. If instead the wires would have gone through the support arms down to the Arduino, the possible degrees of rotation might have been improved and it would also improve the aesthetics.

6.2 Future Work

The research question ”How much more energy will be produced if solar tracking is implemented?” could be expanded into if it’s possible to get more energy out of the solar panel with regard to the extra energy taken from the tracker system. If any project of this kind will be taken to the consumer market, this question is central for the prospects of such a project.

One could think it would be interesting to increase the scale of this project. In that case one would certainly have to redo the construction of the stepper motors. One way to redo it would be to put both stepper motors on the bottom plate. The stepper motors could transfer the momentum with a belt attached to the axis of respective plate. In this way the problem of the stepper motors being to weak could be removed with the transmission of these belts. Further on the stepper motors could be changed into DC motors. With a low gearing and the fact that the sun moves very slowly over the sky, a DC motor run at a relative slow pace would be well adapted to the system.

A possible twist to this project is to direct a solar collector to point in the suns direction instead of a solar panel. Unlike the solar panel, there is no physical limit of how much energy a solar collector could pick up as long as there is something to heat up. This kind of project would of course include a set of other difficulties to solve such as how to design a dynamic water to panel connection. However, this might be a better application for the solar tracking system.

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Appendix A

Arduino Code

```
/*
 * University: KTH Royal Institute of Technology
 * Authors: Colin Lawless and Erik Karrfelt
 * Date: 2018-05-17
 * Bachelor's Thesis at ITM
 * Description: Arduino code for Sun Following Solar Panel
 */

#include <Stepper.h>     // Include stepper library

const int stepsPerRevolution = 6400;  // Number of steps per
revolution

// Initialize the stepper library on pins 2 through 5:
Stepper myStepperVert(stepsPerRevolution, 2, 3);
Stepper myStepperHor(stepsPerRevolution, 4, 5);

int stepCountVert = 0;  // Number of steps the vertical
motor has taken
int stepCountHor = 0;   // Number of steps the horizontal
motor has taken
int stepCountTemp = 0;  // Temporarily saves old stepCount

int horMin = 0;        // Minimum value for horizontal motor
int horMax = 1400;     // Maximum value for horizontal motor
int vertMin = -1800;   // Minimum value for vertical motor
int vertMax = 1800;    // Maximum value for vertical motor

// LDR pin connections
int ldrlt = 0; // Left top
```

```
int ldrrt = 3; // Right top
int ldrld = 1; // Left down
int ldrrd = 2; // Right down

const float referenceVolts = 5.0; // The default reference
on a 5-volt board
const int batteryPin = 5;          // Battery is connected to
analog pin 5

void setup()
{
  myStepperVert.setSpeed(10);    // Sets step motor speed
  myStepperHor.setSpeed(10);     // Sets step motor speed
  Serial.begin(9600);
  delay(1000);     // Sets delay before start
}

void loop()
{
  int lt = analogRead(ldrlt); // Top left
  int rt = analogRead(ldrrt); // Top right
  int ld = analogRead(ldrld); // Down left
  int rd = analogRead(ldrrd); // Down rigt
  int val = analogRead(batteryPin); // Read the value from
  the sensor

  int dtime = 10;
  int tol = 20;

  int avt = (lt + rt) / 2;  // Average top value
  int avd = (ld + rd) / 2;  // Average down value
  int avl = (lt + ld) / 2;  // Average left value
  int avr = (rt + rd) / 2;  // Average right value

  int dvert = avt - avd;     // Check the top/down difference
  int dhor = avl - avr;    // Check the left/right
  difference

  if (-1*tol > dvert || dvert > tol) // Check if dvert is
  within tolerance
  {
    stepCountTemp = stepCountHor; // Set temp step count
    if (avt > avd) // Check which is bigger
    {
```

```
    stepCountHor -= 96; // Change step count
    if (stepCountHor < horMin) // Check min-value
    {
      stepCountHor = horMin;
    }
  }
  else if (avt < avd) // Check which is bigger
  {
    stepCountHor += 96; // Change step count
    if (stepCountHor > horMax) // Check max-value
    {
      stepCountHor = horMax;
    }
  }
  myStepperHor.step(stepCountHor-stepCountTemp);  // Step
  the motor
  delay(dtime); // Short delay
}

if (-1*tol > dhor || dhor > tol) // Check if dhor is
within tolerance
{
  stepCountTemp = stepCountVert; // Set temp step count
  if (avl > avr)  // Check which is bigger
  {
    stepCountVert += 96;  // Change step count
    if (stepCountVert > vertMax)  // Check max-value
    {
      stepCountVert = vertMax;
    }
  }
  else if (avl < avr) // Check which is bigger
  {
    stepCountVert -= 96;  // Change step count
    if (stepCountVert < vertMin) // Check min-value
    {
      stepCountVert = vertMin;
    }
  }
  myStepperVert.step(stepCountVert-stepCountTemp);  // Step
  the motor
  delay(dtime); // Short delay
}
delay(150); // Delay between iterations
```

```
}
```

Appendix B

Wiring Diagram

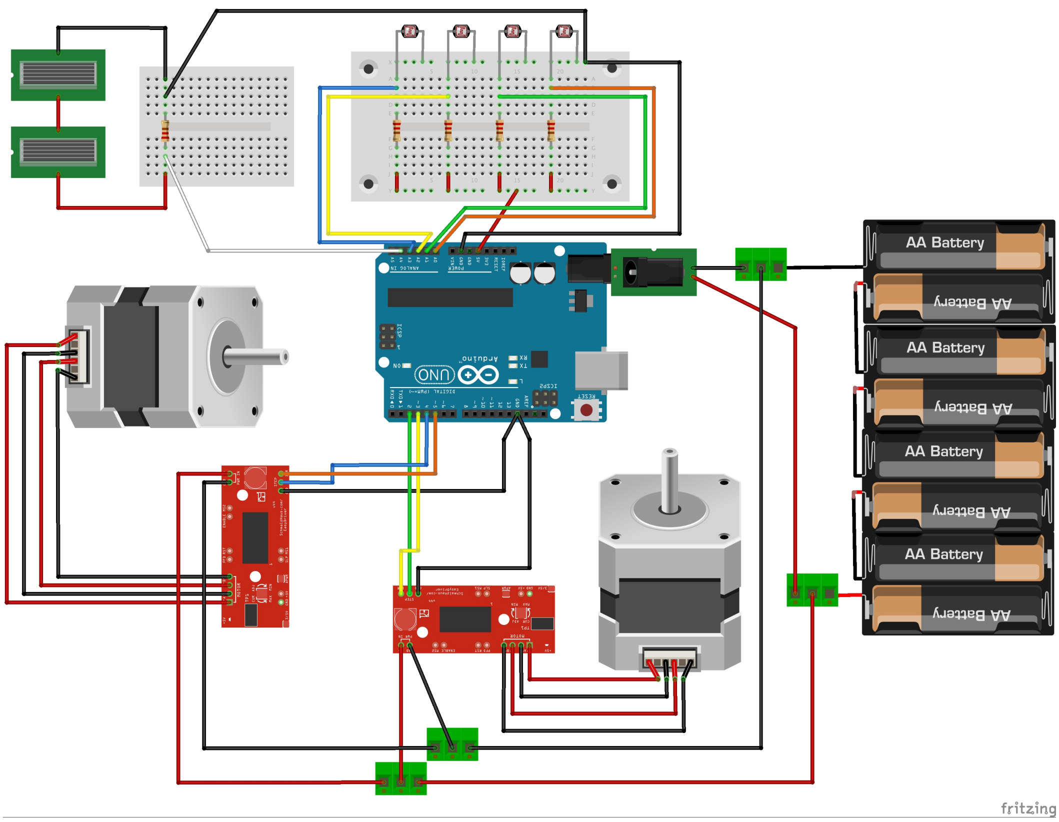

Figure B.1. Wiring diagram, created with Fritzing.org.

Appendix C

LDR Circuit

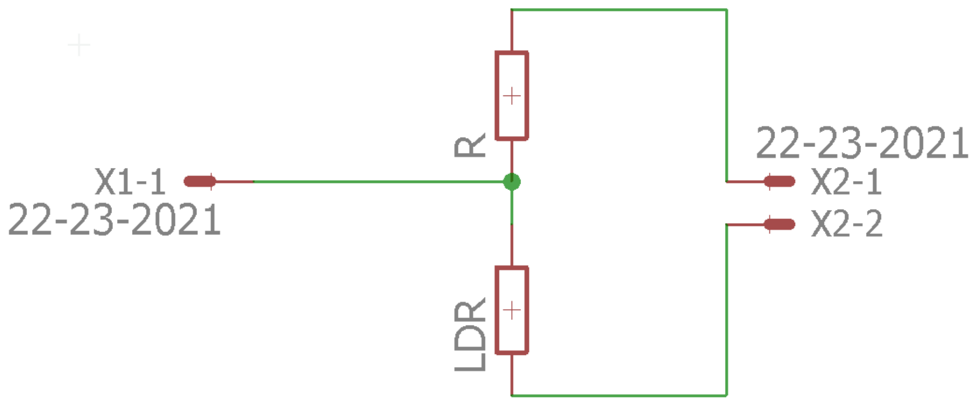

Figure C.1. LDR circuit, created with EAGLE.

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