

DOKUZ EYLÜL UNIVERSITY
GRADUATE SCHOOL OF NATURAL AND APPLIED SCIENCES

**DESIGN OF RENEWABLE ENERGY SOURCE
FOR EMBEDDED SYSTEMS AND
IMPLEMENTATION ON COMPLEMENTARY
SENSOR STRUCTURES**

by

Kamil İBRAHİMOV

November, 2019

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DESIGN OF RENEWABLE ENERGY SOURCE FOR EMBEDDED SYSTEMS AND IMPLEMENTATION ON COMPLEMENTARY SENSOR STRUCTURES

**A Thesis Submitted to the
Graduate School of Natural and Applied Sciences of Dokuz Eylül University In
Partial Fulfillment of the Requirements for Master of
Science in Computer Engineering**

by

Kamil İBRAHİMOV

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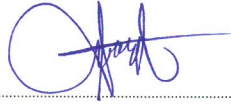
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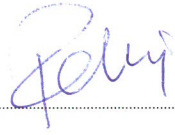
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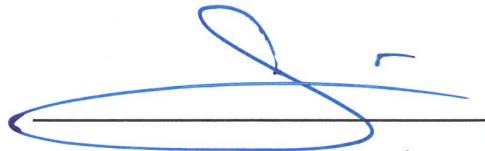
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DESIGN OF RENEWABLE ENERGY SOURCE FOR EMBEDDED SYSTEMS AND IMPLEMENTATION ON COMPLEMENTARY SENSOR STRUCTURES

ABSTRACT

While meeting the increasing energy demand today, preserving the balance of the world we live in and not harming nature and the environment has gained importance for our world. For these reasons, the use of renewable energy sources is becoming more and more important. We often encounter embedded operating systems in most of the electronic devices we use in everyday life. These systems are used by integrating these electronic devices. The main goal of this thesis is to find methods using a renewable energy source for embedded operating systems and to apply the designed method on this operating system. However, in our study, since the non-continuous structure of renewable energy sources causes low reliability, this discontinuity of solar and wind energy has been tried to be tolerated by using hybrids to solve this problem. In our study, the system is designed to operate more independently of the network by saving more energy, and it is ensured that accurate and accurate results are obtained from the sensors installed on the system. In the project we designed, the hybrid system enables us to meet our summer and winter energy needs. Also, the energy obtained from the hybrid system is stored on a rechargeable Lithium-Polymer (LiPo) battery so that system is maintained whenever a failure happens in the energy with the hybrid system. It is applied to Arduino Uno in the designed project to install and operate the sensors.

The sensor is mounted on Arduino to determine the temperature and moisture of the environment. The information achieved from the sensors are sent to the central computer via a Bluetooth module and the control of the project is provided by the computer reliably according to the data obtained. Also, the data of the sensors are presented via the screen having LCD properties. Recording is done via the SD card. In this way, it is ensured that the system and the obtained data are safely protected. Also, the accuracy, usefulness, performance of the proposed design has been proven

by operating and simulating.

Keywords: Renewable energies, solar cell, wind turbine, hybrid systems, Arduino, electronic key sensors, electric power generation



GÖMÜLÜ SİSTEMLER İÇİN YENİLENEBİLİR ENERJİ KAYNAĞININ TASARIMI VE TAMAMLAYICI SENSÖR YAPILARI ÜZERİNDE UYGULANMASI

ÖZ

Günümüzde artmakta olan enerji talebini karşılarken yaşamakta olduğumuz dünyanın dengesinin korunması, doğaya ve çevreye zarar vermemek dünyamız açısından önem kazanmıştır. Bu nedenlerden dolayı yenilenebilir enerji kaynaklarının kullanılması günü günden daha çok önem kazanmaktadır. Gömülü işletim sistemlerine günlük hayatta kullanmakta olduğumuz elektronik cihazların birçoğunda sıklıkla karşılaşmaktayız. Bu sistemler kullandığımız elektronik cihazların sistemlerine bütünleştirilerek kullanılmaktadır. Bu çalışmamızın amacı Gömülü işletim sistemleri için yenilenebilir enerji kaynağı kullanan yöntemler oluşturmak ve tasarlanmış yöntemi bu işletim sistemi üzerinde uygulamaktır. Ancak, çalışmamızda yenilenebilir enerji kaynaklarının sürekli olmayan bir yapıda olmaları güvenilirliğinin az olmasına sebebiyet verdiği için, bu sorunun çözümünün sağlanması için güneş ve rüzgar enerjisi hibrit bir şekilde kullanılmıştır. Çalışmamızda daha çok enerji tasarrufu yaparak şebekeden bağımsız bir şekilde çalışan sistemin tasarlanması, ayrıca sistem üzerinde monte edilmekte olan sensörlerden kesin ve doğru sonuçlar elde edilmesi sağlanmıştır. Tasarlanmış olduğumuz projede hibrit sistemi yaz-kış enerji ihtiyacımızın karşılanmasını bize sağlamaktadır. Ayrıca, hibrit sistemden elde edilen enerji şarj edilebilir LiPo pil üzerinde depolanarak olası bir enerji kesintisi sonucu oluşabilecek arızada önlenmiş bulunmaktadır.

Projede, sensörleri monte etmek ve çalıştırmak için Arduino Uno kullanılmaktadır. Arduino üzerine havanın sıcaklık ve nem oranının tespiti için sensör monte edilmiştir. Sensörlerden elde edilen veriler bluetooth modül ile merkezi bilgisayara gönderilmekte ve projenin kontrolü elde edilen verilere göre güvenilir bir şekilde bilgisayar tarafından gerçekleştirilmektedir. Ayrıca, sensörlerin verileri Arduino üzerine monte edilmiş LCD ekran üzerinde görülmekte ve SD kart ile kayıt

edilmektedir. Bu şekilde sistemin ve elde edilen verilerin güvenli bir şekilde korunması sağlanmıştır. Ayrıca, tasarımın doğruluğu, kullanılabilirliği ve performansı hem çalıştırılarak ve hem de simülasyonu yapılarak kanıtlanmıştır.

Anahtar kelimeler: Yenilenebilir enerjiler, güneş pili, rüzgar türbini, hibrit sistemler, Arduino, elektronik anahtar sensörler, elektrik enerjisi üretimi



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CHAPTER ONE

INTRODUCTION

The geriatric population is continuously going up on a daily basis in Turkey as well as all over the world. As the population grows, energy is needed in all fields of activity especially in developed countries all over the world. Population growth is important since Turkey is a developing country. In parallel, in the growing economy requires the increasing consumption of energy day by day. As revealed in Figure 1.1, installed energy capacity increased from approximately 16 thousand MW in 1990 to 78,500 MW in 2016 and 86,500 MW in 2018.

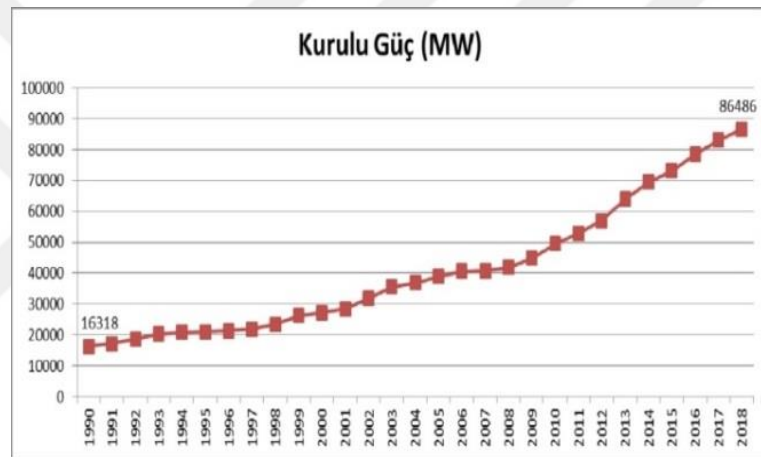


Figure 1.1 Turkey's installed capacity by year (MW)(TÜİK, 2018)

Electricity sector of Turkey during the last 28 years are shown in Figure 1.2. Electricity production, which was 58 thousand GWh in 1990, increased to 292 thousand GWh in 2017 and electricity consumption increased from 57 thousand GWh to 290 thousand GWh. Electricity consumption tends to increase except for 2001 and 2009. The economic crisis in 2001 and 2009 significantly reduced electricity consumption. By the end of May 2018, our electricity production was 118 thousand GWh and consumption was 120 thousand GWh (EPIAŞ, 2018).

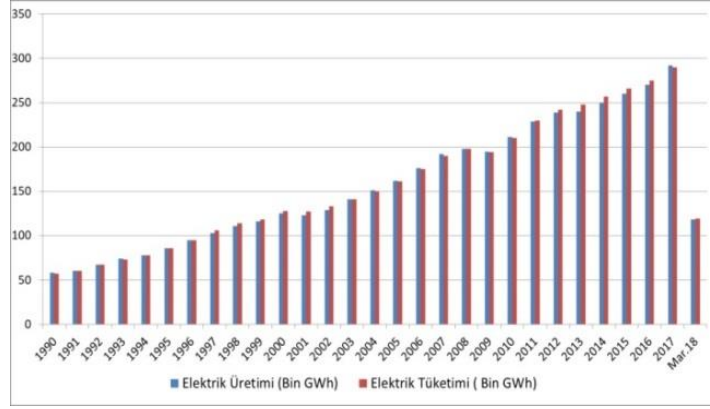


Figure 1.2 Electricity production and consumption in Turkey (GWh) (EPIAŞ, 2018)

Today, Turkey's foreign dependency rate is 72% in the energy field. For these reasons, Turkey is carrying out studies on fossil energy resources exploration work on the one hand and also struggle to determine the potential of renewable energy sources to reduce this rate. In our country, use of renewable energy sources other than our hydraulic resources was also insufficient (Figure 3). Our energy potential, especially wind and sun, should be determined in a healthy manner and parallel to this, the share of our clean and renewable resources in total energy consumption should be increased and used on the technology devices used in our daily lives. In the study we propose, to create methods that use renewable energy sources for embedded systems, which are present in most of the smart devices we use today, and to save energy by applying them on these operating systems.

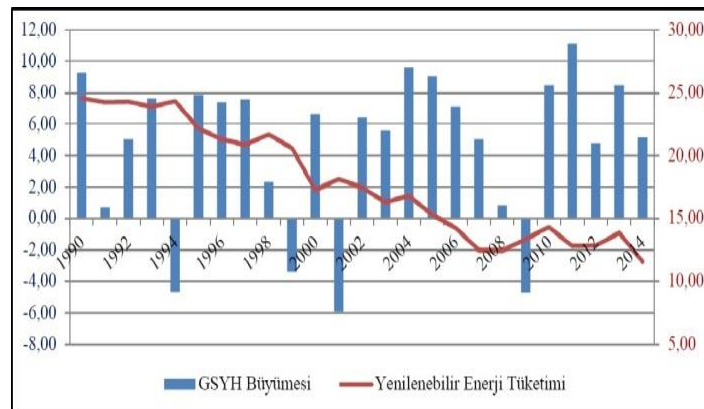


Figure 1.3 Renewable energy consumption and economic growth relationship in Turkey (World Bank data, 2017)

To design the proposed system, we should examine the solar and wind energies separately. After investigating these energy systems, both of these systems work together as a hybrid system and are applied to embedded systems. In the third stage, the embedded systems used for the project are investigated and the business principles are examined. The prototype of the wind turbine to be designed is shown in Figure 1.4. The energy requirements of Arduino Uno and its connected components are met by this system as shown in Figure 1.4. Three sensors that measure the warmth and moisture are mounted on Arduino. Data obtained from the sensors are displayed on the LCD screen mounted on the Arduino and recorded on the micro SD card. Also, it is transferred to the central computer through the Bluetooth Module to ensure that data is protected and stored securely.

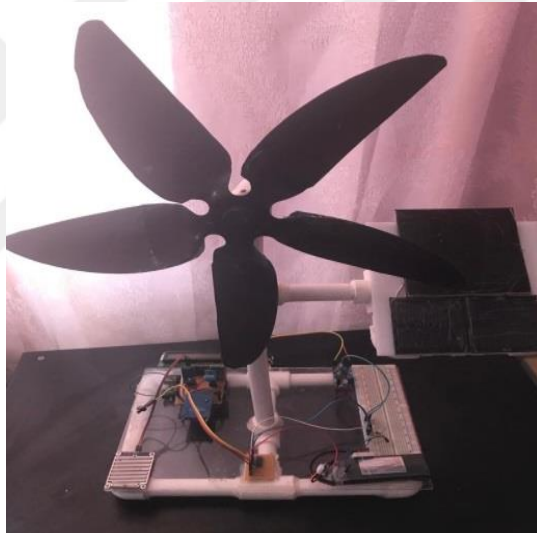


Figure 1.4 Designed prototype (Personal archive, 2019)

CHAPTER TWO

MATERIALS

The proposed design consists of three parts. In the first part, the hybrid energy system is created by using wind propeller and solar cell, and the energy supply is provided. In the second part, it is provided that the embedded systems work with the energy obtained from the hybrid system. Finally, all data obtained are sent to the central computer and monitored, and then remote communication is provided. Existing part explainan the setup of the hybrid system and then on the embedded equipment using the obtained energy. General information about the software of the designed system and the tools used in the system is explained in the second section.

The following hardware components were used in the proposed and designed project. The features and hardware functions are briefly described below.

- Wind propeller (Wing)

When the wind blows, the wind propeller (blade) is a means of assisting the turning of the motor. When the wind blows, the blades help to rotate the rotor, preventing some of the wind as a percentage, which is the percentage that is converted into energy. The better the blade of the rotor, the higher the power to be obtained from the wind turbine. Specially designed horizontal axis wing with 16 cm length and 7-5 cm width was used in the designed project (Figure 2.1).

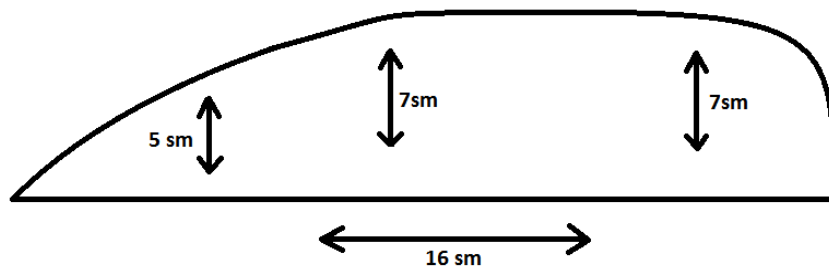


Figure 2.1 Wing design and sizes

- 20 Pprc pipe

The system was installed on a specially designed frame. 20 mm diameter Pprc(Polypropylene Random Copolymer) was used in the construction of the skeleton. This type of pipe defined as Pprc is produced from 3rd class raw material. This product is easy to assemble, it does not cause scale and rust and it is light and smooth. In addition, having resistance to heat, pressure and chemicals makes it suitable for outdoor use.



Figure 2.2Pprc pipe (Google, 2019)

- Arduino Uno

Arduino Uno is controlling all other components in the system: to enable the setup of all sensors and modules on the designed system, to transfer and accept data between sensors, and to make the necessary calculations.

- HC – 06 Bluetooth module

The HC - 06 is a convenient Bluetooth SPP (Serial Port Protocol) module that allows communication between any computer and sensor. Arduino Uno can be mounted and used. What this module does is send and receive data between microcontrollers and data collectors. If the data is collected and sent on time, there are no problems such as communication delay.

- Breadboard

It is a circuit board with 1660 solderless plug-in ports on the breadboard. It is a tool that allows us to easily test and connect established circuits without soldering to each other.

- Lithium-Polymer Battery

The Lithium-Polymer (LiPo) battery provides the electrical power required for the Arduino platform and other modules. The LiPo battery works with a polymer electrolyte system instead of the more commonly used liquid electrolyte, it is rechargeable.

- LCD Display (Liquid Crystal Display)

The LCD panel is part showing electronics. The 16x2 LCD display is a very simple module and is widely used in a wide range of devices and circuits. The data obtained from the data collectors are used to show on the circuit.

- Rain sensor module

The rain sensor module is an Arduino microcontroller mounted on the sensor and has a value on the sensor output pin as a result of contact with the conductor lines drawn in parallel.

- DHT 11 Temperature and Relative Humidity Sensor Module

It is mounted on an Arduino microcontroller and measures the relative humidity and humidity in the air.

- LM 2596 Adjustable Step-Down Voltage Regulator Module

Microcontroller and the voltage regulator module are used to reduce the voltage supply and ensure a constant voltage transfer to the Arduino Uno.

- Micro SD memory Card module

The Micro SD memory card module and the SD card module are mounted on the microcontroller to copy the data collected from the sensors and to secure the data being obtained.

- Micro Metal Geared Motor

This metal reducer motor is used to generate voltage by the movement of the propellers from the wind. The gearboxes in the motor content provide independent

movement between the two rotating elements, transmitting movement and power, obtaining the direction of rotation, obtaining a big moment with a little power.

- Solar cell

Solar cells, also known as solar panels, are the means of absorbing solar energy and transforming it into electrical energy.

2.1 General Description of Hybrid System

Hybrid energy systems are energy systems formed by combining multiple energy sources. The design of the hybrid system is realized by using dual or triple energy systems together. Nowadays, wind and solar energy are preferred in the majority of hybrid systems with dual energy sources and the design of these systems. Hybrid applications are generally applied in the summer and winter times where the energy requirement is compulsory and the power cut should not happen even for a moment. These systems also give us high advantages in terms of safety, comfort, and cost. Hybrid systems are designed in three ways:

- On-Grid / Grid Connected
- Network independent (Off-Grid / Stand Alone)
- Network-supported (Green-Line / Storage System)

The scheme of the hybrid system designed from solar and wind energy is shown in Figure 2.3.

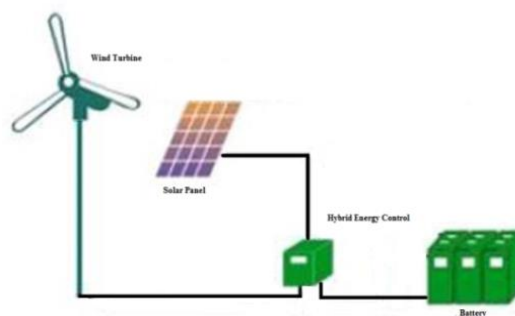


Figure 2.3 Hybrid system

2.1.1 Wind Energy Systems and Definition of These Systems

Wind energy is one of the renewable energy sources. It is an energy source that does not harm nature and does not emit any harmful waste to the environment. The history of wind energy goes back to ancient times. This energy system has been used in mechanical pumping, windmills, sailing ships and many other areas in the past. Today, it is used in the production of electric energy for a completely different purpose. Wind turbines are designed and used to generate energy from wind. The operating principle of wind turbines converts mechanical energy into electrical energy and provides energy production. The main parameter of wind energy depends on the mass and speed of the amount of air that the wind moves. Wind energy increases as the mass and speed of the air increase. In other words, whatever the heavy air mass blows fast, the wind energy in its structure is as much.

2.1.2 Mechanical Properties of Wind Turbines

The operating principle of the wind turbine is very simple. Propeller blades are the starting point of energy production in the wind turbine. The air moving in the turbine area with a certain speed scale causes the turbine to rotate its blades. With the movement of the turbine, the kinetic energy of the wind is converted into mechanical energy and energy production is provided and the energy obtained is transferred to the generator. Our wind turbine consists of a wing, engine, and tower. The design components of the wind turbine are shown in Figure 2.4.

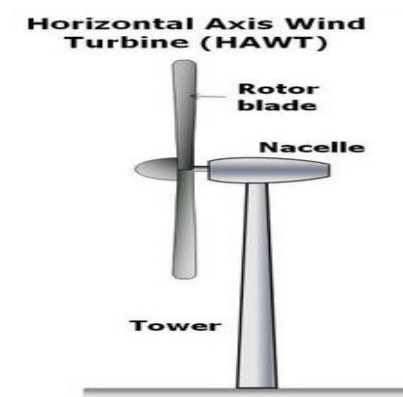


Figure 2.4 Wind turbine design

Wind turbines are divided into two classes horizontally and vertically according to the design of their blades. In wind turbines with horizontal axis, the axis of rotation of the blades to the wind is parallel. In other words, if we give a more detailed explanation, the shape of the wings is parallel to the direction of the wind's arrival. However, in turbines with vertical axes, the turbine shaft is vertical and perpendicular to the direction of arrival of the wind, unlike the turbines with horizontal axes. The rotor of wind turbines is classified as one, two, three and multi-bladed. The efficiency rate of horizontal axis wind turbines is 45% and the efficiency rate of vertical axis wind turbines is 35% (Enerji Portalı, n.d.). One, two and three blades are used in the rotor of horizontal axis turbines. In general, three-bladed rotors are given superiority. The main reason for this is that the propeller has a constant moment of inertia at all speeds. Multi-bladed turbines operate at low speeds and therefore have a lower efficiency rate. For these reasons, horizontal axis wind turbines are mostly used today.

2.2 Solar Energy Systems and Definition of Solar Energy

The energy of heat released as a result of the fusion process in the solar core is called solar energy.

As a result of many thermonuclear reactions, solar energy is formed by the conversion of hydrogen into 3 atomic helium isotopes and 4 atomic helium. In the sun, 564 million tons of hydrogen are converted to 560 million tons of helium every second and 38×10^{22} kJ of energy is released from 4 million tons of mass lost during this transformation. Solar energy consists of ultraviolet and infra-red rays and the wavelengths of the earth's rays vary between 0.1-3 μm . 9% of the rays coming to Earth are ultraviolet, 45% are visible and 46% are infrared rays. These rays reach the Earth in an estimated 8 minutes after the sun comes out. The energy of the sun's rays falling to an area of 1 m^2 outside the world is 1357 J (Joule). 30% of the energy from the sun is returned to space by being exposed to reflection and scattering. The remaining 20% is absorbed in the atmosphere and 50% is absorbed on the surface. 1.7×10^{11} MW thermal power comes from the sun to the world. (Balikesir.edu.tr, 2014).

Nowadays, solar panels are used to generate energy from the sun. The solar panel

was discovered in 1839 by Alexander Edmond Becquerel, who discovered this effect during his work on platinum layers. Solar panels are made up of many solar cells made of elements called silicon. In these cells, there exists parts, one of which creates positive current and the other creates negative current of electricity. Whenever the cell soaks in the sunrays, sun is stored on the panels and electron particles take action. These electrons move towards the panel's lower parts, creating a current by coming out of the connection cable that is on that part of the panel, and this current is called electricity.

2.2.1 General Description of Solar Cell and Solar Panel

These are systems designed from silicon and similar materials that produce energy due to the sunlight falling on the solar cell. Silicon is the most widely used material in solar cell construction since it has typical semiconductor properties. Solar cells cannot store energy on themselves and can generate energy during the time of daylight.

Solar panels are classified as mono and polycrystal according to their production structures. Solar panels with monocrystalline cells are composed of cells of higher purity. Monocrystalline solar panels are capable of producing higher energy even in low light. Monocrystalline solar panels are mostly used and preferred in countries with low sunlight. Polycrystalline solar panels, unlike monocrystalline solar panels have a simpler cell structure. In terms of energy efficiency, polycrystalline panels have lower energy efficiency than monocrystalline panels. For these reasons, monocrystalline solar panels are mostly used today. The appearance of mono and polycrystal panels is shown in the Figure 2.5 (Choosing Between Mono-Crystalline & Poly-Crystalline Solar Panels, 2018).

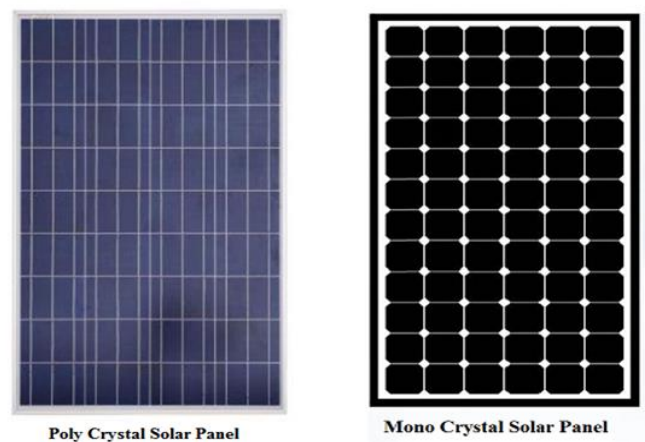


Figure 2.5 Poly and Mono Crystal Panel (Choosing Between Mono-Crystalline & Poly-Crystalline Solar Panels, 2018)

2.3 General Description of Arduino Platform

Arduino is an easy-to-use, flexible hardware, software architecture and open-source electronics development board developed in 2005 by Italian electronics engineers. Arduino is used to creating stand-alone interactive objects, as well as software that runs on a computer. Arduino switches can be used to control sensors, modules, motors, and other similar physical outputs and to develop interactive objects. The foundation is based on an open-source project called Wiring.

The components are microcontroller cards that accommodate processing-based development environments (IDES) and microcontrollers from companies such as ATMEL (Microchip) and ST Microelectronics. More detailed, the microprocessor (Atmega 328) on the Arduino is programmed using the Arduino programming language. Atmega 328 is installed on the board with the help of the Processing-based Arduino development environment (IDE). The language used by the Arduino is very simple, with a basic knowledge of C, which can be direct.

We know our microcontroller to program and run real-time applications. When Arduino cards are compared with other microprocessor cards, we see that these cards have many advantages compared to others (Arduino, 2016). Advantages of Arduino cards can be seen in Table 2.1.

Table 2.1 Advantages of Arduino

Advantages :
<p>Cheap: Arduino cards are relatively inexpensive compared to other microcontrollers.</p> <p>Simple programming environment: Easy to use, flexible hardware and software architecture.</p> <p>Open source and extensible software: The Arduino IDE software is published on the official website of the Arduino as open source, which can be expanded by professional programmers.</p> <p>Open source and extensible software: Since the plans of Arduino cards are published under the Creative Commons License by designers, their module versions are known to be developed.</p>

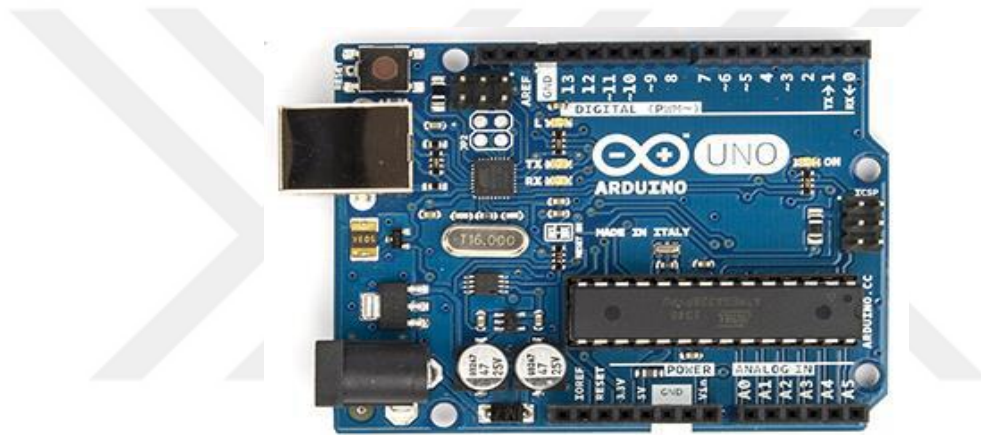


Figure 2.6 Arduino Uno microcontroller board (Arduino, 2016)

2.3.1 Arduino Uno's Microcontroller Unit

In this system, the use of Arduino UNO R3, one of the Arduino cards, is deemed necessary. When we look at the microcontroller unit of the Arduino UNO R3 board, we see that there is an Atmel ATmega328 microprocessor. This working microprocessor has a 32 kb flash memory to store programs, 2 kb RAM at 5V, and 1kb EEPROM to store parameters on the Arduino UNO board. Furthermore, unlike other types of cards, FTDI integrated is used as USB serial communication converter and instead, Atmega 8U2 performs the conversion work. This allows for faster transfer. Another feature of the fact that the FTDI chip is not used is the ability to introduce the Arduino UNO as a keyboard, mouse, joystick, etc., and to provide ease of use in the system. The clock speed is 16 MHz. This executes 300,000 lines of C

source code per second. There are 14 input/output pins on the board. 6 of these outputs have an analog input pin which is used as PWM output.

There is also a USB connector on the card to communicate with the computer. It is also possible to run any program on the card without connecting it to the computer. For this purpose, an external 6-20 V power supply is available on the board. In our study, the data obtained from sensors and modules are collected using the Arduino UNO board and sent to the external data collector. Since the Atmel ATmega328 microcontroller is sufficient for data collection and transmission process time and the number of input/output pins is sufficient, the use of Arduino UNO R3 is preferred in our project. Figure 2.7 shows an electronic diagram of the Arduino Uno R3 card.

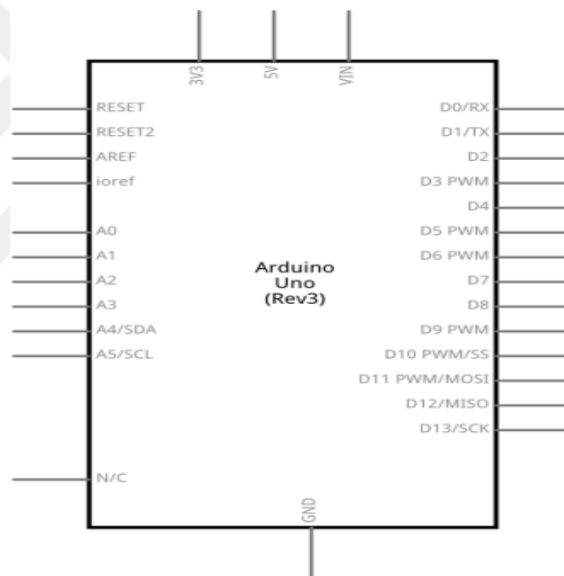


Figure 2.7 Arduino Uno R3 Electronic diagram (Arduino, 2016)

2.3.2 Technical Specification of Arduino Uno

Despite there are many smaller and much larger Arduino models in size, the size of the Arduino Uno R3 is the most common in these projects. The general features of Arduino Uno are briefly shown in Table 2.2 (Arduino, 2016)

Table 2.2 Features of Arduino Uno R3

- *Microcontroller: ATmega328*
- *Operating Voltage: 5V*
- *Input Voltage (recommended): 7-12V*
- *Input Voltage (limit): 6-20V*
- *Digital I/ O Pins: 14 (6 of them are PWM outputs)*
- *Analog Input Pins: 6*
- *Current for each I/ O: 40 mA*
- *Current for 3.3V Output: 50 mA*
- *Flash Memory: 32 KB (ATmega328)*
- *SRAM: 2 KB (ATmega328)*
- *EEPROM: 1 KB (ATmega328)*
- *Clock Speed: 16 MHz*
- *Length: 68.6 mm*
- *Width: 53.4 mm*
- *Weight: 25 g*

The external power supply limit of the Arduino Uno varies within a range of 6-20 V. However, the recommended external supply voltage is 7-12 V range. When the supply voltage of the Arduino board is more than 12V, it causes the voltage regulator on the board to overheat and damage the panel. The card can be powered externally via the USB or adapter port. Power can be supplied by a device, adapter, or battery, regardless of any computer's USB port or computer. Power can also be supplied directly from the Vin (+) and GND (-) pins on the board (Arduino, 2016).

- *Vin: Pin used for external power supply.*
- *5V: Provides 5V output voltage from the regulator.*
- *3V3: 3.3V regulator output pin on the board. Max. It can output 50mA.*
- *GND: Ground (-) pins.*

The resettable fuse via Arduino Uno protects your computer's USB port from short circuits or over current consumption. When the card draws more than 500mA current through the USB port, it automatically cuts off the power it receives from the USB. When the overcurrent condition or short circuit is removed, the fuse returns to its original place and the communication is satisfied again.

As described in the above paragraph, Atmega328 on Arduino Uno R3 has 32KB flash memory, 2Kb SRAM and 1KB EEPROM code storage. Atmega328 also has I2C and SPI ports. The wire library in the Arduino IDE uses the SPI library for I2C use and for SPI communication. Communication related to Arduino Uno is known in many ways. The simplest and most common of these is serial communication using the RX and TX pins. The Atmega16u2 USB-to-serial converter opens a virtual serial port on the computer to enable communication between Atmega328 and the computer. The Arduino IDE provides a serial monitor for sending and receiving text-based information between Arduino and the computer.

When a USB communication is established between the Arduino and the computer, the LEDs on the arduino Uno read the RX and TX, and the LED lights up.

Arduino Uno card programming is done with Arduino IDE like all Arduino cards. By bypassing the bootloader software, the card is programmed directly with the ISP programmer using the ICSP header of the microcontroller. Located on Arduino Uno, Atmega328 comes pre-programmed with a boot loader by the factory. A new code can be loaded into the Arduino UNO with the boot loader.

2.3.3 Arduino Uno Connectors

As shown in Figure 2.8, there are many connectors on the Arduino Uno board. These connectors are sensors, modules, buttons and so on. As mentioned earlier, the Arduino Uno board has the connectors shown in Table 2.3. The characteristics of these connectors are described in Tables 2.4 and 2.5 (Arduino, 2016).

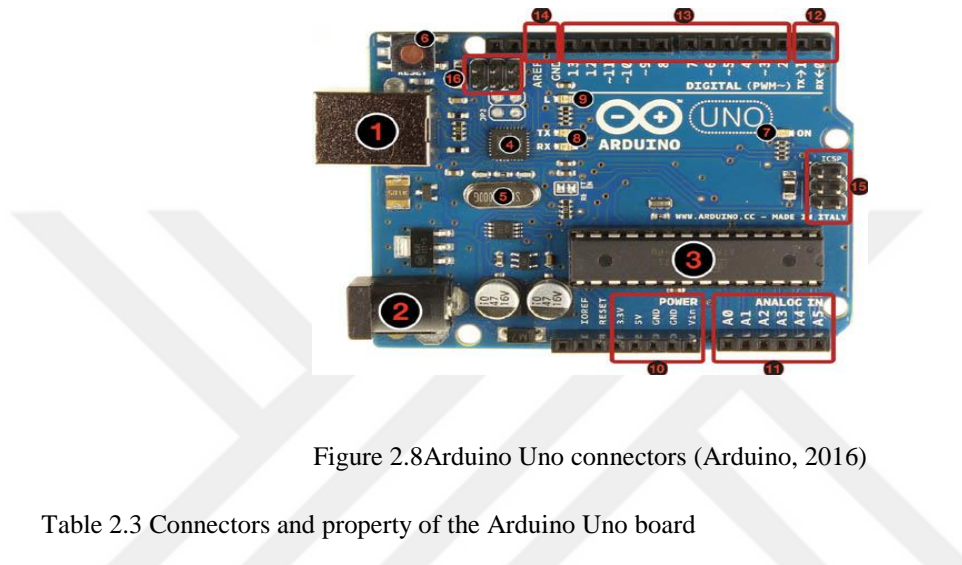


Figure 2.8 Arduino Uno connectors (Arduino, 2016)

Table 2.3 Connectors and property of the Arduino Uno board

- 1: USB jack
- 2: Power jack (7-12V DC)
- 3: Microcontroller ATmega328
- 4: Communication chip
- 5: 16 MHz crystal
- 6: Reset button
- 7: Power led
- 8: TX / RX LEDs
- 9: Led
- 10: Power pins
- 11: Analog inputs
- 12: TX / RX pins
- 13: Digital input / output pins (pins with ~ sign next to them can be used as PWM output.)
- 14: Ground and AREF pins
- 15: ICSP for ATmega328
- 16: ICSP for USB interface

Table 2.4 Power pins that are on the Arduino Uno

<p>Power Pins</p> <p>VIN pin : The Arduino card is normally powered by USB. In addition, 7-12 V external power can be supplied via this pin.</p> <p>5V pin: It is the 5V regulator output of the Arduino Uno board. The card can be supplied with power in 3 ways: with a 7-12 V adapter from the DC power jack; 5 V USB jack or 7-12 V from the VIN pin. Supplying power using 5 V and 3.3 V pins discard the regulator hence can damage the card.</p> <p>3.3 V pin: It is the 3.3 V regulator output of the board. It draws a maximum of 50 mA.</p> <p>GND pin: It is the Ground (earth) pin. The negative (-) end of all components on the Arduino is connected to this pin.</p> <p>IOREF pin: The voltage reference for microcontroller operation is provided thru this pin. An appropriately configured shield can read the IOREF pin voltage and select the appropriate power supplies or enable voltage converters on their outputs to operate at 3.3 V and 5 V.</p>

Table 2.5 INPUT and OUTPUT Pins

<p>• INPUT and OUTPUT Pins</p> <p>Serial 0 (RX) and 1 (TX): These pins are serial communication pins. These pins are for TTL serial data receive (RX) and transmit (transmit - TX). This means that we can send data with TX pin and receive data with RX pin.</p> <p>2 and 3 Pins: These pins are featured pins. External pins are used with these pins.</p> <p>PWM: pins 3, 5, 6, 9, 10, and 11: These pins provide an 8-bit PWM signal with the analogWrite () function.</p> <p>SPI: 10 (SS), 11 (MOSI), 12 (MISO), 13 (SCK) pins: These pins enable SPI communication with the SPI library.</p> <p>LED 13 Pin: It is a led connected to digital pin 13. Lights up when the value of the pin is High, goes out when Low. There are 6 analog inputs from A0 to A5 on the Arduino Uno board. Each of these input pins supports 10-bit resolution. At the default settings, they measure up to 5 V from the ground. However, the upper limit can be set using the AREF pin and analogReference () function.</p> <p>TWI or I2C Pins: Communication with pins A4 and A5 can be achieved using the protocol known as TWI or I2C.</p> <p>RE AREF: Reference voltage for analog inputs. Used with the analogReference () function.</p> <p>RESET: To reset the microcontroller. Usually used to add a reset button on the shield.</p>
--

2.4 Software, Simulation, Connectivity and Visual Publishing Tools

Arduino Uno can connect with a computer, another Arduino or another microcontroller. The ATmega328 microcontroller provides UART TTL (5V) serial connection and this connection can be done with RX and TX pins. ATmega16U2 can provide this serial communication via USB. The 16U2 uses standard USB com drives and no need to an external drive. But, Windows needs an .inf file. While connecting to the USB port on the computer, the USB serial chip, RX and TX LEDs on the Arduino Uno card start flashing. The SoftwareSerial library allows serial communication over any of Arduino Uno's digital pins. ATmega328 also supports I2C (TWI) and SPI communication.

2.4.1 Arduino IDE

In this study, Arduino IDE (Integrated Development Environment) was used to design the software of the all system. The Arduino IDE is a software development tool that allows compilation and uploads the compiled code directly to the Arduino kit (connected to the USB port of the PC). The interface of the Arduino IDE is shown in Figure 2.9. The interface of the Arduino IDE is shown in Figure 2.9.

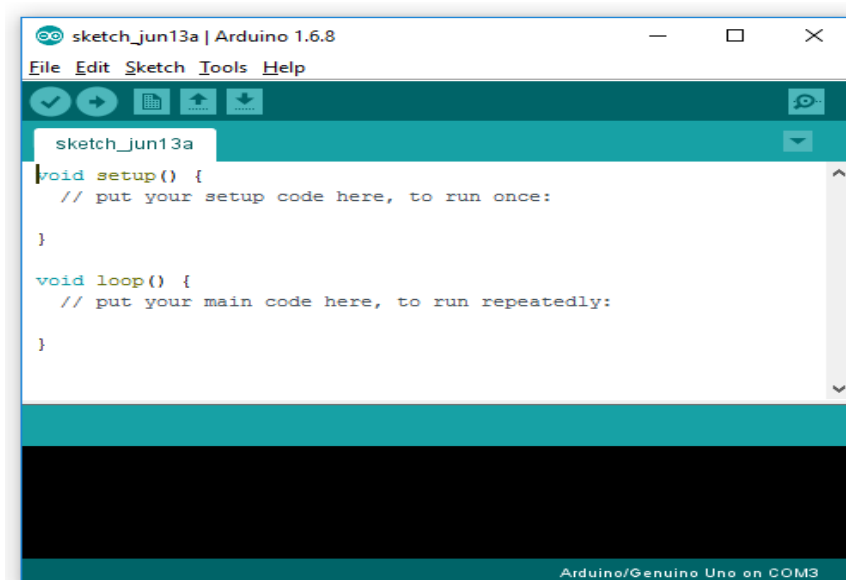


Figure 2.9 Arduino IDE (Arduino, 2016)

There are text editor, text console, buttons for common functions and various menus for writing code on the program. Arduino connects to the UNO via cable to upload written codes to the UNO and communicate with the Arduino UNO. The message field sends feedback and shows errors when saving and exporting text.

2.5 MATLAB (Matrix Laboratori)

Matlab programming language is used to create the interface to control the system over the computer on the designed project. Developed by MathWorks since 1980, this program is a programming language that allows matrix processing, function and data drawing, algorithm application, user interface creation, and interfacing with C, C ++ and many other programs. Figure 2.10 shows the interface of the Matlab program (Özel, 2018).

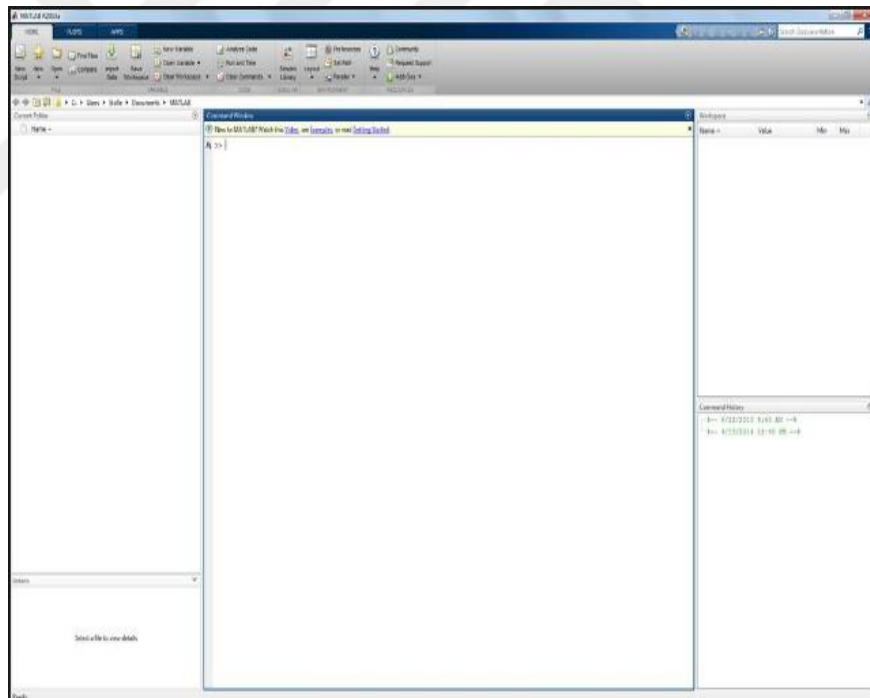


Figure 2.10 Matlab program interface view (Özel, 2018)

Matlab is briefly explained below (Özel, 2018):

The classic look of the Matlab work environment consists of 4 main parts.	
1. Current Folder	
2. Command Window	
3. Workspace	
4. Command History	
File extensions are used for opening and using files on Matlab program. The most commonly used of these extensions and their description are given below.	
.fig	MATLAB figure
.m	MATLAB function, script, or class
.mat	Binary file for MATLAB storage variables
.mex ...	MATLAB executable (specific platform, eg ".mexmac" for Mac, ".mexglx" for Linux, etc.)
.p	MATLAB content-obscured .m file (result e ())
.jkt	GPU cache file (AccelerEyes) generated by Jacket for MATLAB
.mum	MATLAB CAPE-OPEN Unit Operation Model File (AmsterCHEM)

2.6 Proteus Electronic Circuit Simulation Program

Electronic circuit simulation of the proposed project is made with the Proteus program. This program is a simulation, animation and PCB drawing program of electronic circuits offered by Labcenter Electronic. Proteus program consists of two sub-programs: ISIS and ARES. Electronic circuit drawing and circuit analysis can be done in ISIS. In ARES, printed circuit drawing is realized by transferring the circuits drawn in ISIS to the ARES environment. Also, the manual (manual) printing circuit drawing can be made. With this program, it is possible to run and observe the result by changing the values of all the vehicles on the circuit. Most importantly, after designing the electronic circuit through this program, he can design an error report and give the material list very regularly. Figure 2.11 shows the interface of the Proteus program (Burhan, 2017).

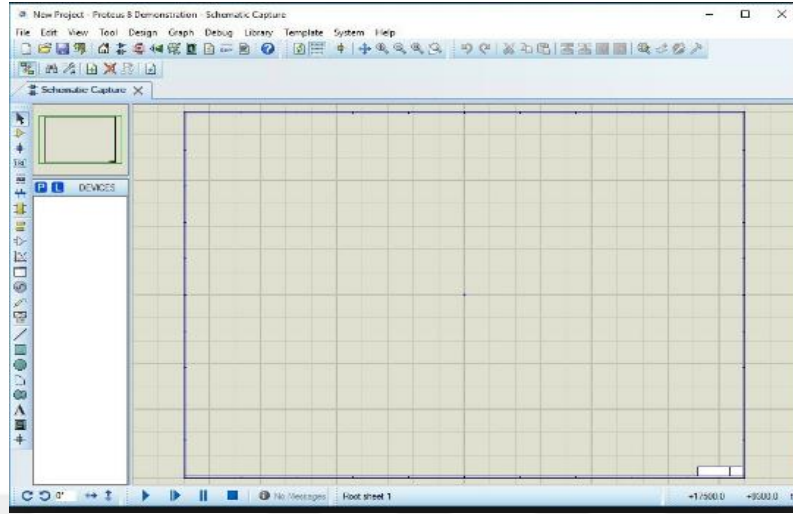


Figure 2.11 Proteus program interface view (Burhan, 2017)

2.7 Excell-Spreadsheet program

On the project, the data obtained from the sensors and hybrid system were tabulated and the graphic drawing of the data according to the table was made on Excel. It is a spreadsheet program developed by Microsoft to store all kinds of data, especially numerical data in tables and lists, to calculate, analyze and perform all graphs. Excel can run on Windows-based OS (operating system) and Apple Macintosh OS. Figure 2.11 shows the interface of the Excel program.

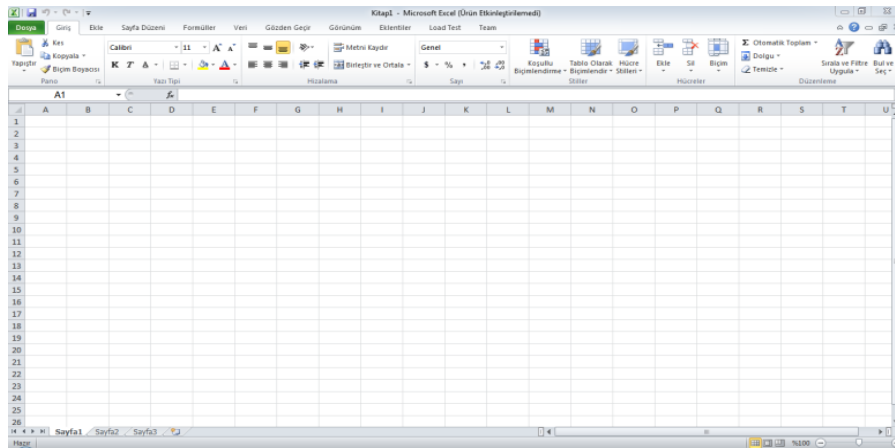


Figure 2.12 Excel program interface view (Wmaraci, n.d.)

2.8 Hardware Features of Breadboard

The breadboard is a circuit board with 1660 solderless plug-in connection points used to control and test the circuits of our project. Circuits can be installed and removed on the breadboard. Figure 2.13 shows the external and internal structure of the breadboard.

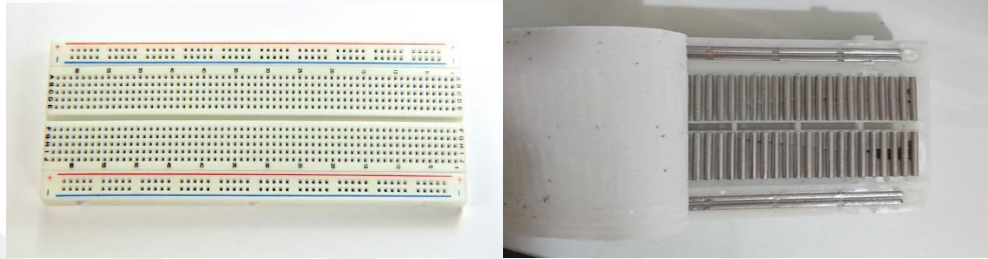


Figure 2.13 External and internal design of breadboard (Google, 2018)

As we can see in Figure 2.14, the internal structure of the breadboard consists of metal clamps. These clamps are placed parallel to each other in the form of vertical and horizontal. The red and blue parts are shown in the figure are the line parts of the breadboard and are transmitted in a line-by-line manner. The lines “+” and “-” on the breadboard are used to provide voltage connections. After providing voltage connections, the power requirements of the components placed on the board are met through these lines. The columns, which consist of 5 holes in the middle part, are also in communication with each other since they are located on the same piece of metal. These sections are on both sides of the board as in the lines.

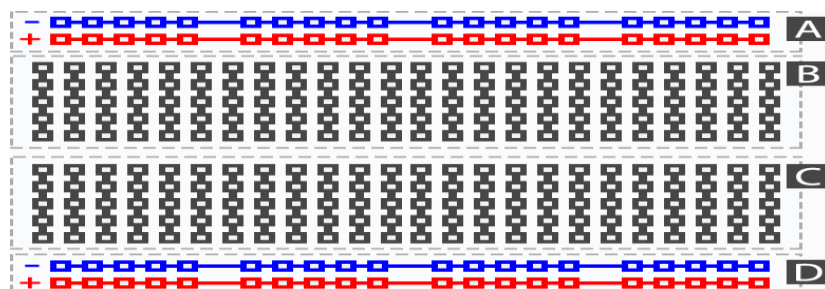


Figure 2.14 Breadboard interior design

2.9 Distinctive hardware property of the HC-06 bluetooth module

The purpose of using the HC-06 Bluetooth module on the project is to transfer the data obtained from the sensors to the central computer quickly and reliably. This module can be used only in slave mode to communicate with short-term connections and is capable of responding to incoming communication requests. It is capable of communicating in an open area with a radius of 10 to 100 m. Figure 2.15 shows the external appearance of this communication module and Table 2.6 shows its features.



Figure 2.15 HC - 06 Bluetooth module (HC-06 Bluetooth Modul, 2016)

Table 2.6 Features of HC-06 bluetooth module

<ul style="list-style-type: none">• 2.4 GHz communication frequency (ISM)• Sensitivity: ≤ -80 dBm• Output power: $\leq +4$ dBm• Asynchronous speed: 2.1 MBps / 160 KBps• Synchronous speed: 1 MBps / 1 MBps• Operating voltage: 1.8 - 3.6 V (Recommended 3.3 V)• Current: 50 mA• Signal coverage: 30ft• Size: 1.55cm * 3.98cm• Authentication and encryption• Storage temperature range: -40 °C to 85 °C, Work temperature range: -25 °C to $+75$ °C• External Flash: 8 Mbit
--

The operating principle of the HC-06 bluetooth module is based on serial communication. When looking at the Bluetooth module, there are 4 pins as VCC, GND, Rx and Tx. The purpose of these pins is to feed the VCC and GND module. To ensure communication between the Arduino and the Bluetooth module and to receive Arduino commands by the module, the Tx pin of the Arduino is attached to the Rx leg of the Bluetooth module. Similarly, to transmit messages to Arduino via Bluetooth, the Rdu pin of the Arduino must be plugged into the Tx pin of the Bluetooth module. It operates at voltages between 3.3V and 5V. However, data exchange is done with 3.3V. Bluetooth modules come with their own names, passwords and connection rates set. The HC-06 is set to a password of 0000 or 1234 and a baud rate of 9600. The baud rate of the receiver and transmitter must be the same for communication with other devices. This module allows us to change the name, password and baud rate. This can be done with AT commands.

In addition, the ATE STATE command can be used to check if the module is connected to the device. The pin description diagram of the HC-06 Bluetooth module is shown in Figure 2.16 (HC-06 Bluetooth Modul, 2016)."

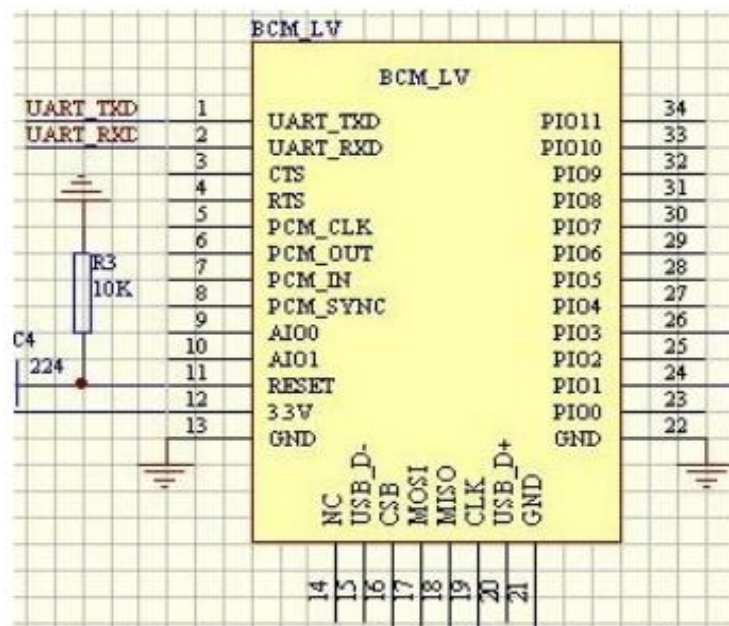


Figure 2.16 Module Pins Description (HC-06 Bluetooth Modul, 2016)

The property of the pins on the HC-06 bluetooth module are as follows (HC-06 Bluetooth Modul, 2016)

- **KEY**: according to the data sheet, I need to pull-up this pin while power-on-reset of the module to enforce AT mode.
- **VCC** is indicated in the range of 3.6V-6V.
- **GND**: Ground
- **TXD**: serial *output* of the module, to be connected to RX of the microcontroller.
- **RXD**: serial *input* of the module, to be connected to the TX of the microcontroller.
- **STATE**: connected to LED2

2.9.1 Software property of HC-06 bluetooth module

Software property of HC-06 Bluetooth module are given as a list below (HC-06 Bluetooth Modul, 2016)

Software Property of the module

- **Default Baud rate**: 38400
- **Data bits**: 8
- **Stop bit**: 1
- **Data control**: has.
- **Supported baud rate**: 9600, 19200, 38400, 57600, 115200, 230400, 460800.
- **Status instruction port PIO1**: decreased amount of discommunication, increased amount of connection
- When bluetooth module powered on, Auto-connect to the last device as default
- Permit pairing device to connect as default.
- Bluetooth module default pincode is "1234". It can be change for security reasons.
- When module disconnected as a result of beyond the range of connection, auto-reconnect in 30 minutes.
- When HC-06 bluetooth module is powered on, Auto-connect to the last device is default. If the module is out of connection range, auto-reconnect occurs in 30 minutes.

2.10 LiPo Battery

In our project, the energy source obtained from the hybrid energy system is transferred to the LiPo battery to ensure that the battery is charged and the system operates continuously. The project uses a battery with a capacity of 7.4 V, 2S and 1750mAh (Li-Polymer battery , 2018). A LiPo battery is a lithium-ion battery that uses polymer electrolyte and is rechargeable. When not in use, these batteries are of great advantage because their energy losses are slow and they provide high power during operation. Figure 2.17 shows the external view of the battery used in the project.



Figure 2.17 LiPo battery (Li-Polymer battery , 2018)

“LiPo cells are composed of cells and each cell should be 3V empty and 4.2V full. Cells of LiPo cells are connected in series (S) and parallel (P) and are named according to their connection type. If 5 cells in LiPo battery are connected in series, they are called ‘5S’, if 2 cells are connected in parallel, P 2P’, 4 cells are connected in series and if there are 2 cells connected in parallel, they are called ‘4S2P’. The higher the ‘S’ value, the higher the voltage value of the battery and the higher the ‘P’ value. The mAh on the battery indicates the capacity of the battery and C shows the discharge rate. On all LiPo batteries, there are 2 groups of cable ends, one of which is the balance end and the other is the main power or discharge end. There is only one set of cables from only one-cell batteries” (Li-Polymer battery , 2018).

2.11 LCD Display

In our proposed project, an LCD panel is used to provide a continuous impression of the data obtained from the sensors on Arduino Uno. LCD, Liquid Crystal Display (Liquid Crystal Display) is a display technology based on the principle that the electrically polarized liquid transmits light in a single-phase and can be seen with a polarizing filter attached to it. LCD panels are available in different sizes such as 1x8, 2x8, 1x16, 2x16, 1x20, 2x20, 1x40 and 2x40 according to the number of rows and columns. The external view of the LCD panel is shown in Figure 2.18.

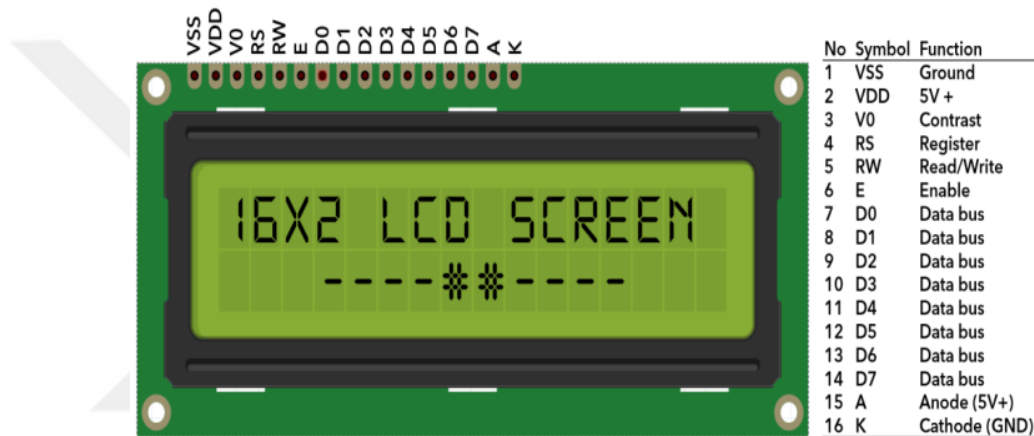


Figure 2.18 LCD panel (Vishay, 2018)

2.11.1 Hardware Features of LCD Panel

The LCD panel we use on our project is the 2x16 size. There are 16 pins on the panel we use. The first 14 pins are used for control and connection of the panel, and the last two are used for backlighting the panel (Vishay, 2018)

- Works with 5V.
- Back Lighting feature.
- The LCD draws 4mA current without backlight.
- Dimensions are 80x36x9.4mm
- Operating temperature is between -20 and 70 degrees.

VEE: Contrast of LCD panel can be adjusted by resistance connected to contrast input. The higher the resistance value, the lower the contrast, the lower the contrast increases.

RS: Specifies whether to send commands or data to the LCD. If the RS input is "0" (ground), the command register is selected, and 5V, the data register is selected.

RW: Specifies whether to read from lcd or write to lcd. When the RW input is connected to ground, ie in the "0" state, the LCD is in write mode.

2.12 Rain Sensor

Multiple sensors and modules are used in the proposed project. One of these sensors is the rain sensor. One of the simplest tools for detecting rain is the YL-83 model rain sensor. The operating principle of the rain sensor is realized by contacting the conductor lines drawn in parallel with water to a value at the sensor output pin. As a result of the contact of the conductor lines on the sensor with water, the sensor output pin has a value between 0 and 1023. When the value decreases from 900 to 0, rainfall intensity increases. It is possible to provide a simple use of the sensor by connecting the supply voltage and ground. Figure 2.19 shows the external view of the YL-83 model rain sensor.

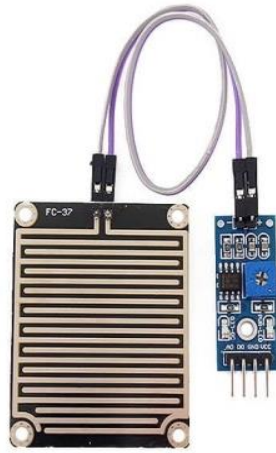


Figure 2.19 Rain sensor (Maker, 2019)

2.12.1 Hardware Features of Rain Sensor

The analog output is used to detect declines in the amount of precipitation. When connected to a 5V power supply, the LED will light when the induction card is not raining and the DO output is high. When a small amount of water inlet, the DO output is low, the switch indicator will light. Brush the water droplets and return to the first state, high-level outputs (Maker, 2019).

Specifications:

- Adopts high quality of RF-04 double sided material
- Area: 5cm x 4cm nickel plate on side
- Anti-oxidation, anti-conductivity, with long use time
- Comparator output signal clean waveform is good, driving ability, over 15mA
- Potentiometer adjust the sensitivity
- Working voltage 5V
- Output format: Digital switching output (0 and 1) and analog voltage output AO
- With bolt holes for easy installation
- Small board PCB size: 3.2cm x 1.4cm
- Uses a wide voltage LM393 comparator

The diagram of the rain sensor is shown in Figure 2.20.

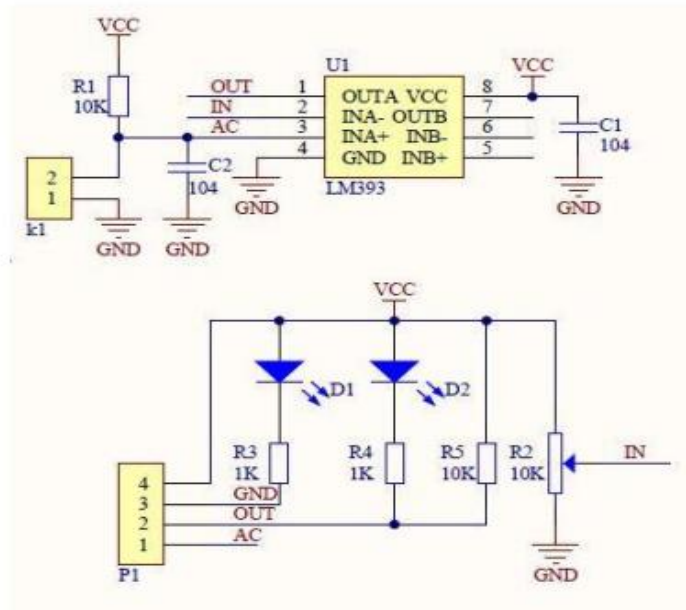


Figure 2.20 Electronic diagram of the rain sensor (Maker, 2019)

2.13 DHT11 Temperature and Humidity Sensor

One of the sensors used in the project is DHT11 Temperature and Humidity Sensor. It is an advanced sensor tool used to detect air temperature and humidity in the area and provides a calibrated digital signal output. The calibration coefficient of the DHT11 sensor is stored in the OTP memory in a program of some sort, and this sensor has a precise calibration feature. Figure 2.21 shows the sensor used in the project.

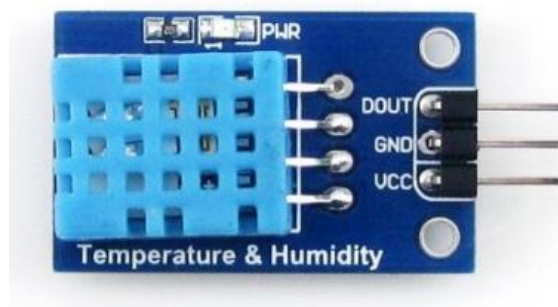


Figure 2.21 DHT11 temperature and humidity sensor (Mouser, n.d.)

2.13.1 Hardware features of DHT11

DHT11 Temperature and Humidity Sensor The unit which measures temperature with an error margin of $\pm 2^{\circ}\text{C}$ between 40°C and 80°C , can measure humidity with an error rate of $\pm 4\%$ (max 5%) between $20\text{-}90\%$ RH. As a sensor measurement, measurement results can be obtained in 2 second periods due to the data collection period of the sensor (Mouser, n.d.).

Specifications:

- Operating voltage: 3 VDC - 5.5VDC
- Humidity: $20\text{-}90\%$
- Temperature: $0\text{-}50^{\circ}\text{C}$
- Detection element: Polymer capacitor
- Sensitivity Humidity: $\pm 4\%$ (Max 5%) RH
- Sensitivity Temperature: $< \pm 2^{\circ}\text{C}$
- Measurement Period: 2 s
- Product Dimensions: $12\text{mm} \times 23.5\text{mm} \times 5.5\text{mm}$
- This sensor requires an 8-bit microprocessor. As seen in Figure 2.22 there are 3 pins on the sensor. These are Date, GND and VCC pins.

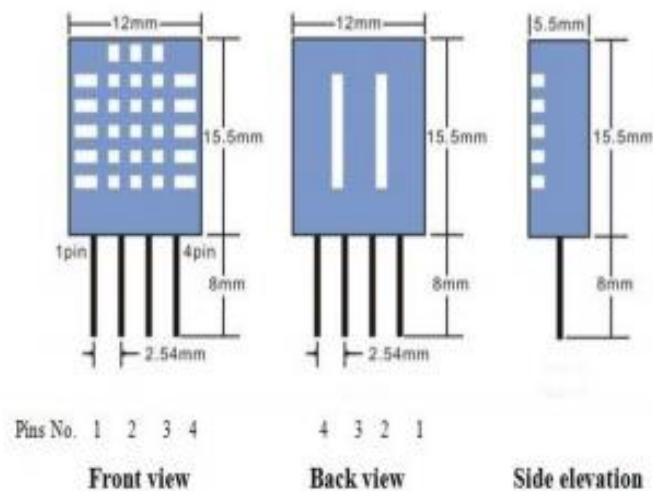


Figure 2.22 DHT11 sensor design and dimensions (Mouser, n.d.)

2.14 N20 Micro Metal Gearmotor DC Motor (500 RPM - 12V-50: 1)

In the designed project, wind fairy was used to obtain energy from wind. DC motor with Micro Metal Gearbox is used in the design of the wind fairy. First of all, geared motors are systems consisting of elements such as shafts, gears, bearings etc. placed in the housing. The gearboxes provide independent movement between the two rotated elements, transmitting movement and power, obtaining directions of rotation, achieving large torque with little power. Our aim is to provide DC motor with many advantages. Figure 2.23 shows the external design of the DC motor and its advantages in Table 2.7



Figure 2.23 Metal geared micro DC motor (Pololu Electronics, 2019)

Table 2.7 Advantages of DC motor

Advantages of DC motor
<i>• DC motors are cheap in price</i>
<i>• DC motors are small in size</i>
<i>• DC motors are easy to locate and supply</i>
<i>• DC motors operate at low currents</i>
<i>• DC motors are easy to drive, with plenty of options and are inexpensive</i>

“In DC motors, gearbox design can be connected from any side and provides an easy installation with a changeable body system. The direction of rotation of the

DC motor depends on the plus-minus terminals supplied from the power supply. When the current direction is changed, the direction of rotation of the DC motor changes. The speed of the DC motor is measured in RPM. The speed of the motor varies with voltage and load. The speed of the motor decreases as the load increases and the power decreases due to the change of the load. In other words, a conclusion is known here”(Pololu Electronics, 2019).

- Voltage constant, load variable, speed variable, current variable
- Voltage is constant, load is low, speed is high, current is less
- Voltage low, load same, speed low, current less
- The hardware features of the engine used in the design of the wind turbine are as follows:
 - Model: N20 metal geared DC motor
 - Reducer Length (reduction ratio): 50: 1
 - Stress Current: 5 A
 - Structural type: Gearbox
 - Operating voltage: 12V DC
 - Speed: 500RPM
 - Dimensions: 36 x 12 x 10mm
 - Operating Temperature: (-20 to +60 C)

➤ Rpm - the speed of the motor is measured in Rpm (rotations per minute). The speed of the motor varies with voltage and load. It is a system that does not load DC motor or has a constant load. In such a system, the speed of the DC motor depends on the applied voltage and the higher the voltage, the higher the speed. In another case, it is a system in which the load on the DC motor varies with time or task performed. In this case, the speed of the DC motor will depend on the load. As the load increases, the applied power increases, and as the power increases, the speed decreases.

➤ Current - When a DC motor is operated at the specified voltage, the current that the DC motor draws depends on the load. As the load increases, the current drawn by the DC motor increases. Generally, the application current range of DC motors can be from 50 mA to more than 2A.

➤ Power - Power is the product of the current and voltage of a motor.

2.15 SD (Secure Digital Memory) Card and Card Module

SD Memory card is a tool for storing data from sensors. In the designed project, the data obtained from the sensors are stored and stored instantly on the SD card for storage and protection. For this, SD card module is mounted on Arduino Uno and data is transferred to 8 Gb SD card (Ada, 2019). SD cards have SD and SPI communication protocol. Since the built-in SD card library in the Arduino IDE allows to communicate with the SD card in SPI mode, we are communicating with our SD card through the SPI communication protocol. SD cards operate between 2.0V and 3.6V. The external view of the module and card being used is shown in Figure 2.24.



Figure 2.24 SD card module and SD card (Ada, 2019)

The SD Memory card module has many features such as uploading the read data to the memory card and recording the incoming data continuously. There is also an internal 3.3V voltage regulator on the card module. In this way, 3.3V and 5V systems can be used easily. Figure 2.25 shows the electronic design of the SD card module.

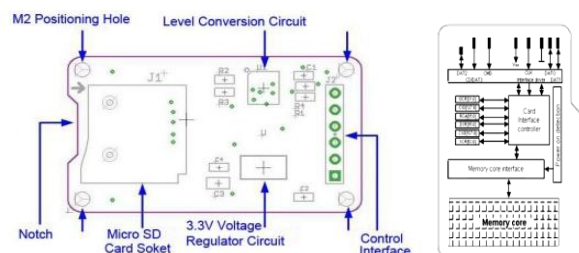


Figure 2.25 SD card module and SD card architecture (Ada, 2019)

2.16 Solar Cell

In our project, the solar cell is used to get energy from the sun. A solar cell is an electronic system that can convert sunlight directly into electricity. The other name of solar cells is photovoltaic cells. The areas of solar cells are generally 100 cm². Their thickness varies between 0.2-0.4 mm. The solar cell has an efficiency between 5% and 20% compared to the materials used in its construction.

It is a tool that produces direct current (DC) when light falls on solar cells. When these PV cells come together, they form the solar modules (PV modules). The most basic PV cell is a cell of silicon-crystal. Such a cell produces approximately 0.5-0.6 DC voltage. A PV module consists of the serial connection of these PV cells. The view of the solar cell we are using on the project is shown in Figure 2.26.



Figure 2.26 Solar cell (Google, 2018)

Table 2.7 Features of Solar Cell

The solar cell we use has the following features:

- Max working voltage: 5.5V,
- Max working current: 0ma - 90ma,
- Power: 0.6W,
- Dimensions: 65mmx65mmx3mm.

2.17 LM2596 Regulator

The working principle of the regulator used on the system is to ensure that the energy obtained from the hybrid energy system which is designed is transferred to the embedded systems by making voltage regulation as a constant energy value. The regulator is an electrical device that can maintain and change physical quantities such as frequency, speed, power, pressure, voltage and current to a certain degree. Figure 2.27 shows the external view of the regulator being used.



Figure 2.27 LM2596 regulator (Onsemi, 2008)

Table 2.8 Features of LM 2596 regulator (Onsemi, 2008)

Specifications:

- Regulator Type: Non-Isolated input to Output
- Input Voltage: +4 to 40vdc Output Voltage: +1.23 to 35vdc
- Output Current: 2A rated, (3A maximum with heatsink)
- Efficiency: Up to 92% (when output voltage is set high)
- Switching Frequency: 150kHz
- Dropout Voltage: 2vdc minimum

Protection: Short circuit current limiting

Load Regulation: +/- 0.5%

Voltage Regulation: +/- 2.5%

Temperature: -40 to +85 deg C (output power less than 10Watts)

Board Size: 43.6mm L x 21mm W x 14mm H

The main purpose of the voltage regulator is to convert the high voltage to a lower voltage to make it a more constant value. In more detail, the regulator cannot convert the low voltage to a higher voltage value and therefore the input voltage value should be higher than the output voltage value. In addition, the input voltage is not less than 4 V maximum 40 V, and the output voltage is not more than minimum 1.25 V maximum 37 V. The recommended current utilization value is 2 A, although a maximum current of 3 A has passed through the regulator. There is a button on the regulator board to display the input and output voltage values in 7 segments.

The input and output values can be read and monitored from this screen and the values can be observed during the adjustment and the voltage display of this panel has a sensitivity of 0.1 V. Figure 2.28 shows the electronic circuit diagram of this regulator board. The input and output pins on the board are as follows:

- • IN + Positive supply input
- • IN - Grounding
- • OUT + Positive output pin
- • OUT- Ground output

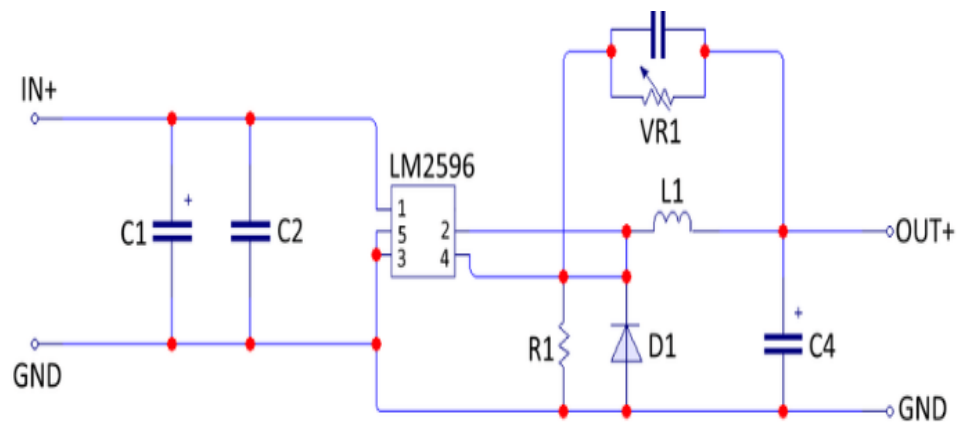


Figure 2.28 LM2596 SMPS voltage regulator schematic (Onsemi, 2008)

CHAPTER THREE

PREVIOUS STUDIES

Machines that are used in the field and which are not easy to maintain or which have embedded systems such as safety types of equipment, automatic filling devices, which are located at long distances to be maintained, should also work in case of power failure. Any power outage to be experienced is a big problem for the software flow of embedded electronic systems and unexpected situations are encountered. Data losses are experienced, causing designer companies and user companies to suffer financial losses.

Many projects have been realized by using solar, wind, hybrid energy systems and different energy sources and researches have been realized. Most of the projects have been developed by using different systems and different methods. In some of the studies, the design of the hybrid system is changed, in the other part of the project, the intelligent charge control unit is designed for the application and storage of the energy obtained from the hybrid system and many similar projects have been realized. However, most of the work is usually done and designed on the battery charging circuit of hybrid and embedded systems. There are several books, doctoral theses, master's theses, papers and articles that can be used to design the Renewable Energy Source for Embedded Systems and their Application on Complementary Sensor Structures in the literature:

In one of the researches, the system is designed to consume low power or energy. While charging the battery group with the energy it receives from wind turbine and solar panel, energy is supplied to the load by means of an inverter from the same battery group. The Intelligent Charge Controller for Wind and Solar Power operates with a microcontroller and PWM (Pulse Width Modulation) technique.

The system displays the voltage and temperature information of the batteries, the charge and load current information of the wind turbine and the solar panel voltage values on an LCD screen as well as can be accessed from anywhere in the world via

an internet site. The site has analysis and graphs of these values and can be monitored by panel and turbine cameras.

In another project, only one renewable energy source is used. In this study, the parking lighting system was designed by using the solar energy system. Also, wireless cameras were used in the project not only to illuminate the park but also to ensure its safety. All types of equipment can make instant and retrospective monitoring with the web-based control system (Data Logger) designed by Mikrodizayn, lighting power can be adjusted gradually and maximum power saving can be achieved.

Unlike other projects, the hybrid system was created by using both wind and solar energy at the same time and applied to embedded systems. Also, although most of the projects generally use solar panels and 3-bladed wind turbines, the solar cell and multi-bladed wind turbines are used in the project we proposed. Also, a rechargeable LiPo battery was preferred instead of a high-cost generator for energy storage. Unlike other projects, the regulator is used as the energy stabilizer because the energy we want is low. By designing the project, the target is achieved by providing the continuous operation of the embedded systems and the sensors on the system by providing uninterrupted energy needs.

CHAPTER FOUR

HARDWARE DESIGN OF THE SYSTEM

In this study, to provide continuous operation of the embedded systems it is aimed to create an hybrid power plant consisting of solar and wind energy to provide endless energy for embedded systems. Figure 4.1 shows the demo model of the system.

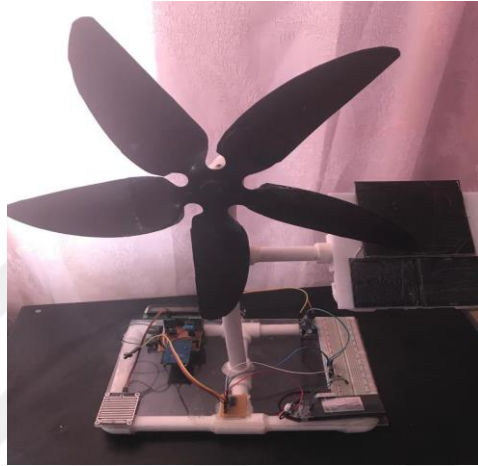


Figure 4.1 Designed prototype (Personal archive, 2019)

The project is designed according to the stage consists of 3 parts. In the first part, solar and wind energy systems were designed, combined and transformed into hybrid systems. In the second part, sensors and modules were mounted and operated on Arduino Uno. In the last part, these two parts were combined into a single model and the data obtained from the design were sent to the central computer, stored and controlled.

4.1 Designment of Hybrid System

Solar and wind energy were used to design the hybrid system in our prototype. Wind turbines are used to get energy from the wind and solar cells are used to get energy from the sun. Finally, these two prototypes were combined to form a single hybrid system.

4.1.1 Design Model of Wind Turbine

In the project, the horizontal axis wind turbine model is used as seen in Figure 3. The reason for using a horizontal axis wind turbine is a high energy efficiency ratio of this model and this ratio is 45%. The height of 10 m is sufficient for the operation of these turbines. The horizontal axis wind turbine captures the movement energy of the wind up to 59% and converts it into mechanical energy. The rotor rotates more quickly as the number of rotor blades decreases in the horizontal axis turbine. Multi-wing RT is used as the wing structure on the wind turbine. The reason for choosing this wing structure is that multi-wing RTs can operate at low speeds. This allows us to use the design even in low wind speeds. Generally designed wind turbine has a horizontal axis, a multi-bladed model. Since we do not need high voltage for the operation of embedded systems, such a design knows the energy that we need. The designed wind turbine is equipped with an N20 model DC motor with a working voltage of 12V, current of 5A and speed of 500 RPM. The reason for using a geared motor is that it can provide us with opportunities such as moving and transmitting power, turning directions and obtaining big torque with a little power. In the wind turbine, the gear motor DC motor is used with the direction of rotation of the motor reversed to generate electricity. The direction of the communication of the power source with DC motors is related to the flow of the current. By this way, the motor works my sole electric consumption. Whenever the flow of electricity has been turned backwards, then the energy is generated by the wind (Figure 4.2).

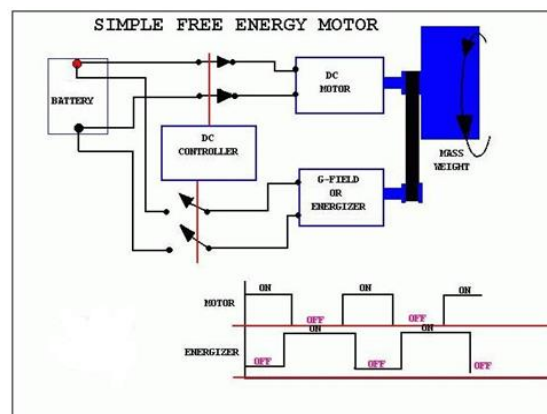


Figure 4.2 Electric production diagram of geared DC motor

In wind turbines, rotor blades are the starting point of energy production. In the turbine area, when the wind comes into contact with the blades with a certain speed value, the blades begin to rotate, and this cycle converts the kinetic energy of the wind into mechanical energy. Figure 4.3 shows the operation diagram of the wind turbine.

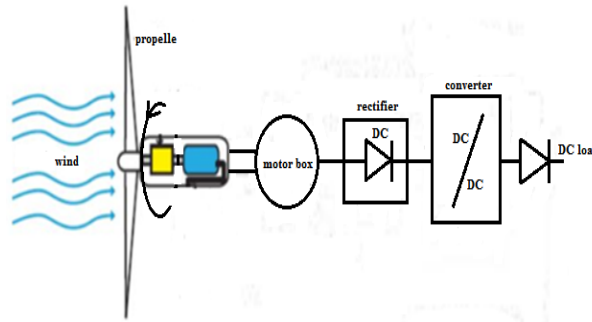


Figure 4.3 The operation diagram of the wind turbine

4.1.2 Design Model of Solar Energy

On the hybrid system, the solar cell is used to get energy from the sun. The solar cells in use are connected in series. On the project, 3 solar cells with the same current, voltage, and amperage values were connected in parallel and a solar panel was formed. The connection diagram of the solar cells in parallel is shown in Figure 4.4.

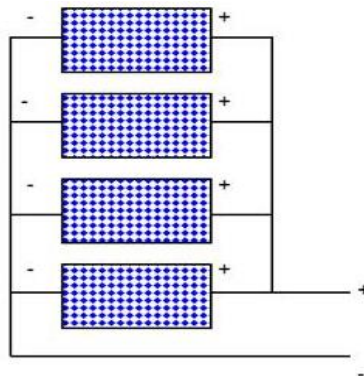


Figure 4.4 Combination of solar cells in parallel(Google, 2018)

The polycrystalline solar cell is used in the design of the solar system. Polycrystalline solar cell efficiency is lower than monocrystal panels. However, since the voltage we want to obtain is not too high, the polycrystalline panel meets our needs. The solar panel absorbs photons from the sun through the panel cells on the solar panel. As a result of this process, the energy electrons move freely to provide DC energy output from any part of the panel. The schematic of this process is shown in Figure 4.5.

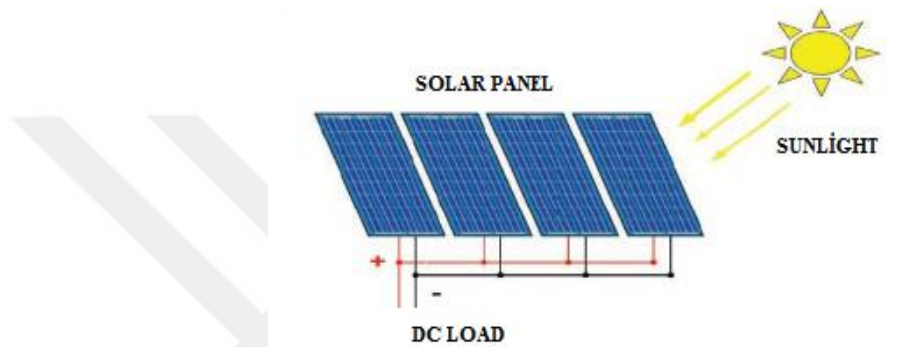


Figure 4.5 Architecture of solar panel (Google, 2018)

4.1.3 Conversion of Solar and Wind Energy into Hybrid System

Parallel electric circuit connection is used to make the wind turbine and solar panel assembled and operate as a hybrid system. Figure 4.6 shows the electronic connection diagram of the hybrid system.

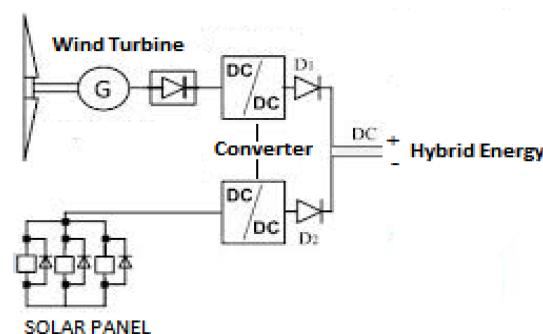


Figure 4.6 Electronic connection diagram of the hybrid system (Google, 2019)

4.1.4 Parallel electrical circuit (parallel connection)

In general, circuits are divided into two types according to the connection type: serial and parallel connection. We used parallel connection method for the installation of the hybrid system on the designed project. The parallel connection is the circuits formed by connecting the elements on the circuit in parallel on two lines. In parallel circuits, unlike serial circuits, the circuit elements are connected parallel to each other between the plus and minus lines, not one after the other on a single line as in the series. That is, when creating a parallel connection on the circuit, the positive (+) terminals of the circuit elements must be connected to the positive terminals and the negative (-) terminals to the negative terminals. As a result, the positive and negative ends of the circuit elements are connected at one point. Figure 4.7 shows the schematic of the parallel connection.

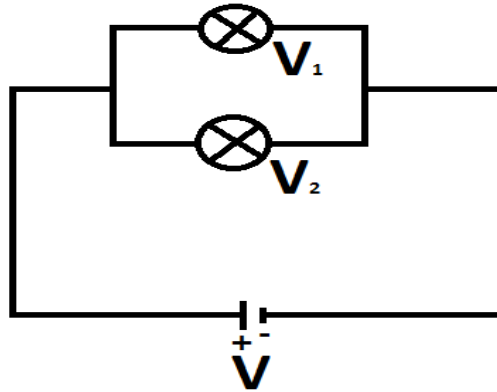


Figure 4.7 Parallel connection

The parallel connection pattern has a number of features. The features mentioned are:

The voltage (volts) of each circuit element in the parallel circuit is equal to the total voltage (Fen Bilimleri).

$$\text{Total Voltage: } U_T = U_1 = U_2 = U_3 \quad (4.1)$$

The current summation is the addition of the currents drawn by every single circuit element.

$$\text{Total Current: } I_T = I_1 + I_2 + I_3 \quad (4.2)$$

More than one circuit element is connected in parallel in the parallel-connected circuit. The resistance of each of these circuit elements can be different, or same. The sum of all resistors (R_T , equivalent resistance) is always smaller than the resistance of the element with the lowest resistance value in the circuit. The total resistance formula is:

$$\text{Total Voltage: } 1/R_T = 1/R_1 + 1/R_2 + 1/R_3 \quad (4.3)$$

The R_T value in this formula gives us total resistance.

4.2 Design Model of Arduino Uno And Components

The entire system is designed with Arduino UNO. Multiple sensors and modules are used on the Arduino. The purpose of these sensors is to determine whether the voltage value obtained from the hybrid system is sufficient or not if we use all components together. Figure 4.8 shows the prototype of the hardware on Arduino Uno.



Figure 4.8 Arduino uno and all components (Personal archive, 2019)

YL-83 rain sensor and DHT11 temperature and humidity sensor are used on Arduino Uno. YL-83 sensor reads an analog value at the sensor output pin when the conductor lines drawn in parallel with each other on the sensor are in contact with water when it rains.

This value is defined as the looting value of rain. DHT11 moisture and warmth sensor is useful to measure moisture and warmth of the air. I2C model 16x2 LCD screen is mounted on Arduino Uno to monitor the data obtained from these sensors and the voltage value of the proposed hybrid system. This screen displays the instantaneous values of the hybrid energy system and the data obtained from the sensors. Also, micro SD circuit board is mounted on Arduino Uno to store the data obtained from the sensors. The data of the whole system is stored in a flash with 8Gb memory placed on the Micro SD circuit board. Communication protocol has been applied to provide remote monitoring and control of the system. The HC-06 Bluetooth module is installed on Arduino Uno to ensure both the control of the system from the central computer and the transfer of the data to the computer and display on the computer. Except for communication and data transfer, the entire circuit control is known to the computer by the HC-06 module and can be switched on and off at any time. The electronic circuit diagram of the connection of sensors and modules on the Arduino platform to the Arduino is shown in Figure 4.9.

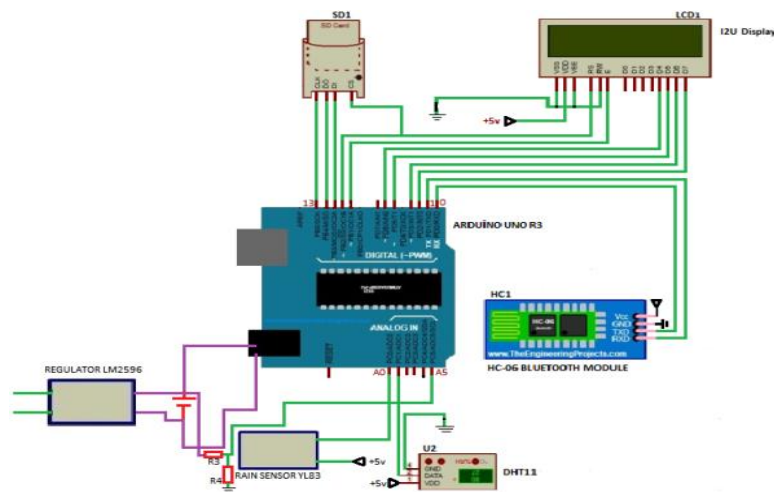


Figure 4.9 Arduino uno and all components connection diagram

Since multiple sensors and modules are mounted on the Arduino Uno, the number of input pins of the Arduino Uno is insufficient.

It is impossible to install all the equipment used on the Arduino Uno due to an insufficient number of cable inputs and outputs on the Arduino. The circuit board is designed to eliminate this problem. The designed circuit board is mounted on the Arduino Uno, increasing the number of cable entry and output sockets on the Arduino so that all hardware can be mounted on the Arduino Uno. The circuit board and Arduino Uno are identical, providing only the principle of increasing the number of inputs and outputs. The designed circuit board and circuit design are shown in Figure 4.10.

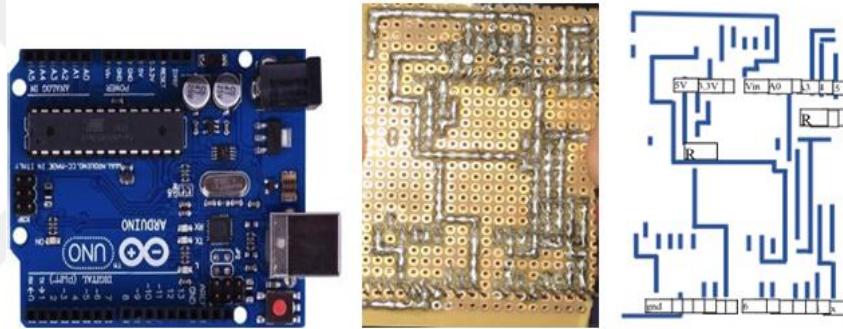


Figure 4.10 Circuit board designed for Arduino Uno R3 (Personal archive, 2019)

4.3 Hybrid Energy Design and Integratiin of Embedded Systems

The electronic circuit design of the project is shown in Figure 4.11.

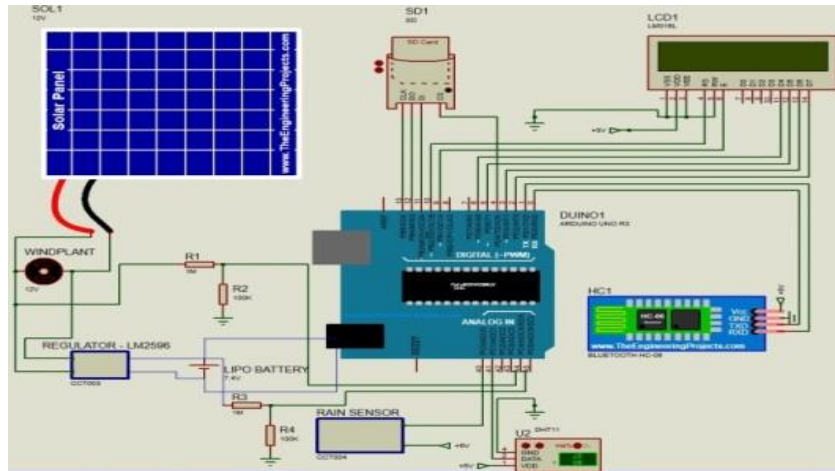


Figure 4.11 Electronic circuit diagram of the project

As seen in the figure, the energy obtained from the hybrid energy system on the project is transferred to a rechargeable battery with a supply value of 7.4V. Since the energy obtained from the hybrid system produces a variable voltage value, it makes it impossible for us to transfer this energy to the battery. If the nutrition value of the battery we use is higher than 7.4V, it causes the battery to deteriorate. To overcome this problem, the LM2596 model Step Down Voltage Regulator is used on the design. Since the voltage value obtained by the hybrid system is variable, the regulator board is used to reduce this voltage value and keep it at a constant value. The hybrid system is connected to the positive input of the regulator and the negative input is connected to the negative input. The output voltage of the regulator is fixed to 7V by adjusting the trim pot on the board. 7V constant energy output from the regulator is transferred to the LiPo battery via Breadboard. The regulator and the LiPo battery are mounted parallel to each other. The energy obtained from the hybrid system has enabled us to charge the battery and to feed the embedded systems.

4.4 Arduino Uno Components Installation

The sensors on the Arduino Uno Platform start to generate data when they operate. The data obtained from the sensors are read by Arduino Uno and transferred to the LCD Display. Temperature, humidity and rain data obtained by the sensors are displayed on the LCD screen. Also, the voltage produced by the hybrid system and

the charge percentage of the LiPo battery is displayed on the LCD screen. The voltage divider method has been applied to display the values of the hybrid system and the LiPo battery on Arduino Uno and display on the LCD screen. Arduino Uno cannot read this value because the voltage we obtain is higher than 5V. The voltage divider method is used to solve this problem. The voltage divider method is used to convert the voltage in the line to a lower voltage. With the software that is used on Arduino Uno, the voltage value that comes to the system is divided and read on the system and multiplied by the same number again to display the actual value on the LCD screen. The electronic circuit is designed and used to ensure that the energy obtained from the hybrid system and the charge status of the LiPo battery are read on the LCD panel.

The design of the circuit is shown in Figure 4.12. By using resistors on the circuit, we ensure that the circuit reads on the Arduino by dividing and reducing the supply voltage.

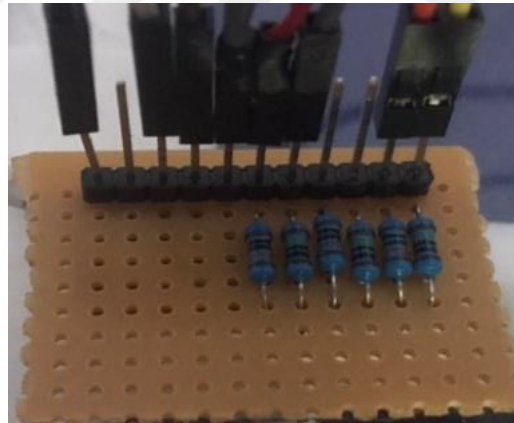


Figure 4.12 Circuit board for reading energy (Personal archive, 2019)

4.4.1 Setup of LCD Panel and Properties

In the designed prototype, the I2U Display panel is used to display all data of the system. This LCD panel consists of 2 lines and displays 16 characters per line. Each

character is displayed on the LCD screen in a 5x7 pixel matrix. There are 16 pins on this LCD screen. After the LCD is mounted on the Arduino Uno, the software needs to be installed on the Arduino to function. This software code is published on the official website of Arduino Uno. The connection of the LCD with Arduino Uno is shown in Figure 4.13 (Vishay, 2018).

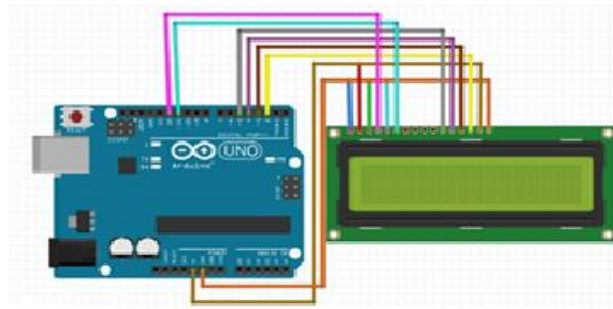


Figure 4.13 Connection of LCD panel on Arduino Uno (Vishay, 2018)

Table 4.1 LCD display and compatible pins for connection of Arduino Uno

I2U LCD Display	Connected pin to Arduino Uno
LCD pin RC	Digital 12
LCD pin D6 (Enable)	Digital 11
LCD pin D7	Digital 9
LCD pin D8	Digital 8
LCD pin D9	Digital 7
LCD pin D10	Digital 6
LCD pin D11	Digital 5
LCD pin D12	Digital 4
LCD pin D13	Digital 3
LCD pin D14	Digital 2
LCD pin R/W	GND
LCD pin D15	GND
LCD pin D15	+5V

4.4.2 Configuration of Rain Sensor

The sensor is mounted to the Arduino Uno on the sensor with a pin that is sent to us. There are 4 input pins on the pin as shown in Figure 4.13. The properties of these pins are shown below (Maker, 2019).

1. VCC: 5V DC
2. GND: ground
3. DO: high/low output
4. AO: analog output

After the sensor is mounted on the Arduino Uno, it is necessary to download and run the sensor software code on the Arduino board to enable the Sensor to operate. The connection diagram of the sensor with Arduino Uno is shown in Figure 4.14

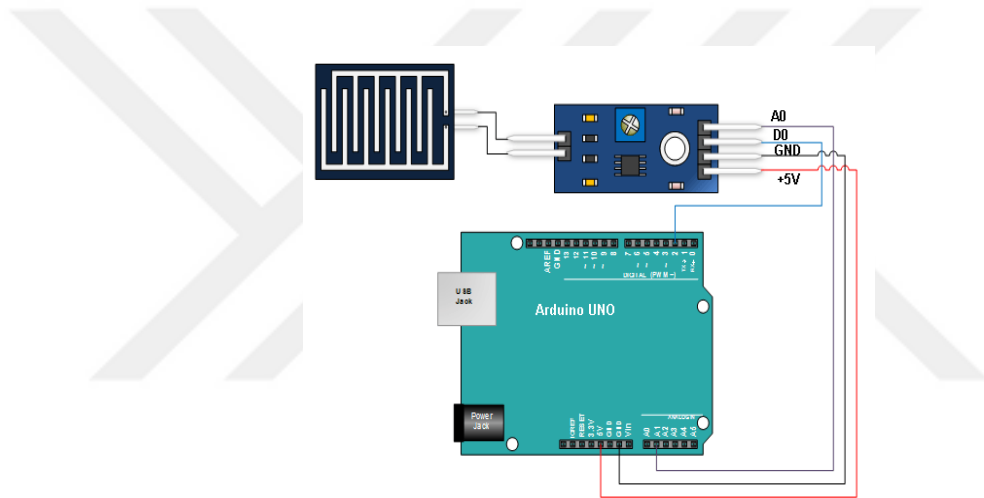


Figure 4.14 Connection of rain sensor on Arduino Uno (Maker, 2019)

Table 4.2 Rain sensor and compatible pins for connection of Arduino Uno

Rain Sensor	Connected pin to Arduino Uno
VCC	+5V Arduino
GND	GND Arduino
DO	2 Arduino
AO	A1 Arduino

4.4.3 Configuration of DHT11 Temperature & Humidity Sensor

The DHT11 humidity and temperature sensor can measure temperature with an error of 2°C between 0 and 50°C and measure humidity with an error of 5% RH between 20-90% RH.

There are 4 pins on the sensor and it connects to Arduino Uno with these pins (Mouser, n.d.). The pins and their features on the sensor are:

1. VDD power supply 3.5~5.5V DC
2. DATA -Outputs both Temperature and Humidity through serial Data
3. NC, empty pin
4. GND ground, the negative power. Connected to the ground of the circuit

The DHT11 sensor has been factory calibrated at the time of manufacture, so it is very simple to set it up. The connection table of the pins on the Arduino Uno of the sensor is shown in Table 4.3 and the connection diagram is shown in Figure 4.15

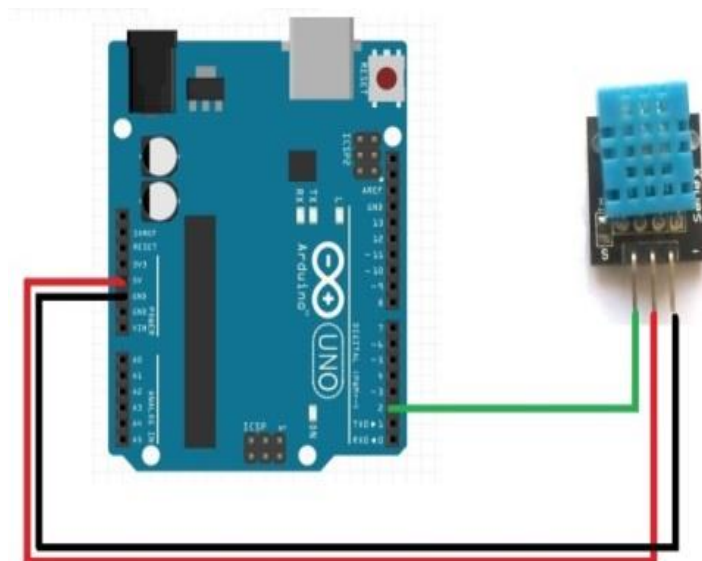


Figure 4.15 Connection of DHT11 temperature & humidity sensor on Arduino Uno (Onsemi, 2008)

Table 4.3 DHT11 module and compatible pins for connection of Arduino Uno

DHT11 module	Connected pin to Arduino Uno
Out DHT11	A0 Arduino
+DHT11	+5V
-DHT11	GND Arduino

4.4.4 Configuration of SD Card MODULE

The SD card module is used in the design to collect and store all data from the sensors. The input pins are directly compatible with the Arduino Uno. There are 6 pins on the SD card module. The characteristics of these pins are as follows (Ada, 2019) :

- 1.VCC** pin supplies power for the module and should be connected to 5V pin on the Arduino.
- 2. GND** should be connected to the ground of Arduino.
- 3.MISO** (Master In Slave Out) is SPI output from the Micro SD Card Module.
- 4. MOSI** (Master Out Slave In) is SPI input to the Micro SD Card Module.
- 5. SCK** (Serial Clock) pin accepts clock pulses which synchronize data transmission generated by Arduino.
- 6. SS** (Slave Select) pin is used by Arduino(Master) to enable and disable specific devices on SPI bus.

The connection of SD card pins on Arduino Uno is shown in Table 4.4 and the connection diagram is given in Figure 4.16.

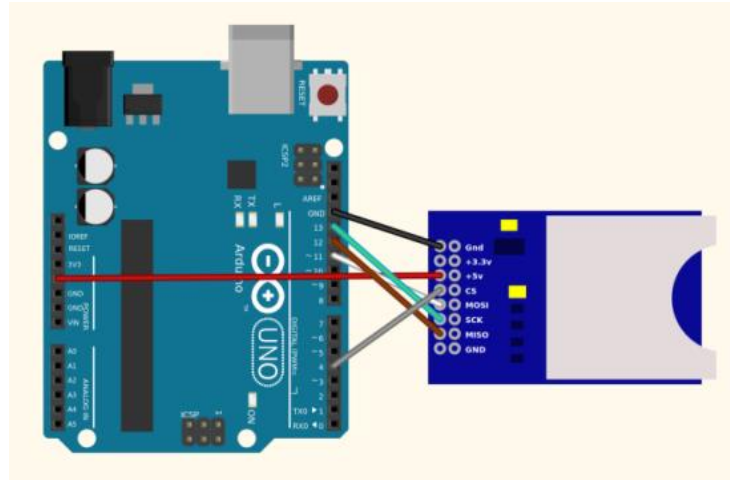


Figure 4.16 Connection of SD card module on Arduino Uno (Ada, 2019)

Table 4.4SD card module and compatible pins to connect Arduino Uno

SD card module	Connected pin to Arduino Uno
VCC	3.3V or 5V (check module's datasheet) Arduino
CS	4 Arduino
MOSI	11 Arduino
CLK	13 Arduino
MISO	12 Arduino
GND	GND Arduino

4.4.5 Configuration of HC-06 Bluetooth Module

HC-06 Bluetooth module is used for communication and data flow in the project. There are 4 pins on the HC-06 Bluetooth module. The module is connected to Arduino Uno with these pins. The connection of the module with Arduino Uno and the connection pins are shown in Figure 4.17 and in Table 4.5 respectively.

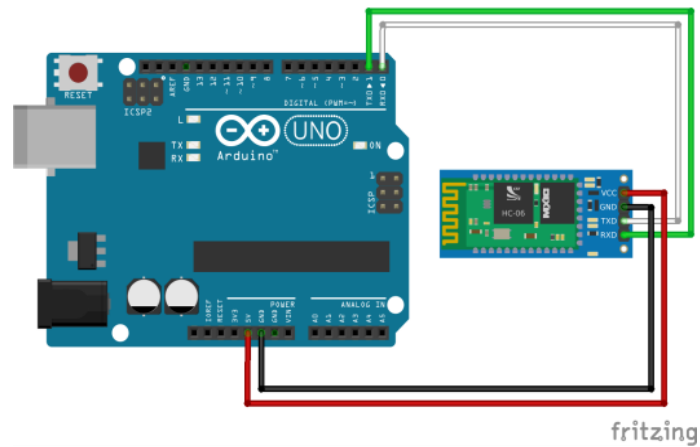


Figure 4.17 HC-06 bluetooth module and arduino Uno connection (HC-06 Bluetooth Modul, 2016)

Table 4.5 HC-06 Bluetooth module and compatible pins for connection of Arduino Uno

HC-06 Bluetooth Module	Connected pin to Arduino Uno
VCC	+5V
GND	GND
RXD	TX
TXD	RX
KEY	-
STATE	-

After the pins are connected to the Arduino Uno card, the code is loaded on the card. The module's baud rate is then set to 9600 via the Arduino sketch software window. After the Bluetooth connection is established on the monitor, an AT command is sent to the Bluetooth module and the Ok response is received. The OK response means that the configuration part of the Bluetooth module has been completed correctly. The following Table 4.6 shows the response of all HC-06 firmware commands:

Table 4.6 AT Commands for HC-06 bluetooth module (HC-06 Bluetooth Modul, 2016)

COMMAND	RESPONSE	COMMENT
AT	OK	Used to verify communication
AT+VERSION	OKlinvorV1.8	The firmware version
AT+NAMExyz	OKsetname	Sets the module name to "xyz"
AT+PIN1234	OKsetPIN	Sets the module PIN to 1234
AT+BAUD1	OK1200	Sets the baud rate to 1200
AT+BAUD2	OK2400	Sets the baud rate to 2400
AT+BAUD3	OK4800	Sets the baud rate to 4800
AT+BAUD4	OK9600	Sets the baud rate to 9600
AT+BAUD5	OK19200	Sets the baud rate to 19200
AT+BAUD6	OK38400	Sets the baud rate to 38400
AT+BAUD7	OK57600	Sets the baud rate to 57600
AT+BAUD8	OK115200	Sets the baud rate to 115200
AT+BAUD9	OK230400	Sets the baud rate to 230400
AT+BAUDA	OK460800	Sets the baud rate to 460800
AT+BAUDB	OK921600	Sets the baud rate to 921600
AT+BAUDC	OK1382400	Sets the baud rate to 1382400

CHAPTER FIVE

EXPERIMENT TEST AND RESULTS

The designed system consists of two parts. In the first part, the hybrid system is designed and energy production is provided. In the other part, the design of the embedded systems was realized by mounting them to the hybrid system and working as a single system. To control the data recording of the designed system on the computer, an interface was created on the program using Matlab program. With the designed interface, functions such as stopping and recording the data of the system can be realized with the computer at any time. This process is done with the Hc-06 Bluetooth module. We manage the operation of the Bluetooth module on the computer and control the components and record the data. The interface used to control the system on the computer is shown in Figure 5.1.

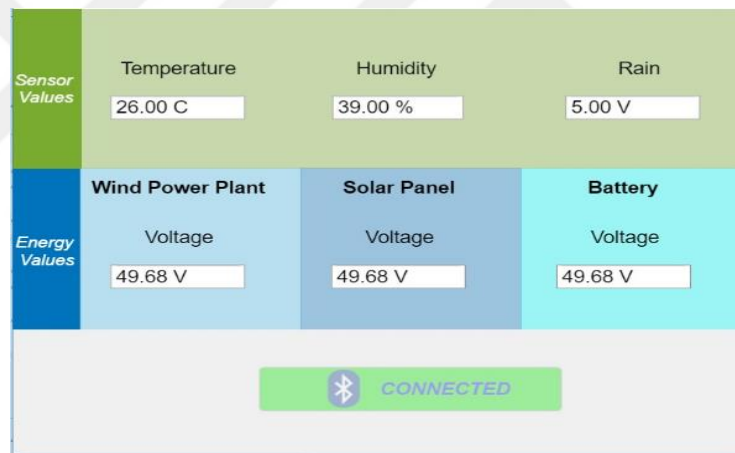


Figure 5.1 Control interface of the system

The design makes it possible to provide an energy intake from the hybrid system in a maximum 7-9 V range and 2 A power. The energy obtained is fixed by means of the regulator to 7 V power and the systems ensures that the LiPo battery is charged. Also, this energy is supplied to the Arduino by applying a 5.5 - 6 V voltage Arduino system and the voltage divider system provides the operation of Arduino and sensors.

The data obtained from the components that are used on the system are recorded on the computer with 10 seconds interval and kept in memory. As a result of

continuous operation from the designed system, 360 data in 1 hour and 8640 data in 24 hours are recorded separately from each component. To check whether the designed project is working properly, 120 data were run at a height of 10 m and 720 data were obtained. Some of the data obtained are shown in Figure 5.2.

DATA - Not Defteri							
Dosya	Düzen	Biçim	Görünüm	Yardım			
Temp. : 32.00	C	Humi. : 6.00 %	Rain : 5.00 v	Batt. : 0.00 v	Generated: 6.72 v		
Temp. : 32.00	C	Humi. : 6.00 %	Rain : 5.00 v	Batt. : 0.00 v	Generated: 5.86 v		
Temp. : 32.00	C	Humi. : 6.00 %	Rain : 5.00 v	Batt. : 0.00 v	Generated: 6.67 v		
Temp. : 32.00	C	Humi. : 6.00 %	Rain : 5.00 v	Batt. : 0.00 v	Generated: 6.67 v		
Temp. : 32.00	C	Humi. : 6.00 %	Rain : 5.00 v	Batt. : 0.00 v	Generated: 6.45 v		
Temp. : 32.00	C	Humi. : 6.00 %	Rain : 5.00 v	Batt. : 0.00 v	Generated: 5.97 v		
Temp. : 34.00	C	Humi. : 16.00 %	Rain : 4.99 v	Batt. : 0.00 v	Generated: 3.33 v		
Temp. : 34.00	C	Humi. : 16.00 %	Rain : 5.00 v	Batt. : 0.00 v	Generated: 1.18 v		
Temp. : 34.00	C	Humi. : 16.00 %	Rain : 5.00 v	Batt. : 0.00 v	Generated: 0.00 v		
Temp. : 33.00	C	Humi. : 5.00 %	Rain : 5.00 v	Batt. : 0.00 v	Generated: 0.00 v		
Temp. : 33.00	C	Humi. : 5.00 %	Rain : 5.00 v	Batt. : 0.00 v	Generated: 4.84 v		
Temp. : 33.00	C	Humi. : 5.00 %	Rain : 5.00 v	Batt. : 0.00 v	Generated: 6.72 v		
Temp. : 32.00	C	Humi. : 6.00 %	Rain : 5.00 v	Batt. : 4.30 v	Generated: 3.60 v		
Temp. : 33.00	C	Humi. : 16.00 %	Rain : 5.00 v	Batt. : 4.30 v	Generated: 4.14 v		
Temp. : 33.00	C	Humi. : 16.00 %	Rain : 5.00 v	Batt. : 4.30 v	Generated: 4.62 v		
Temp. : 32.00	C	Humi. : 6.00 %	Rain : 5.00 v	Batt. : 4.30 v	Generated: 4.78 v		
Temp. : 32.00	C	Humi. : 6.00 %	Rain : 5.00 v	Batt. : 4.30 v	Generated: 5.11 v		
Temp. : 32.00	C	Humi. : 6.00 %	Rain : 5.00 v	Batt. : 4.30 v	Generated: 5.81 v		
Temp. : 33.00	C	Humi. : 16.00 %	Rain : 5.00 v	Batt. : 4.25 v	Generated: 4.03 v		
Temp. : 33.00	C	Humi. : 16.00 %	Rain : 5.00 v	Batt. : 4.30 v	Generated: 3.87 v		
Temp. : 34.00	C	Humi. : 16.00 %	Rain : 5.00 v	Batt. : 4.30 v	Generated: 3.49 v		
Temp. : 32.00	C	Humi. : 6.00 %	Rain : 5.00 v	Batt. : 4.30 v	Generated: 3.12 v		
Temp. : 32.00	C	Humi. : 6.00 %	Rain : 5.00 v	Batt. : 4.30 v	Generated: 5.70 v		
Temp. : 32.00	C	Humi. : 6.00 %	Rain : 5.00 v	Batt. : 4.30 v	Generated: 6.72 v		
Temp. : 32.00	C	Humi. : 6.00 %	Rain : 5.00 v	Batt. : 4.30 v	Generated: 6.56 v		
Temp. : 34.00	C	Humi. : 16.00 %	Rain : 5.00 v	Batt. : 4.25 v	Generated: 4.30 v		
Temp. : 33.00	C	Humi. : 16.00 %	Rain : 5.00 v	Batt. : 4.25 v	Generated: 3.44 v		
Temp. : 32.00	C	Humi. : 6.00 %	Rain : 4.99 v	Batt. : 4.25 v	Generated: 0.00 v		
Temp. : 32.00	C	Humi. : 6.00 %	Rain : 5.00 v	Batt. : 4.30 v	Generated: 0.00 v		
Temp. : 32.00	C	Humi. : 6.00 %	Rain : 5.00 v	Batt. : 4.30 v	Generated: 0.00 v		
Temp. : 34.00	C	Humi. : 16.00 %	Rain : 4.99 v	Batt. : 4.25 v	Generated: 0.11 v		
Temp. : 34.00	C	Humi. : 16.00 %	Rain : 5.00 v	Batt. : 4.25 v	Generated: 2.80 v		
Temp. : 34.00	C	Humi. : 16.00 %	Rain : 5.00 v	Batt. : 4.30 v	Generated: 4.46 v		
Temp. : 33.00	C	Humi. : 5.00 %	Rain : 5.00 v	Batt. : 4.30 v	Generated: 3.82 v		
Temp. : 33.00	C	Humi. : 5.00 %	Rain : 5.00 v	Batt. : 4.30 v	Generated: 3.39 v		
Temp. : 33.00	C	Humi. : 5.00 %	Rain : 5.00 v	Batt. : 4.30 v	Generated: 2.69 v		
Temp. : 33.00	C	Humi. : 5.00 %	Rain : 5.00 v	Batt. : 4.30 v	Generated: 3.23 v		
Temp. : 32.00	C	Humi. : 6.00 %	Rain : 5.00 v	Batt. : 4.30 v	Generated: 3.71 v		
Temp. : 33.00	C	Humi. : 5.00 %	Rain : 5.00 v	Batt. : 4.30 v	Generated: 4.89 v		
Temp. : 33.00	C	Humi. : 5.00 %	Rain : 5.00 v	Batt. : 4.30 v	Generated: 5.11 v		
Temp. : 33.00	C	Humi. : 5.00 %	Rain : 5.00 v	Batt. : 4.30 v	Generated: 5.00 v		
Temp. : 33.00	C	Humi. : 5.00 %	Rain : 5.00 v	Batt. : 4.30 v	Generated: 4.52 v		
Temp. : 33.00	C	Humi. : 5.00 %	Rain : 5.00 v	Batt. : 4.30 v	Generated: 4.68 v		
Temp. : 33.00	C	Humi. : 5.00 %	Rain : 5.00 v	Batt. : 4.30 v	Generated: 5.38 v		
Temp. : 35.00	C	Humi. : 15.00 %	Rain : 1.20 v	Batt. : 4.25 v	Generated: 6.08 v		
Temp. : 34.00	C	Humi. : 16.00 %	Rain : 1.54 v	Batt. : 4.30 v	Generated: 6.18 v		
Temp. : 33.00	C	Humi. : 5.00 %	Rain : 3.40 v	Batt. : 4.30 v	Generated: 6.18 v		
Temp. : 32.00	C	Humi. : 6.00 %	Rain : 4.82 v	Batt. : 4.30 v	Generated: 6.72 v		
Temp. : 32.00	C	Humi. : 6.00 %	Rain : 5.00 v	Batt. : 4.30 v	Generated: 6.72 v		
Temp. : 34.00	C	Humi. : 16.00 %	Rain : 0.69 v	Batt. : 4.30 v	Generated: 6.72 v		

Figure 5.2 Data obtained from sensors

At the 60th minute of the project, a table was formed by transferring 360 data obtained from hybrid data, sensors and LiPo battery to the perfect program. Then, the data is drawn by graph analysis. The graphic figure drawn is shown in Figure 5.3

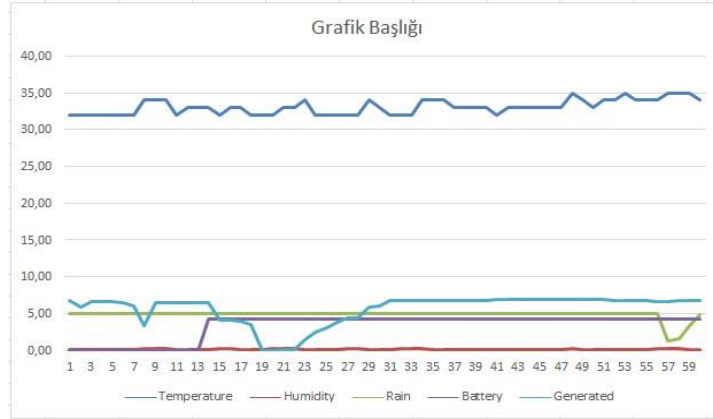


Figure 5.3 Graphical analysis of data

Also, the project has been simulated and the successful results of the project and the accuracy of the data obtained have been determined. The simulation of the project was realized by using the Proteus program. The actual values of the components were used on the program and accurate results were obtained. The simulation performed on the program is shown in Figure 5.4

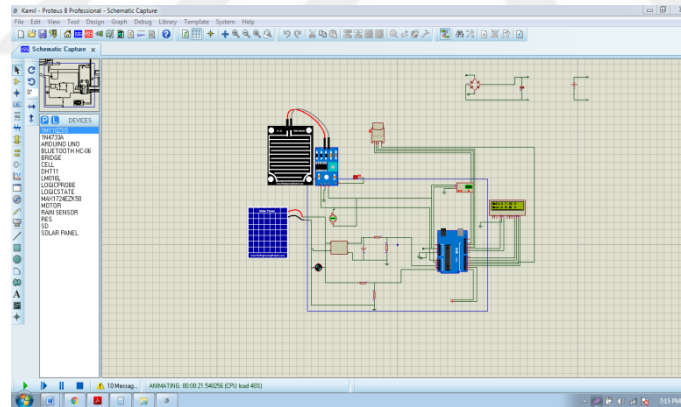


Figure 5.4 Project simulation

As shown in the figure of the simulated project, the solar cell and wind turbine are connected to each other in parallel so that the hybrid system was formed and the design of the electronic circuit drawing of the connections between the components are established by connecting the actual values given and separate data obtained on the project by obtaining the results of separate LCD printed on the panel. The data obtained from the sensors and displayed on the LCD panel is shown in Figure 5.5.

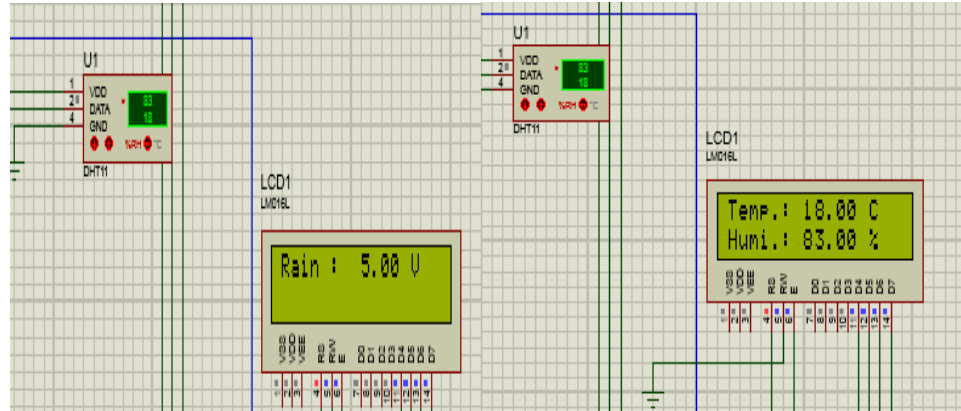


Figure 5.5 Image of data obtained from sensors in simulation

Apart from the data obtained from the sensors on the simulation, the hybrid system is producing as well as the actual project and the charge value of the LiPo battery is recorded and monitored on the LCD panel

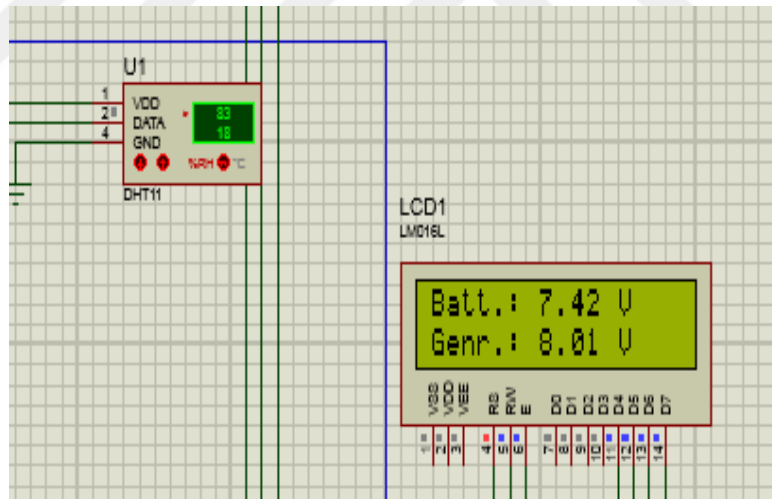


Figure 5.6 Image of data obtained from hybrid system and battery in simulation

By demonstrating the proposed project and simulating it on the Proteus program, the results have been obtained and the working accuracy of the project has been proved.

CHAPTER SIX

CONCLUSIONS

The most important objective of the study is to create a design that uses a renewable energy source for embedded operating systems and to use this design on the system. The second objective is to ensure energy production continuity for the system that we use by saving energy and to obtain exact results from the sensors and modules we use on the system. In this project, hybrid energy system was established by using more than one energy source. Furthermore, the energy obtained from this system and Arduino Uno and the moisture, temperature sensor was installed and the data obtained from the sensor were transferred to central system via by bluetooth device placed on the Arduino and the determinations were made by communicating. In order to make these determinations, different methods have been combined and used as a single system. It has been proposed to use the Hybrid System, which is designed to ensure accurate, reliable and continuous operation continuity of embedded systems and to obtain precise results from the sensors being used. Today, Turkey's foreign dependency rate is 72% in the energy field. For these reasons, Turkey is carrying out studies on fossil energy resources exploration work on the one hand and also struggle to determine the potential of renewable energy sources to reduce this rate. In our country, use of renewable energy sources other than our hydraulic resources was also insufficient. Our energy potential, especially wind and sun, should be determined in a healthy manner and parallel to this, the share of our clean and renewable resources in total energy consumption should be increased and used on the technology devices used in our daily lives. In the study we have proposed, to create methods that use renewable energy sources for embedded systems, which are present in most of the smart devices we use today, and to save energy by applying them on these operating systems. The demo of the proposed system was designed and run and the data obtained from all components were analyzed and the graphical analysis of the data was performed by proving that the mechanism was working in an appropriate way.

In addition, the proposed system was simulated and the way of working was

followed and tested. By designing this method, firstly energy saving and then the embedded systems are provided to work continuously in all areas and in all climates. In future, it is planned to perform intelligent system installation following the sun and wind on the hybrid system and to control the entire system and to monitor and control the data obtained over the internet network.



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