Design And Implement microcontroller for hybrid renewable energy system

Qais Abu Aisheh, Alina Adamova, Kwizera A. Ngiruwonsanga, Ahmad Al Rawashdeh, Abdal R. Nofal and Rami Aljoulani

Abstract *– This research focuses on the design and implementation of a microcontroller-based controller for a hybrid renewable energy system. The controller aims to enhance the operational efficiency and functionality of an existing renewable energy system by providing essential features such as charge control, voltage and current measurements, wind speed measurement, and temperature monitoring. The system incorporates an LCD display and a programmed software for data retrieval. The microcontroller-based controller decides to draw voltage from either the solar panel array or the wind turbine, depending on the power production. The proposed system also includes a USB connection for interfacing with a computer and a user-friendly interface for monitoring system performance and analyzing data. The research draws on important findings from energy engineering, electrical engineering, and computer engineering. The implementation of this project involved teamwork and faced challenges related to component scarcity and access, hindering the application of the maximum power point tracking technique.*

Index Terms *– Microcontroller-based controller, Hybrid renewable energy system, Charge control, Voltage measurement, Current measurement, Wind speed measurement, Temperature monitoring, Operational efficiency, Functionality enhancement, Solar panel system, Wind power system, Battery charging, Battery life extension, Charge controller, Arduino Uno, Maximum Power Point Tracking (MPPT), I-V Curve, Photovoltaic panel, Pn junction, Temperature sensor (DHT11), LCD display, Potentiometer, Arduino programming, Serial connection, User interface, Data monitoring, Data analysis, Graphs and Excel sheets, Flask application, SQLite database, HTML, CSS, JavaScript, Login page, Data management, User management, User roles, Permissions, Data visualization, Plotly library, SQLAlchemy library.*

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1. INTRODUCTION

The research outlined in this report focuses on the design and implementation of a microcontroller-based controller for a hybrid renewable energy system. Renewable energy systems have emerged as a viable alternative to traditional sources of energy due to their environmentally-friendly nature and cost-effectiveness. This controller will be part of an existing renewable energy system currently installed on the roof of the Technopark building (Girne American University's engineering department building) , and it is designed to enhance its operational efficiency and functionality by providing a range of essential features such as charge control, voltage and current measurements, wind speed measurement, and temperature monitoring. As demonstrated by previous research, the microcontroller is a highly effective tool for controlling renewable energy systems.

In addition to the microcontroller, this system will incorporate an LCD display and a programmed software that can retrieve data accumulated by the microcontroller. This graduation project builds on the findings of previous studies, which have shown that renewable energy systems can be controlled effectively using a microcontroller-based controller. To further improve the overall efficiency of the system under different climatic conditions and to ensure optimal utilization of resources, this microcontroller will decide to take voltage either from the solar panel array or the wind turbine, depending on which source is producing more power. The proposed system also includes a USB connection for interfacing with a computer and an interface to be designed for user convenience. our user interface will allow users to monitor system performance, analyze data, and create graphs and Excel sheets.

While this project will focus on the development and implementation of a microcontroller-based controller for a hybrid renewable energy system, it draws on important research from various disciplines including energy engineering, electrical engineering and computer engineering.

2. Literature review

Renewable energy sources have become a popular alternative electrical energy source where power generation is difficult to achieve. The production of solar and wind energy has dramatically expanded during the past several years.

In this project, our team worked on designing a microcontroller-based charge controller circuit for hybrid renewable energy system which combines both solar panel and wind turbine generator. This hybrid renewable system is used to improve the overall efficiency of the system under different climatic conditions and to make usage of sources more practical and effective.

The focus in this project was mainly to avoid the discharging and overcharging of the battery. By maintaining specific conditions to implement this method increasing life of the battery was another objective in this project.

This project also includes a USB connection for interfacing with a computer and an interface is designed for user convenience. The user interface will allow users to monitor system performance, analyze data, and create graphs.

In this project to develop and implement this system, research is being done by various disciplines including energy engineering, electrical engineering and computer engineering.

Advantages	Disadvantages
Providing a sustainable and stable energy source.	High initial costs due to the installation of more than one power system.
Environmentally friendly, where harmful emissions are less or absent in the case of renewable hybrid energy systems	High preventive maintenance costs.
Low operating costs in the absence of dependence on fossil fuels.	

Table. 1: Advantages and disadvantages of hybrid energy systems

2.1. solar panel system

Today, converting solar energy into heat and electricity is a common practice. In 2050, solar array installations will supply around 45% of the world's energy demand, according to a comparison study on energy consumption published by the International Energy Agency (IEA).

In industrial applications, solar thermal energy has been proven to be very well-liked. Fig **1** illustrates an off-grid system using solar thermal energy as an alternative to producing power, handling chemicals, or even space heating.

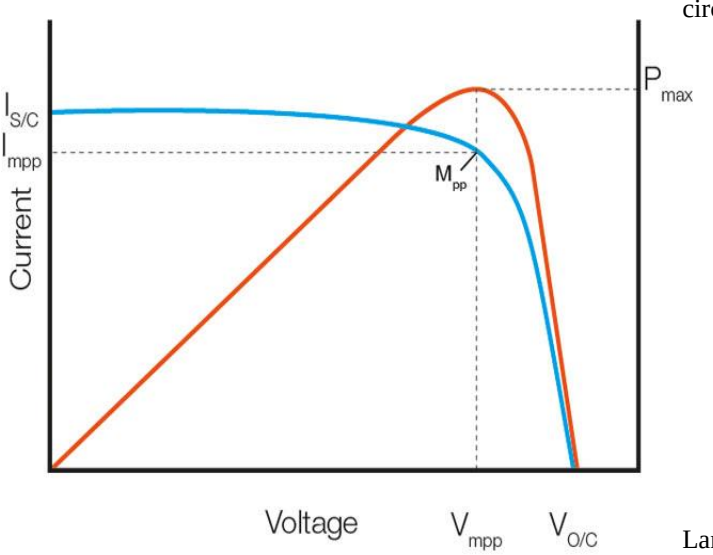

Fig. 1: I-V curve

In order to operate at its best, the BP 365 type photovoltaic panel is intended to be placed with its south side facing up (in the Northern Hemisphere).

Depending on the strength of the solar radiation, it can produce up to 65W of 12V DC electricity into a battery when exposed to sunshine.

PV modules are monocrystalline silicon solar cells which are black in color and very uniform in appearance, which indicates their high purity.

Monocrystalline silicon panels are the most common and most efficient compared to all the solar panels that are used in our project today, as the efficiency rate is usually in the range of 15-20%.

The characteristics of the BP Solar crystalline PV module are given table 2.

Characteristic	Value
Module Nominal Voltage	12V
Module rated power	65W
Module open circuit voltage	22.1V
Module short circuit current	3.99A
Module voltage at max power	17.6V
Module current at max power	3.69A
Length	1111mm
Width	502mm
Height	50mm

Table. 2: The characteristics of the BP Solar crystalline PV module

The Photoelectric Effect is the fundamental theory underlying how each PV cell functions. According to this theory, when a photon particle strikes a PV cell, the semiconductor's excited electrons jump from the valence band to the conduction band and become free to move.

Movement of electrons creates positive and negative terminals and also creates potential difference across these two terminals.

When an external circuit is connected between these terminals an electric current start flowing through the circuit.

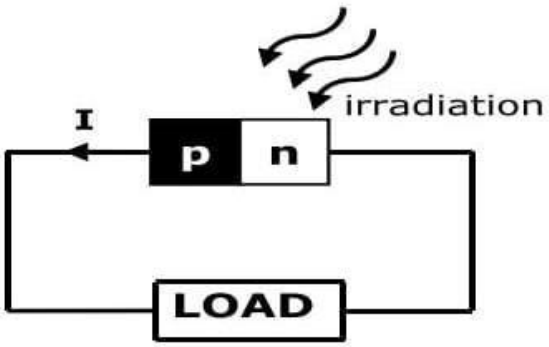

Fig. 2: Pn junction [1]

2.2 Wind Power System

Large-scale research and development initiatives were launched in response to the 1973 energy crisis with the goal of discovering alternatives to the finite fossil fuel stocks. Particular focus was placed on wind energy as a sustainable and eco-friendly energy alternative, alongside photovoltaic, solar, hydroelectric, biomass, and other resources. The last 10 years have seen particularly impressive technological advancements, and as a result of steadily increasing competitiveness, wind power has become a widely used energy source in many nations throughout the world [2].

A wind turbine typically consists of a gearbox-generator set housed inside the nacelle, together with a set of rotor blades revolving around a hub. The diagram below (Fig 3) illustrates the fundamental parts of a wind turbine system.

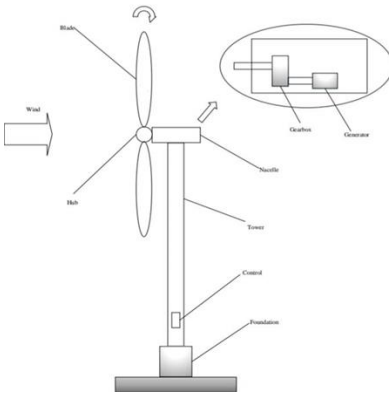

Fig. 3: parts of a wind turbine system [3]

Based on axes the wind turbines are categorized into two kinds: the vertical axis wind turbine and the horizontal axis wind turbine [3]

Advantages	disadvantages
1.Wind is a dependable and limitless source of renewable energy.	1.Because the amount of electricity produced by wind is influenced by the wind's speed and direction, it can be unpredictable.
2.Cost-effective wind energy is available, and costs are still falling.	2. The visual appeal of the terrain may be impacted by wind farms.
3.When wind energy is used in place of fossil fuels, carbon emissions are reduced.	3. The habitats of birds and marine life can be harmed by wind turbines.
4.When the turbines are operating, there are few operating expenses.	4. Building wind farms can be expensive
5. Offshore wind farms can benefit from offshore wind flow without obstructing the view of the surrounding area.	

Table. 3: Advantages and disadvantages of wind turbines system

2.3 CHARGING THE BATTERY

In addition to the generators, a battery is a storage device that utilizes the excess power created to power the load when it is needed. The battery bank and a common DC with a constant voltage are both connected to the PV and wind energy systems.

This constant voltage DC is used for all power transfers, including those from the generator to the battery bank, the generator to the load, and the battery bank to the load.

As the power flow associated with the battery is not unidirectional, a bidirectional converter is needed to charge and/or discharge the battery in case of excess and/or deficit of power respectively [4]. A battery stores electricity produced by a solar and wind electric system.

When the energy sources (solar and wind energy) are abundant, the generated power willpower, will be supplied to feed the battery until it's fully charged and then will satisfy the load demand.

On the contrary, when energy sources are poor, the battery will supply load requirements until its storage is depleted. So, batteries will be used to even out irregularities in the solar and wind power distributions.

Rated voltage: the nominal voltage at which the battery is supposed to operate equal to 12v.

Capacity: the amount of charge that the battery can deliver at the rated voltage, we have two batteries. Each is a minimum capacity of 70 Ampere hours (Ah), the two batteries are to be connected in PARALLEL as it is required to achieve a capacity of 140Ah 12V DC

C-rate: is a measure of the rate of discharge of the battery relative to its capacity. (C20)

To ensure long life batteries must not be over-charged or excessively discharged.

2.4 charge controller

In order to maximize the efficiency and performance of renewable energy systems, various charge controllers have been proposed and developed. One common type is the pulse width modulation (PWM) charge controller, which is widely used for solar power systems. PWM controllers work by switching the power from the solar panels to the batteries in a series of pulses, which helps to regulate the charging voltage and prevent overcharging.

Recently, microcontroller-based charge controllers have gained popularity due to their low cost, high flexibility and programmability. Arduino is one of the most commonly used microcontrollers for charge controllers in renewable energy systems. Arduino-based charge controllers can be programmed to implement various control algorithms, including MPPT algorithms, and can also be used to monitor the system parameters such as voltage, current and temperature.

2.5 Arduino uno

Arduino uno is a small and low-cost microcontroller board that has gained popularity for use in various control applications. In hybrid energy systems, Arduino uno can be used to control the charging and discharging of batteries to improve the efficiency and performance of the system.

Similarly, (2019) proposed a microcontroller-based charge controller for a hybrid energy system that includes solar and wind power sources. The authors used Arduino uno to implement a MPPT algorithm and control the charging and discharging of the batteries. also proposed a control algorithm that adjusts the charging current based on the battery's state of charge (SOC) to prevent overcharging or undercharging. The experimental results showed that the proposed approach can improve the efficiency and prolong the battery life of the system.

In recent years, a considerable amount of literature has been published about the Arduino Uno, covering its features, applications, and programming techniques. One of the most significant advantages of the Arduino Uno is its ease of use and low cost, making it accessible to beginners and hobbyists. The board is equipped with a powerful Atmel AVR microcontroller, which provides a range of input/output (I/O) ports that can be used to connect sensors, actuators, and other devices. Several studies have explored the use of the Arduino Uno in various applications, such as robotics, home automation, and environmental monitoring. For instance, (Russo et al., 2018) developed an autonomous vehicle using an Arduino Uno board and a range of sensors to detect obstacles and navigate around them. Similarly, (Ahmed et al., 2019) developed a smart home system using the Arduino Uno, which allows users to control various home appliances remotely.

2.6 MPPT

Maximum Power Point Tracking is a technique used in solar photovoltaic systems in order to optimize the efficiency and output of the solar panels. The purpose of this technique is to maximize the power obtained from the solar panels by dynamically adjusting the operating parameters.

Solar panels have a characteristic named I-V Curve. This curve represents the relationship between the current and the voltage output at different levels of solar irradiance and temperature. This curve has a unique point called maximum power point (MPP)where the panel operates at its highest efficiency and produces maximum power. By continuously tracking the MPP, MPPT enables the solar system to operate at its highest efficiency under varying conditions, improving the energy efficiency therefore the energy produced in the system.

In MPPT, there are components called MOSFETS. MOSFETS have different applications. they are good for switching applications due to their fast-switching speeds and low resistance. MPPT controllers use MOSFETS as switches to control the flow of current from the solar panel to the load or battery. MOSFETS are being preferred more over other transistors for a lot of reasons, one of them is their high switching speed ensuring efficiency compared to other transistors.

Due to low availability of this component the implementation of it in this circuit could not be done. Therefore, PWM technique is preferred to be carried out instead.

2.7 Available Resources in North Cyprus

Alternative energy solutions, which are ideal for Small Islands in the Mediterranean Sea, may be the answer for North Cyprus. In North Cyprus, the annual average global horizontal irradiation ranges from 1900 kWh/m2 to 2100 kWh/m2, and the air temperature is between 20 and 24 °C. This abundance of solar energy can produce energy for the island, and solar panel systems are regarded as the most suitable systems to supply electricity to the consumers. [5]

Wind turbine Generally, winds blow from different directions in North Cyprus according to the topographical characteristics of the regions. However, the prevailing wind direction throughout Northern Cyprus is west (W), and the average annual wind speed is 4.5 m/s [6].

3. Methodology

In this project the aim was to use two renewable sources (Wind and Solar) as an input to charge the battery. In this project instead of using the sources by themselves two potentiometers and an adaptor were used to supply the voltage to the circuit. Difficulties in finding the correct battery for the circuit were solved by using an adaptor as well.

There is a selector switch in the charge controller circuit to select the source from which voltage will be taken from. The selector will be choosing the source according to which source will be having the most voltage.

Then after selecting the source that supplies more voltage according to the other one its voltage will be calculated using the voltage sensor. After measuring the voltage coming from the source the data will be sent to the microcontroller which will choose if the voltage from the source is enough to supply the battery or not. If the voltage is sufficient enough to supply the battery, the relay switch to the battery will be opened.

The Next Voltage sensor in the circuit will check the voltage of the battery. The voltage of the battery has to be above 7V in order to charge the load. In this situation the relay switch 2 will be opened to the load by the microcontroller. A current sensor is situated before the load to measure current to calculate the power.

In addition, there is also a Voltage Regulator of 5V to supply the microcontroller. The Voltage regulator gets the voltage from the battery and it feeds the microcontroller. The reason it is regulated to 5V is that because the microcontroller used in this circuit is working with 5V not more or less. By supplying the voltage to the microcontroller, the microcontroller will supply the energy to the sensors in this circuit such as; Voltage sensors, Current Sensor and temperature sensor. The LCD Display is also powered by the microcontroller as well. Using the colored LCD Display, the information such as; wind speed, power, battery voltage, load current and ambient temperature will be displayed via this component. Proteus a software used for electronic design automation has been used to simulation our circuit. Fig 4 shows a block diagram of our hybrid renewable system.

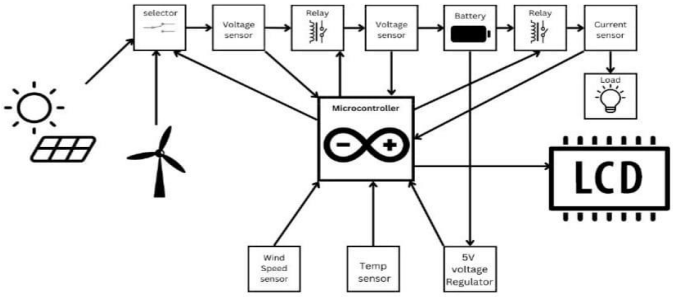

Fig. 4: The Block Diagram

3.1 Components

3.1.1 Relay Switch

A relay switch of 12V is used in this circuit. They are electromechanical devices that use an electromagnet to operate a pair of movable contacts from an open position to a closed position. It can handle switching operations, allowing it to control the flow of electrical current in a circuit. It can be used to open or close circuits, providing a means to control the activation or deactivation of components or devices in the circuit.

The OMISS212D relay switch is used in this circuit it is designed to be compact, making it suitable for use in small circuits with limited space. Its small size allows for easy integration into electronic devices or circuit boards. The relay switch's specifications should be considered to ensure that it can handle the current and load requirements of the specific circuit.

3.1.2 Resistors

Resistors of 100kΩ, 20kΩ are included in this circuit. They are electrical components that limits or regulates the flow of electrical current in the circuit. They are also used to provide a specific voltage for an active device such as transistor. In this circuit they are used in voltage divider operation to help measure the voltages of different components in the circuit.

3.1.3 Transistors

These devices are miniature semiconductors that regulate or control the current or voltage flow. Also, their application includes being a switch or gate.
BC547 npn Transistor is used in this system. Because it is widely available and easily accessible.

The reason the npn transistor is used over pnp transistor is because the “N” substrate can transfer electrons significantly faster than “P” type substrates can transport positive electron holes. Resulting in higher switching speed. It is usually used for quick switching and pulse-width modulation (PWM). The PWM (Pulse-Width Modulation) is a signal with a variable duty cycle. As soon as Arduino sends the voltage a signal (in form of voltage and current) will be received by the base of BJT which in turn allows electric current to pass from collector to emitter turning on the relay.

3.1.4 Capacitors

Capacitor of value 220nF is used in this circuit. They are used in voltage regulator part in this circuit. They are placed in input and output terminals of voltage regulator. Their operations include; supplying additional load during sudden load changes, provides stability, suppressing rapid voltage changes and prevent self-oscillations.

3.1.5 Diode

The diode used in this circuit is 1N4007. It’s often used for rectification of voltage, protection from the wrong polarity, different projects with breadboard etc. Max. voltage that this diode can endure is 1000V and max. current it can carry out is 30A.
In this circuit it is used mainly to ensure one-way current flow to protect the components of this circuit.

3.1.6 temperature sensor

DHT11 is a low-cost digital sensor for sensing temperature and humidity. This sensor can be easily interfaced with any micro-controller such as Arduino, Raspberry Pi etc. to measure humidity and temperature instantaneously.

The temperature range of DHT11 is from 0 to 50 degree Celsius with a 2-degree accuracy. Humidity range of this sensor is from 20 to 80% with 5% accuracy. The sampling rate of this sensor is 1Hz.i.e., it gives one reading for every second. DHT11 is small in size with operating voltage from 3 to 5 volts. The maximum current used while measuring is 2.5mA.

DHT11 sensor has four pins- VCC, GND, Data Pin and a not connected pin. A pull-up resistor of 5k to 10k ohms is provided for communication between sensor and micro-controller.

3.1.7 LCD Display

160x120 LCD Display component is being used in this circuit. This LCD character display is a unique type of display that can only output individual ASCII characters with fixed size. Using these individual characters, a text can be formed.

3.1.8 Potentiometer

A potentiometer is a type of position sensor used to measure displacement in any direction. Linear potentiometers linearly measure displacement and rotary potentiometers measure rotational displacement.
In this circuit the potentiometers are used to replace the sources and therefore they are used to supply the circuit the voltage.

3.1.9 V Adaptor

To supply this circuit the energy 9V Adaptor is used. The reason this amount is being chosen because they are common in market

3.1.10 Arduino Uno

Operations of this circuit are being controlled by the microcontroller (ATMEGA 328). The ATmega328P has 32KB of Flash memory, 2KB of SRAM (Static Random Access Memory) and 1KB of EEPROM (Electrically Erasable Programmable Read-Only Memory) for data storage. It has a total of 23 I/O pins, which can be configured as digital input/output.

4. Arduino code & serial connection

4.1 programming the Arduino

This chapter outlines the development and implementation of an Arduino-based system for monitoring and controlling a power source.

4.1.1 Introduction

Power sources are essential components in modern society, and the ability to monitor and control them is critical for both safety and efficiency. To address this need, we developed an Arduino-based system that employs various sensors and algorithms to monitor and control a power source. The system utilizes the Arduino Uno open source platform and various sensors to collect data on temperature, incoming voltage, and battery voltage.

Furthermore, an algorithm was developed to control the power source and protect the battery from overcharging or discharging. the algorithm can be found in the appendix. and the LCD display was programmed using the TFT library, which allowed for greater flexibility than other libraries.

The Arduino Uno, equipped with sets of digital and analog inputs/outputs, was used to calculate temperature and send data to the computer. The microprocessor, an ATmega chip, was utilized as the main board to perform calculations and initializations. Additionally, the system was designed with a user-friendly interface that displays real-time data on an LCD screen and states of the battery whether it is charging, discharging or non.

Fig 5 shows the overall flowchart of the system which is the decision tree for the Arduino.

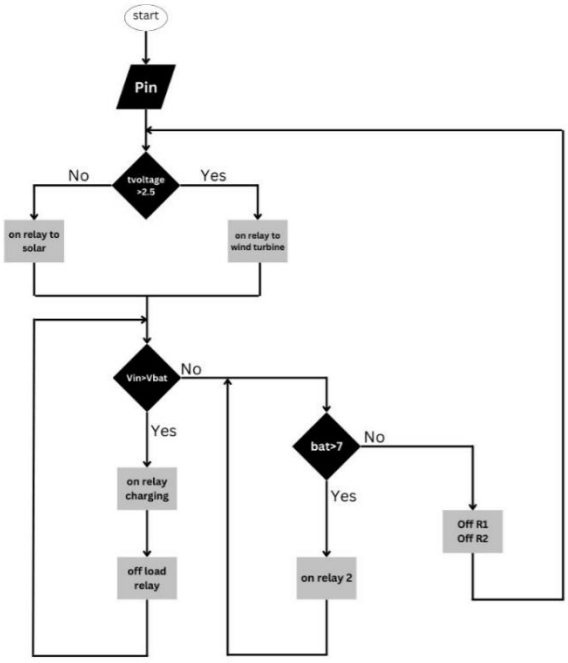

Fig. 5: Arduino code flowchart

4.2 Serial connection

At the beginning of the project, we were tasked to connect the arduino with the computer through a usb cable, in order to do so, we programed a python application that would listen to the serial port and wait for data, after data is recieved it will be decoded, set to variables, and inserted into database.

For the serial connection to work on python, we used pyserial, also sqlite3 for connecting to the database, datetime to get the timestamp.

The Arduino will send the data that has been collected from variables calculated in the algorithm, it will be separeted by whitespace so we can split it with split() function, and with newlines to the new recieved data from the system, over an interval of 1000 ms. New line would also by stripped using strip() function.

We used "Latin-1" for decoding because some values are sent to the serial connection as a packet that is not integers, they contain characters, so by using Latin-1 the whole packet would end up in one latin character, then we trim it from the first line with an if statement.

We assigned the numbers to variables using "map" function that will map through the numbers and asssign the whole numbers until it encounters a whitespace, then the next number will be assinged to the next variable in line. This is done inside a while loop.

we also used an if else to check from where the power is coming, solar or wind, so the graphs and data would be displayed correctly.

finally inserting the data will be done with sqlite3 library, after connecting the application with the database, and doing cursor.execute functions to insert the data, and then conn.commit()

5. User Interface

This chapter provides a comprehensive guide to the Flask application for data monitoring and management in our graduation project Designing and Implementing microcontroller for hybrid renewable energy system with a user interface to display, monitor and manage data.

5.1 Introduction

The Flask application for data monitoring and management provides a user-friendly interface for managing data stored in an SQLite database. Users can access various routes to perform tasks such as logging in, visualizing data, managing users and databases, updating the database with random values for testing, retrieving data from the database through API endpoints, and generating Excel spreadsheet files.

5.1.1 Technology Stack

The Flask application is built on a technology stack that includes SQLite, HTML, CSS, JavaScript and Flask. The main framework was Flask, a lightweight web framework written in Python. Flask provides functionality to serve static and dynamic webpages using data stored in SQLite databases.

5.1.2 Architecture

The Flask application for data monitoring and management follows a client-server architecture. Users access the application through a web browser, which sends requests to

the server. The server then responds to the requests by executing the appropriate code and returning a response.

5.1.3 User Interface

The user interface of the Flask application includes various routes for different pages such as login, wind, users_panel, data_panel and more. These routes are responsible for rendering templates, displaying data visualizations, managing users and databases, and generating Excel spreadsheet files.

5.1.4 Login page

The login page of the Flask application is rendered using the login.html template. This page allows users to enter their username and password to authenticate themselves. Upon successful authentication, users are redirected to the wind route, which is a data visualization page.

5.1.5 Data Management and User Management

In addition to data visualization, the Flask application also offers user and data management features.
The data management features include the update_database route, which is responsible for updating the database with random values for testing purposes. The get_data route provides an API endpoint for retrieving data from the database in JSON format, while the generate_spreadsheet route generates an Excel spreadsheet file containing data from the database. On the other hand, user management features include routes such as users_panel and data_panel. These routes enable system administrators to manage users and databases. The Flask framework used in the data monitoring and management application offers several key features that make it an ideal choice for this project.

5.2 Login and Security Functionality

The purpose of this section is to outline the login and security functionality implemented in our web application. The login and security functionality implemented in our web application involves the use of the POST method to retrieve user input data on the /login route. Once the user submits their login credentials, our server queries the database to authenticate their username and password. In order to ensure the security of user information, we have implemented several measures. For example, we use session management to store and retrieve user authentication data securely. This functionality ensures that user authentication data is only accessible to the authorized recipient and secure from unauthorized access or tampering. in addition, we also used a secret key for signing the session cookies to prevent cookie spoofing and strengthen the encryption of session data.

5.3 User Roles and Permissions in Flask Application

User roles and permissions play a crucial role in building secure web applications. By controlling access to different parts of the web application based on the roles assigned to each user, developers can ensure that sensitive information and functionalities are only available to authorized users.

The Flask application implements two user roles, admin and regular users. Users assigned the admin role have administrative privileges, allowing them to access additional functionalities and actions such as creating and deleting user accounts. Moreover, they have access to the "users_panel" and "data_panel" routes where they can manage user accounts and data records. In contrast, regular users do not have administrative privileges. They can log in to the system using their username and password, and have access to the main functionalities of the application such as viewing data records and generating spreadsheets.

5.4 Data Visualization

The Flask web application with plotly data visualization is a project that showcases the capability of using Flask, Plotly, and SQLAlchemy libraries to create visually appealing and interactive data visualizations. This project is a great example of how Flask can be used to create web applications that manage databases and provide data visualization functionality with the help of Plotly, a powerful graphing library that allows for the creation of professional-looking charts and graphs. The website we built displays the data and then draws a graph based on the data given. Fig 5.1 is a showcase of how the data of the battery is displayed in our website. And Fig 5.2 is a showcase of how the data of the current and voltage from the solar panel are graphed in our website.

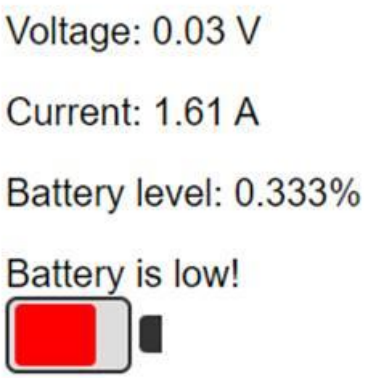

Fig. 6: battery data display from the UI

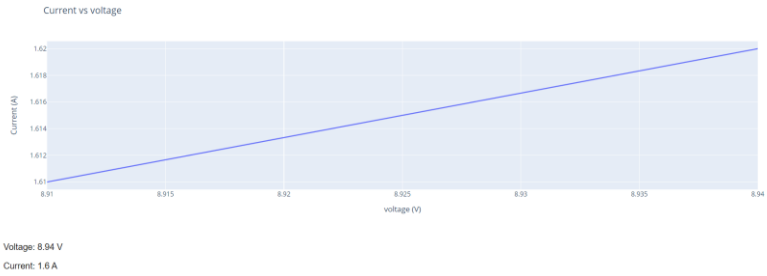

Fig. 7: an example of a graph

5.5 Database

Field Name	Data Type	Constraint	Description	Example
id	INTEGER	NOT NULL	Unique identifier	1
time	DATETIME	-	Timestamp	2023-05-21 10:30:00
windspeed	FLOAT	-	Wind speed	12.5
tcurrent	FLOAT	-	Wind Current	25.7
tvoltage	FLOAT	-	Wind Voltage	5.3
tpower	FLOAT	-	Wind Power	30.6
spower	FLOAT	-	Solar power	12.9
temperature	FLOAT	-	Temperature	28.3
scurrent	FLOAT	-	Solar current	8.9
svoltage	FLOAT	-	Solar voltage	11.7
bvoltage	FLOAT	-	Battery voltage	24.8
bcurrent	FLOAT	-	Battery current	5.3
bcharge	FLOAT	-	Battery charge	85.2%
email	VARCHAR(120)	NOT NULL, UNIQUE	User's email	example@example.com
password	VARCHAR(120)	NOT NULL	User's password	********
username	VARCHAR(120)	NOT NULL, UNIQUE	User's username	example_user
is_admin	BOOLEAN	-	User's admin status	true or false

Table. 4: Date Dictionary

Table 4 shows the data dictionary. It was important to create the database structure before starting to develop the User Interface because it is the base the Flask application relies on the database to store and retrieve data. By establishing the database before launching the website, we guarantee that the required database tables and schema are in place and ready for usage by the website.
there are a total of 14 tables in the database. Here's a brief description of each table:
• WindSpeed: This table stores wind speed measurements over time. It has columns for id (primary key), time (DateTime), and windspeed (Float).

• TCurrent: This table stores current measurements over time. It has columns for id (primary key), time (DateTime), and tcurrent (Float).

• TVoltage: This table stores voltage measurements over time from the wind turbine. It has columns for id (primary key), time (DateTime), and tvoltage (Float).

• Tpower: This table stores power measurements over time. It has columns for id (primary key), time (DateTime), and tpower (Float).

• Spower: This table stores power measurements over time. It has columns for id (primary key), time (DateTime), and spower (Float).

• Temperature: This table stores temperature measurements over time. It has columns for id (primary key), time (DateTime), and temperature (Float).

• SCurrent: This table stores current measurements over time. It has columns for id (primary key), time (DateTime), and scurrent (Float).

• SVoltage: This table stores voltage measurements over time from the solar panel. It has columns for id (primary key), time (DateTime), and svoltage (Float).

• BVoltage: This table stores battery voltage measurements over time. It has columns for id (primary key), time (DateTime), and bvoltage (Float).

• BCurrent: This table stores battery current measurements over time. It has columns for id (primary key), time (DateTime), and bcurrent (Float).

• BCharge: This table stores battery charge measurements over time. It has columns for id (primary key), time (DateTime), and bcharge (Float).

• User: This table stores user information for authentication purposes. It has columns for id (primary key), email (String), password (String), username (String), and is_admin (Boolean).

5.6 Usability and Navigation

Effective website usability and navigation are essential factors in ensuring a positive user experience. Analyzing the relationship between website usability and user satisfaction is crucial for optimizing website design. In order to achieve optimal website usability, attention must be paid to various factors such as the design of the navigation bar and page layout. Additionally, performance indicators such as browser and error management must also be considered. The purpose of usability is to ensure that the use of a website is practical, simple and effective. Navigation is intended to be effective, efficient and satisfactory for the user. Considering appropriate usability guidelines can reduce the risk of errors during navigation and increase ease of use, benefiting both the user and their objectives. In our website, navigation is clear and allows for easy access to different sections such as Wind, Solar, and Battery. The website is designed to be responsive and work well on different screen sizes, with a meta tag included in the design to help achieve this. Each page contains a logo at the top, indicating brand identification. The content is organized using appropriate headings, paragraphs, and div elements to ensure readability and comprehension. Furthermore, the website's usability is enhanced by dynamic data updates and relevant buttons for data manipulation. Overall, our website excels in usability and navigation.

5.7 summary

The Flask Charge Controller User Interface is a web application that provides an interface for users to interact with a charge controller. It allows users to log in, view measurement data, generate spreadsheets, and manage users (admin-only). The application is built using the Flask micro-framework for Python, and uses HTML and CSS for the front-end interface. The application has user authentication and authorization features, ensuring that only authenticated users with the appropriate privileges can access specific routes. Various database models have been defined to record

wind speed, current, voltage, temperature and charge status data.

The application also uses SQLAlchemy for interacting with a SQLite database, which creates necessary tables and adds an admin user during the first request. The Flask Charge Controller User Interface provides users with an intuitive interface that is easy to use. It is particularly suitable for users who require an easy-to-navigate platform to manage the measurement data of a charge controller. Overall, the Flask Charge Controller User Interface is a powerful tool that enables users to effectively manage and visualize data collected from charge controllers. It is a user-friendly, lightweight and flexible application that can be used for various purposes.

However, it is important to note that the Flask Charge Controller User Interface may not be suitable for more complex applications or systems that require extensive data management and analysis functionalities. For such cases, alternative solutions may be required.

6. Results and Discussion

6.1 Expectations

From the Wind turbine we are expecting the circuit to be able to measure the wind speed(W) and voltage (Vin) generated by the wind turbine. And from the solar panel we are expecting to the circuit to be able to measure the temperature (T) and voltage (Vin) generated by the solar panel. And from the battery we are expecting the circuit to be able to measure the voltage inside the battery (Vbat). And the measurement of the current will be taken from the circuit.

6.1.1 voltage input

$V_{R2} = \frac{V_{in}}{R_2+R_1} \times R_2$ (Eq. 1) (suppose) $R_1 = 20K$

$V_{R2}(R_1 + R_2) = V_{in} \times R_2$ (Eq. 2) (suppose) $R_2 = 100K$

$\therefore \frac{12(120)}{100} = \frac{V_{in}}{100} \times 100$ (Eq. 3) $\therefore V_{R2} = 12V$

$V_{in} = 14.4 \approx 15V$

6.1.2 Kirchhoff's law

Saturation: $VCE = 0$

W_{tt}.: $VCE = VCC$

$VCC = VCE + V_{Relay}\,(VRC)$

$VCE = V_{Relay}$

$VCE = 12V$

6.2 Indirect Measurements

6.2.1 power measurements

we need to calculate the power generated by each source of energy. Therefore, measuring the voltage and current generated by these sources would allow us to accurately calculate power values. Once the power values for both solar and wind energy are calculated, they can be saved in a database to assist in further analysis.

$$P = v \times i \quad \textbf{(Eq. 4)}$$

Using Eq. 4 we can calculate the power by multiplying voltage by the current. When the circuit is using the solar panel voltage (Vin) generated by the solar panel will be multiplied by current (i) to get power generated by the solar panel. If the source was the wind turbine, then (Vin) generated by the solar panel will be multiplied by current (i) to get power generated by the wind turbine.

6.2.2 battery percentage

Most rechargeable device like a phone or a laptop must supply the user with the percentage of charge left in their batteries to notify the user to charge their batteries. To display the battery percent on the LCD or in the User interface. We need to calculate it first. Eq. 5 shows the method we implemented to calculate the battery percentage.

$$B_{percent} = \frac{V_{bat} \times 100}{9v} \quad \textbf{(Eq. 5)}$$

We are dividing by 9 because the battery we are using is a 9V battery. After multiplying the voltage from the battery by 100 and dividing it over 9 we get the percentage of charge.

6.3 LCD results

The LCD is expected to display the wind speed value, V_{in} supplied by the source, Vbat and the state of the battery whether it is charging, supplying the load or preserving its charge. And it worked just like we expected it to do. Fig 8 displays all the different battery states with different values of V_{in} and $V_{bat.}$

Fig. 8: LCD results

6.4 User Interface results

6.4.1 Normal user display

The user interface is expected to display 3 main tabs for the normal user and 2 extra tabs for the admin. The first tab is

wind which contains all the data and graphs regarding the wind turbine. Like the Voltage, Current, power & wind speed. And it worked just like we expected it to do. Figure 9 displays the wind tab. Figure 10 displays the solar tab.

Fig. 9: example of the wind turbine statistics

Fig. 10: example of the battery statistics

6.4.2 Admin Display

As mentioned above the admins have 2 more tabs to control the users and all the data in the database. Users don't register themselves they have to ask an admin to create an account for them as this application must be only employees authorization and not anyone on the web has the right to get access to the application Figure 11 displays the users tab. Figure 12 displays the data tab.

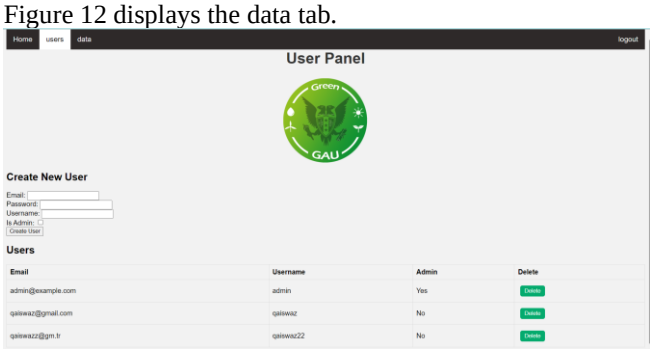

Fig. 11: user panel display

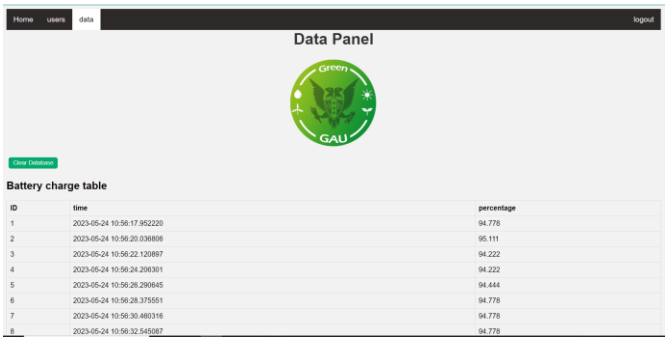

Fig. 12: data panel display

7. conclusion

This project was implemented by team work, where the tasks were distributed to each member of the team each according to his or her department and the results of each step were shared among the team members to obtain new suggestions. Different point of views contributed to the acquisition of teamwork skills within the team for better understanding of the nature of the work on the engineering disciplines and understanding the integration between these disciplines.

Some difficulties were faced during the implementation of the project. Scarcity and difficulty of access to some key components such as the MOSFET and dc-dc converter prevented the implementation of the MPPT technique on the circuit. The technique that is more advanced in the maximum power point tracking which would give better performance in terms of efficiency and in terms of battery charging speed.

8. References

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