ECE 445

SENIOR DESIGN LABORATORY

FINAL REPORT

Smart Power Routing

Team #2

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Abstract

The "Smart Power Routing" project develops a dynamic power management system that adapts to real-time user interactions and varying energy inputs. The system efficiently distributes power from electrical outlets and manual inputs, such as hand-crank generators and a pneumatic turbine, into a battery and subsequently allocates it to devices like a fan and a light bulb. Utilizing advanced algorithms and real-time data analysis, the system ensures stable power distribution, even under fluctuating conditions. Key results include the successful integration of multiple power sources, real-time monitoring, and user-friendly control interfaces.

Keywords: Smart Power Routing, Dynamic Power Management, Renewable Energy Integration, Real-time Data Analysis, User-friendly Interface

Contents

1 Introduction

1.1 Problem

In the evolving landscape of energy management, the "Smart Power Routing" project confronts not only the challenge of efficiently distributing and utilizing power among diverse devices but also the critical issue of maintaining stability in the power supply. Traditional energy systems exhibit significant shortcomings when faced with the dynamic nature of modern electrical demands, particularly in scenarios requiring the seamless operation of devices with varying energy needs.

The stability of power supply is paramount, especially as we integrate more renewable energy sources and adopt more sophisticated electrical devices. The inherent variability in power generation from sources like wind and solar, coupled with the unpredictable nature of user interactions—such as switching devices on/off, plugging/unplugging, or even manually generating power introduces a level of complexity that traditional systems are ill-equipped to handle. Our solution is a dynamic power management system that intelligently adapts voltage supply in real-time, responding to user interactions like switching devices or manual power generation.

This project aims to demonstrate the practicality of smart power management in real-world scenarios, offering an accessible and engaging illustration of these principles for a broad audience [1]. STEM education has become a strategic choice for education reform in countries around the world because it helps develop students with key abilities to adapt to the future and have the potential to play a role in future life and work [2]. In the realm of STEM education, fostering an early interest and understanding of electrical circuits is crucial. Electrical circuits serve as the backbone of modern technology, and comprehension of their principles lays the foundation for future innovations. Investing to ensure a pipeline of workers skilled in STEM competencies is a workforce issue, an economic-development issue, and a business imperative [3]. We hope this project would be educational as well as enjoyable to children in kindergarten and primary school by showing a simplified version of smart power system about how power is distributed and controlled in our daily life.

1.2 Solution

Our smart routing system manages and stores energy from electrical outlets and manual inputs — including hand-crank generators and a pneumatic turbine — into a battery. After receiving power information from the sensor, it then dynamically allocates power to a fan and light bulb in response to user interactions. The system's adaptability is managed by a microcontroller, which ensures efficient energy distribution and maintains device operation through variable conditions.

In greater detail, our smart routing system merges power harvested from electrical sockets with manually generated energy, utilizing hand-crank generators and a pneumatic turbine squeezed air pump—to efficiently convert mechanical energy into electrical power.

The power is transferred to the electrical appliance and the excessive power is stored in a battery to ensure a stable supply. We also have an intuitive user interface, comprising switches and buttons that allow users to easily control the system, toggling the state of the socket, light, and fan, or activating the manual generators as needed. The operational demands of the fan and lightbulb are monitored by current sensors, which relay information on power consumption fluctuations to the microcontroller. This central processing unit, acting as the system's brain, analyzes the input from sensors and user interactions to dynamically adjust power distribution and output commands to transister-based circuits, ensuring that energy supply meets demand in real time and maintains uninterrupted device operation. Complementing this, an LED screen offers users a clear visual representation of the battery's storage levels and the real-time power usage of both the fan and lightbulb, highlighting the system's operational efficiency and the intricate power dynamics between the energy sources and the devices powered.

1.3 Visual Aid

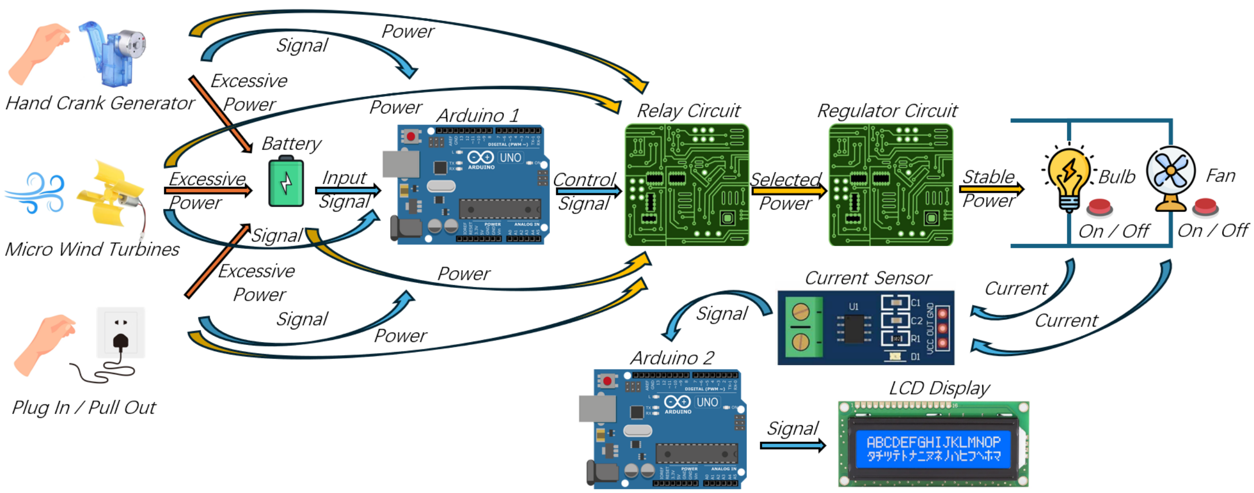

Figure 1: Visual Aid of Smart Power Routing

1.4 High-level Requirements List

- **Reliability:** The system should consistently maintain power levels within a ±5% fluctuation range to both the fan and the lightbulb regardless of user interactions, such as turning switches on and off and the presence of manual power generation from hand cranks or turbine inputs.
- **Efficiency:** It should maximize the energy harvested from manual inputs, targeting a minimum energy conversion and distribution efficiency of 90%.
- **Good Visualization:** The project should successfully demonstrate the principles of smart power routing in a way that is understandable and engaging for viewers, with clear displays of current power and battery condition.

2 Design

2.1 Block Diagram

There are four subsystems in our design: User Interface, Power, Control and Display. The block diagram of the Smart Power Routing shown in Fig.2 depicts the integration of all subsystems within a larger framework that is crucial for achieving functionality, efficiency, and user-friendliness.

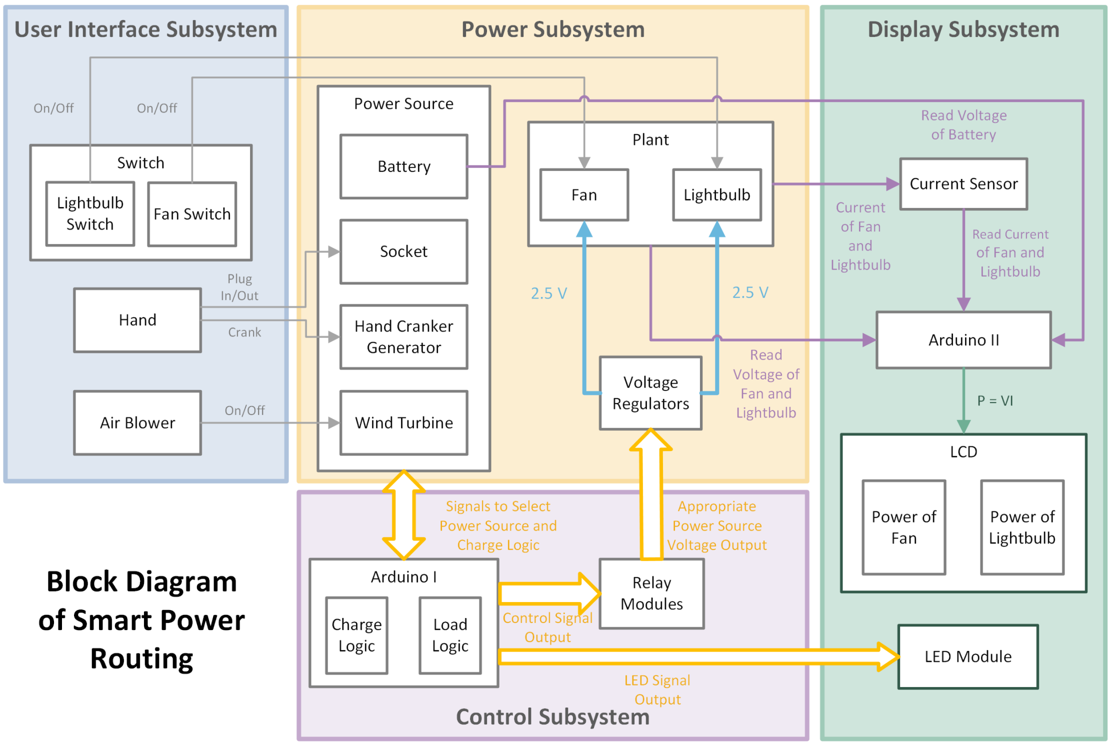

Figure 2: Block Diagram of Smart Power Routing

2.2 Physical Diagram

The physical design consists of a portable plastic box with two layers. The design drawings for each layer are as follows:

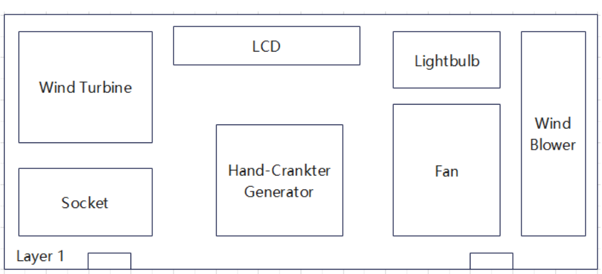

Figure 3: The top view of the layer 1

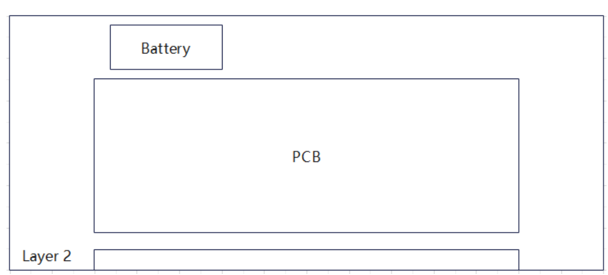

Figure 4: The top view of the layer 2

The outermost layer is a transparent plastic case. Inside the box, there are two separate levels: the first layer contains various instruments that interact with the audience. Separating the first and second layers is a filler material made of high-temperature-resistant, fireproof cotton and lithium battery assembly self-adhesive engine insulation film flame-retardant insulating sponge padding. The second layer houses the core PCB and the batteries. Surrounding and protecting the second layer on all sides and the bottom is a versatile, tearable grid sponge, shockproof box packaging sponge – used for DIY camera grid cotton box with high density.

2.3 Subsystem Overview

2.3.1 User Interface Subsystem

The User Interface Subsystem acts as the interactive interface between the user and the system, including a socket, a hand crank generator and a pneumatic turbine. The user can choose to plug in/out the socket, pump the hand crank generator, or blow wind into the turbine to provide external power for the system. As shown in Fig.5. There are also two switches for users to turn a light bulb and fan on and off respectively. The system is designed to allow users to dynamically interact with the power supply choice and load options of the whole system.

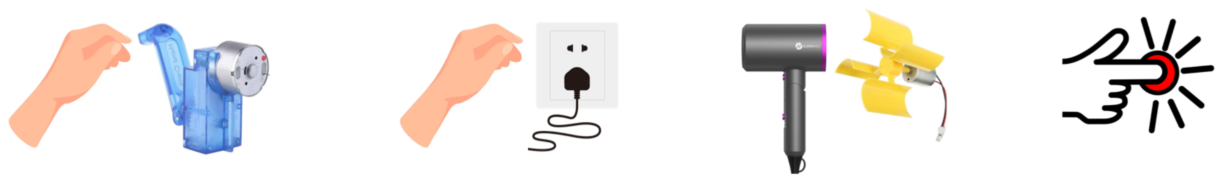

Figure 5: User Interface Ways

In the original design for the user interface subsystem, users would generate wind by blowing directly into the system. However, this method only produced 1-2 volts, insufficient for our needs and raised hygiene concerns. We switched to using a hairdryer, which increased voltage output to 5-15 volts and improved the overall safety and hygiene of the operation, offering more consistent results for demonstrations.

2.3.2 Power Subsystem

2.3.2.1 Overview

The Power Subsystem plays a critical role in providing and managing electrical power within the system. It is engineered to convert voltage from a 220 V AC source to 9 V DC using a transformer, and is adept at accommodating power inputs from a hand crank generator and a pneumatic turbine. There is also a battery designed to store excess electricity, ensuring a reliable power supply even when the input from conventional sources falls short.

As different power source candidates including socket, hand generator, wind turbine and battery have different voltage values. Moreover, sources like hand generator and wind turbine can fluctuate significantly over time, we connect these power sources to a switching regulator shown in Fig.6 which is utilized for providing stable voltage conversion to precisely meet the voltage requirements our loads, including a lightbulb and a fan.

2.3.2.2 Circuit Design

Initially, we considered utilizing a PWM (Pulse Width Modulation) signal from an Arduino to control a MOSFET circuit and incorporate a feedback mechanism to adjust the power supply dynamically. However, upon further exploration, we discovered that using a single voltage regulator would be more effective. A voltage regulator is an integrated component specifically designed to maintain a stable voltage output. It operates faster and more reliably in this capacity compared to an Arduino setup. Consequently, we decided to implement a voltage regulator to achieve enhanced stability in our power supply system. And the circuit is shown in Fig.7.

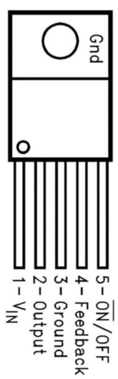

Figure 6: LM2575 Switching Regulator and Pins

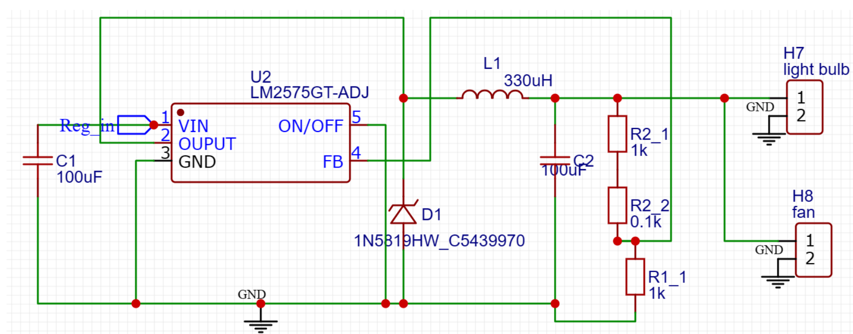

Figure 7: Power System Circuit

LM2575-ADJ Voltage Regulator (U2), which is a chip that functions as an adjustable voltage regulator, as shown in Fig.6. It achieves voltage stabilization through a feedback loop within its integrated circuit design. Notably, the output voltage is precisely set by the ratio of two external resistors connected to its Feedback pin. The output voltage formula is displayed as follows:

$$V_{out} = V_{ref}\left(1 + \frac{R_2}{R_1}\right) \tag{1}$$

Where V_{ref} is the chip's internal reference voltage of 1.23 V [4].

For the intended application, resistors $R_1 = 1$ kΩ and $R_2 = 1.1$ kΩ have been selected to achieve a stable output of 2.5 V, ideal for powering the light bulb and fan as shown in Fig.7. This ensures that the system operates reliably, with consistent device functionality irrespective of input voltage or load changes.

Additionally, several components are crucial for reliable operation. The Schottky diode (D1) minimizes power loss and accelerates switching to prevent overheating. Both the input (C1) and output (C2) capacitors, rated at 100 uF/50 V, regulate voltage in electronic circuits. C1 absorbs voltage spikes and filters high-frequency noise, while C2 smooths output voltage fluctuations and reduces ripple, essential for sensitive electronics. Together, these components ensure stable and clean power delivery.

2.3.3 Control Subsystem

2.3.3.1 Overview

In the Control Subsystem, Arduino, our efficient and powerful micro-controller, receives input signals from the Power Subsystem and processes the signals through load logic and charge logic to determine the power source to load and the charge. The output arduino digital signals are then sent to relay modules which accordingly connect appropriate branches for loading and charging.

2.3.3.2 Loading and Charging Code Logic

The Arduino processes analog inputs from a battery, DC socket, wind turbine, and hand-cranker generator to select the most suitable power source, using sources over 5V(VL_min) for power supply and over 7V(VC_min) for charging the battery to store excess energy. In our first design version, we considered using multiple power sources simultaneously, but safety concerns arose due to combined voltages exceeding the safe human contact limit of 35V. Ultimately, we chose to select only one optimal source for charging and supplying power, prioritizing external sources to conserve battery power and selecting the most stable source among those meeting voltage criteria. The supply priority is socket, wind turbine, hand-cranker generator, and battery, while the charging priority is socket, wind turbine, and hand-cranker generator.

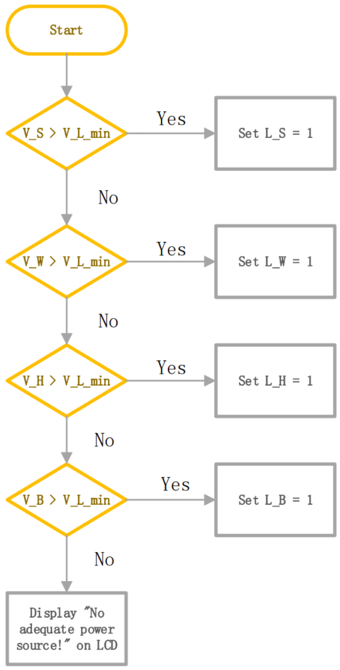

Figure 8: Control Load Logic

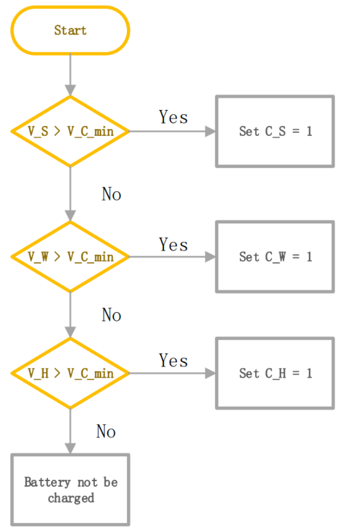

Figure 9: Control Charge Logic

Algorithm 1 LOAD

$L\_S, L\_W, L\_H, L\_B, LCD \leftarrow 0$ ▷ Initialization of variables
if $V_S > VL$_min **then**
    DIGITALWRITE(L_S, 1) ▷ Socket is used to supply power
else if $V_W > VL$_min **then**
    DIGITALWRITE(L_W, 1) ▷ Wind turbine is used to supply power
else if $V_H > VL$_min **then**
    DIGITALWRITE(L_H, 1) ▷ Hand-cranker generator is used to supply power
else if $V_B > VL$_min **then**
    DIGITALWRITE(L_B, 1) ▷ Battery is used to supply power
else
    DIGITALWRITE(LCD, 1) ▷ Giving print signal to display subsystem
end if

Algorithm 2 CHARGE

$C\_S, C\_W, C\_H \leftarrow 0$ ▷ Initialization of variables
if $V_S > VC$_min **then**
  DIGITALWRITE(C_S, 1) ▷ Using Socket to charge the battery
else if $V_W > VC$_min **then**
  DIGITALWRITE(C_W, 1) ▷ Using Wind Turbine to charge the battery
else if $V_H > VC$_min **then**
  DIGITALWRITE(C_H, 1) ▷ Using Hand-cranker Generator to charge the battery
end if

2.3.3.3 Circuit Design

The circuit diagram for the Arduino control system have two parts: signals connecting to Arduino and signals connecting to relays.

Initially, we were uncertain whether to use current, voltage, or power as the input signal for the Arduino's switching decision. Upon reviewing the Arduino datasheet, we discovered that it can directly read a voltage range of 0-5 V with a resolution of 1024 levels. While it's possible to measure current and power by integrating a current sensor, we opted for voltage as the primary signal due to its direct compatibility and ease of use in rapid decision-making.

Circuit of signals connecting to Arduino is shown in Fig.12. Since the Arduino's analog read pin is only capable of processing 0-5V, we incorporated a voltage divider circuit at each output. Let V be the voltage read at Arduino's analog read pin, V_in be the primary input source voltage signal, the voltage division formula is:

$$V = V_{\text{in}} \times \frac{R_1}{R_1 + R_2} \tag{2}$$

, where $R1$ and $R2$ are resistors in series, with $R1$ connected to ground, $R2$ to V_{in}, and the junction between $R1$ and $R2$ to the Arduino's analog read pin.

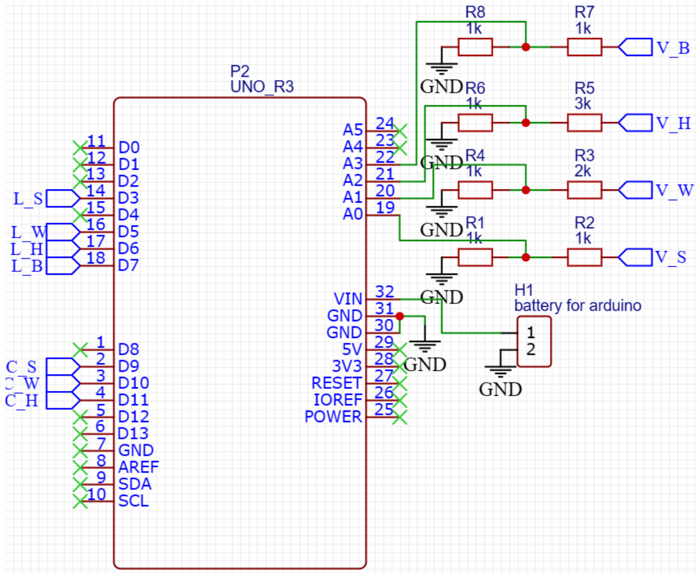

Figure 10: Control Circuit for Arduino

There are 4 inputs, and 7 outputs in the control part of Arduino. The Arduino Control signals and parameters are shown in Table.1

Signal Description	**Symbol**	**Pin**
Voltage of Socket 5 V	V_S	A0
Voltage of Wind Turbine	V_W	A1
Voltage of Hand-cranker Generator	V_H	A2
Voltage of Battery	V_B	A3
Socket to Load	L_S	3
Wind Turbine to Load	L_W	5
Hand-cranker Generator to Load	L_H	6
Battery to Load	L_B	7
Socket to Charge	C_S	9
Wind Turbine to Charge	C_W	10
Hand-cranker Generator to Charge	C_H	11

Table 1: Arduino Control Table

The digital output pins of Arduino are then connected to seven XYF-7HA relay modules to control the switching of the three charge signals and the four load branches. XYF-7HA is a mini-SSR-relay module for PCB with four pins, IN+, IN-, OUT+, OUT- as shown in Fig.11 .The XYF-7HA SSR relay module accepts a control signal voltage of 3-5 V at IN+ and is normally open. It closes the circuit from OUT+ to OUT- when the input pin receives a HIGH signal at IN+ and opens it when receiving a LOW signal at IN+.

We primarily designed to connected the outputs of the four control relays directly, but encountered issues due to the polarity of the relay modules. Even if the input to one relay was LOW, only current from OUT+ to OUT- is prohibited ,if another source was powered, current could backflow from the OUT- to OUT+, inadvertently powering the supposedly off relay. This misled the Arduino into making incorrect control decisions. To resolve this, we added diodes 1N5401 to the OUT- pin of all seven relays, preventing backflow and ensuring that the outputs of different relays do not interfere with each other. Circuit of signals connecting to relays with diodes integrated is shown in Fig.12.

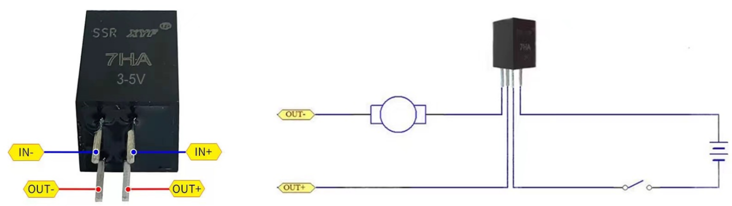

Figure 11: Relay Module and its Wiring Diagram

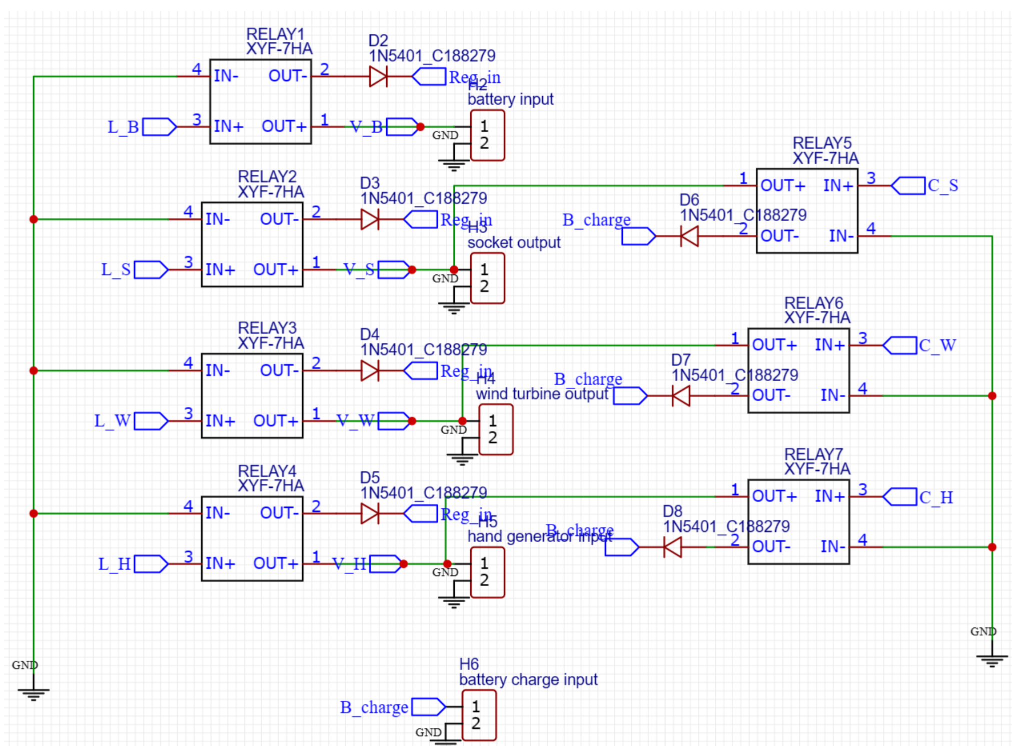

Figure 12: Control Circuit for Relays

2.3.4 Display Subsystem

2.3.4.1 Overview

The display subsystem presents the power condition of the light bulb and fan to show the stability of the whole system. We get the voltage through the analog read pin of the Arduino board and current from Allegro ACS758 sensors which convert the sensed current into voltage. Then the second Arduino will read the data, convert it back to the current magnitude, and multiply it with the voltage to calculate the power. Finally, it utilizes LCDs to show numbers and screens to show graphs indicating the power status.

2.3.4.2 Display Logic

1. **Calculation of the Power**
   The Arduino converts the analog voltage output read from the current sensor into a current value for the fan and light bulb using the formula below:

$$current = \frac{V_{\text{sensor}} - V_{\text{quiescent}}}{sensitivity} \tag{3}$$

   Then, we multiply current with the directed read voltage to calculate the power.

$$Power = Voltage \times Current \tag{4}$$

2. Display of the Power and Trend Chart
   - **LiquidCrystal [5]:** LiquidCrystal library supports the display of number for power. It allows communication with alphanumerical liquid crystal displays (LCDs). This library allows an Arduino/Genuino board to control LiquidCrystal displays (LCDs) based on the Hitachi HD44780 (or a compatible) chipset, which is found on most text-based LCDs. The library works with in either 4 or 8 bit mode. Initially, we considered using an 8-bit interface for the LCD due to its capacity for faster data transfer. However, after further analysis, we found a 4-bit interface adequate and could reduce the number of required GPIOs, simplified the hardware setup, and improved the system's stability and power efficiency.Table 2 describes the specific usage of each pins in LCD [6] and Algorithm 3 shows the pseudo-code of display logic.
   - **Serial Plotter:** The serial plotter supports the display of graph for power. It retrieves values from a predefined serial port and plots them on an XY axis graph. The X-axis represents time, divided into 500 equal parts, and shifts one unit to the left with each new set of data received. The Y-axis represents values from the serial port. Different sets of data on the same row are separated by *serial.print(",")*, while different rows within the same set are delimited by *serial.println("")*.

LCD Pin	Usage	Arduino Pin
GND	Ground	GND
VCC	Power supply	VCC
Vo	control the contrast and brightness	VCC
RS	Register Select	12
En	Enable the display	11
D0-D3	Data Bus	6-9
A & K	Anode and Cathode	GND & VCC

Table 2: LCD Display Inputs

Algorithm 3 Display logic

$lcd \leftarrow$ LIQUIDCRYSTAL$(12, 11, 9, 8, 7, 6)$ ▷ connect the LCD
$C\_F, V\_F, C\_L, V\_L \leftarrow A0, A1, A2, A3$
procedure SETUP
  LCD.BEGIN$(16, 2)$ ▷ Initialize the LCD mode
  PINMODE(C_F, V_F, C_L, V_L, INPUT) ▷ Initialize the value
  SERIAL.BEGIN(9600) ▷ Start serial communication at 9600 baud
end procedure
procedure LOOP
  $v\_f, v\_l \leftarrow (V\_F, V\_L) * (5.0/1023.0)$ ▷ Transform voltage
  $c\_f, c\_l \leftarrow ((C\_F, C\_L) - 2.5)/40 * (5.0/1023.0)$ ▷ Transform current
  $p\_f, p\_l \leftarrow c\_f \times v\_f, c\_l \times v\_l$ ▷ Calculate the power
  LCD.PRINT(p_f, p_l) ▷ Print the number in LCD
  SERIAL.PRINT(p_f, p_l) ▷ Print the graph of power in screen
end procedure

2.3.4.3 Circuit Design

The Display Circuit comprises two primary components.

Firstly, it uses two ACS758LCB-050B current sensors to monitor the electrical current in appliance circuits, sending this data to an Arduino microcontroller. The ACS758 is a hall-effect current sensor that produces an analog voltage signal proportional to the sampled current, I_P, with a range of ± 50 A and sensitivity of 40 mV/A, allowing it to detect small changes in current flow. Fig. 13 and 14 illustrate the sensor's output and a typical application, respectively.

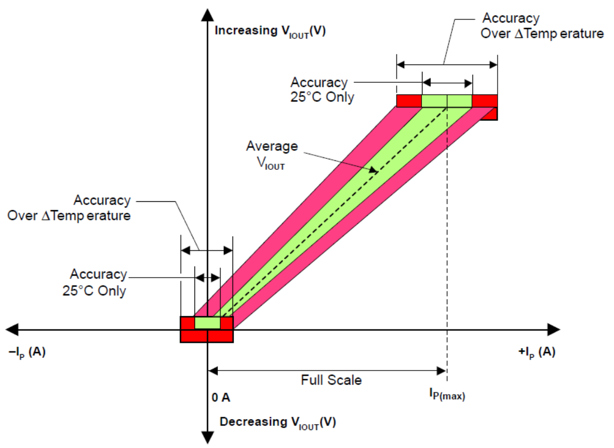

Figure 13: Output Voltage versus Sampled Current

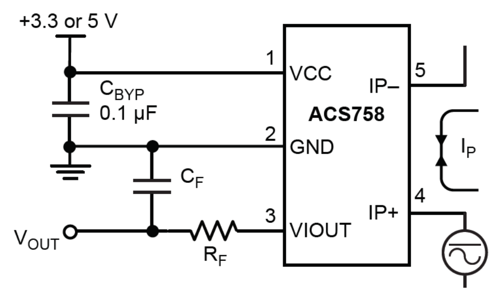

Figure 14: Typical Application of ACS758LCB

Secondly, the system employs an LCD 1602 display to indicate the power status of devices such as fans and lightbulbs. The features and pin configuration of this display are detailed in Table 2 mentioned earlier.

At first, the LCD was displaying garbled characters. We discovered that this was because we directly read the voltage of the bulbs and fans into the Arduino, and the current from these devices exceeded the Arduino's safe current limit of 40mA, causing unstable outputs and garbled characters on the LCD. To resolve this issue, we added a protective resistor in the circuit where the voltage was being read to ensure the current remained sufficiently low.

The overall display system circuit is shown in Fig.15.

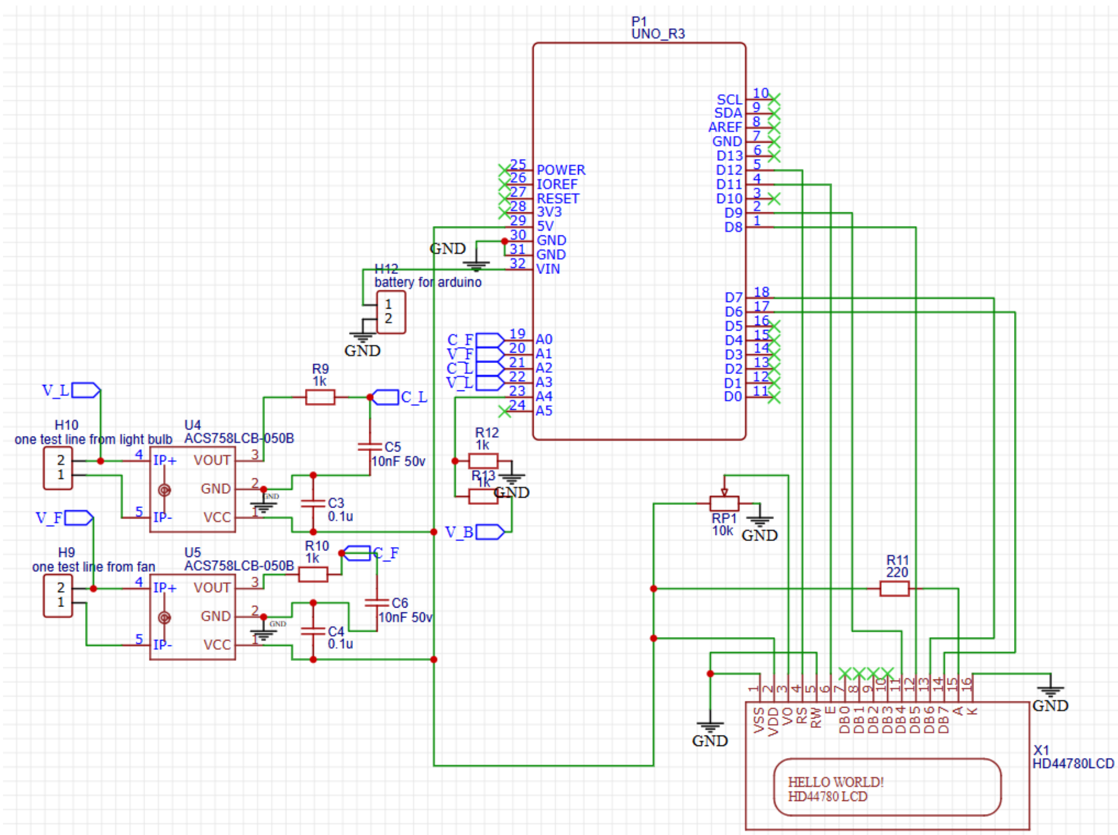

Figure 15: Display System Circuit

3 Requirements and Verification

3.1 User Interface Subsystem

#	Requirement	Verification
1	The subsystem must ensure that users can use these power generates to generate enough power supply for the load, with minimum voltage required for the voltage regulator for the loads 4.75 V.	After testing with a multimeter to measure the generators' output, we found that the hand crank generator produces voltages between 3.2 V and 12.0 V at normal cranking speeds of 60 to 180 rpm, and the wind turbine generates 4.2 V to 11.6 V at speeds of 38,000 to 80,000 rpm. In over 80% of cases, both power sources exceed the 4.75 V minimum requirement of the voltage regulator, proving adequate for power supply.
2	The user interface subsystem should be safe, within the safe contact voltage of 36 V.	The maximum voltage output from various sources is capped at less than 20 V, well below the safe threshold for human contact of 36 V. Multimeter testing of the 220 V DC casing showed a voltage of 0.04 V, indicating strong insulation.

Table 4: RV Table for User Interface Subsystem

3.2 Power Subsystem

#	Requirement	Verification
1	The power subsystem must provide stable voltage with fluctuation of less than 5% with the switching of power sources.	We used a function generator to produce a continuously varying voltage from 4.75 V to 20 V. Then, using an oscilloscope, we monitored the changes in the output voltage of the voltage regulator to assess its stability across these varying input conditions. The output voltage stays constant at 2.62 V regardless of the input and load change as shown in testing result graph Fig.16.
2	The power subsystem is required to maintain a voltage stability within a 5% fluctuation range despite changes in the load.	We fixed the input voltage at 10 V and connected different sets of loads: no load, fan only, lightbulb only, both fan and light at the output, monitoring the regulator output voltage to verify that the regulator output was not affected by the varying loading condition.The output voltage is 2.62 V, 2.60 V, 2.59 V and 2.55 V respectively, which is less than 5% (0.13 v) of the total voltage.

Table 6: RV Table for Power Subsystem

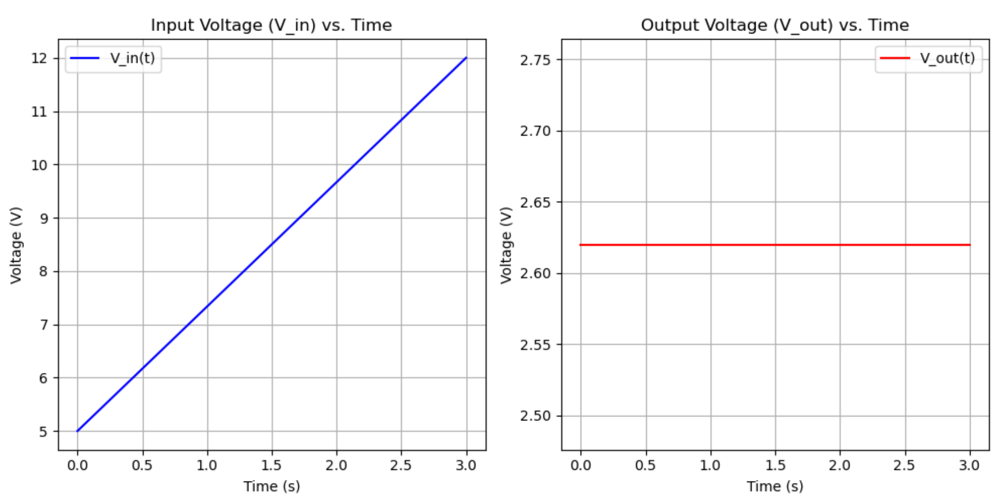

Figure 16: The Vin-t and Vout-t Graph of LM2575 switching regulator

3.3 Control Subsystem

#	Requirement	Verification
1	The system must be capable of reading voltage values from socket, hand crank generator wind turbine and battery using Arduino's analog read pin, with at least 0.01 V precision.	Based on the previously mentioned voltage division formula, the actual source voltage V_{in} can be derived from the Arduino read voltage V as follows: $V_{\text{in}} = V \times \frac{R1+R2}{R1}$. Given the original resolution of $\frac{1}{1024}$ and the maximum ratio of $\frac{R1+R2}{R1}$ being 4 in our design, the resolution of the voltage measurement becomes $\frac{1}{1024} \times 4 = \frac{1}{256}$, corresponding to 0.0039 V, finer than the target of 0.01 V. We also use a multimeter to measure the voltage at the source output and compare it with the Arduino result displayed on the Arduino IDE serial monitor; the average error is 0.003 V and the is indeed less than 0.01 V.
2	The control system should have a command response time of no more than 1 second to ensure immediate feedback.	In the control coding section, we set a delay of 5 ms for each loop. From the datasheet we learned that the relay module features a typical operate time of $70\,\mu s$ and a typical release time of $0.7\,ms$. The combined duration of these times is significantly less than 1 second, ensuring that the control system's response time is fast enough to meet the requirements.
3	The relay modules should close the output circuit when receiving HIGH input signal and opens the output circuit when receiving LOW input signal.	We connected one of the Arduino's digital pins to the IN+ of the relay module, OUT+ is connected to a power source of 9 V, and we measure the voltage at OUT-. The result is that when digital signal is LOW, the OUT- voltage is 0 V, which indicates that the circuit is cut off at relay output pins. When the digital signal is HIGH, the OUT- voltage is 9 V, same as OUT+ voltage which proves that the circuit is connected at output pins of the relay.

Table 8: RV Table for Control Subsystem

3.4 Display Subsystem

#	Requirement	Verification
1	The display system must be capable of obtaining power value of light bulb and fan with the accuracy within 1%.	We first used an ammeter to measure the current through different resistors (50 ohm, 100 ohm, 200 ohm, and 500 ohm) at 2.5 V. Then, we calculated the current based on the output voltage and printed them in Arduino serial monitor. Comparing these values, we found an average error of 3 mA, which is less than 1% of the true current. Therefore, the accuracy of the current reading meets the requirements.The voltage precision, as seen in the control subsystem RV table, also has precision of 1%, so the total multiplied result of measured voltage and current should have accuracy within 1%.
2	The display subsystem must ensure fast enough display update but also slow enough for the monitor to display the number clearly. The desired updating time is 0.75 s to 1.25 s.	We use DELAY(1000) in our Arduino code ensures that the displayed value is updated every 1 s, which is within the desired updating time range.

Table 10: RV Table for Display Subsystem

4 Cost and Schedule

4.1 Cost Analysis

1. Labor Cost

   According to the average salary of UIUC ECE undergraduates, our hourly wage is 60 $, and our average working hours is 20 hours per week. For this project, we approximately work 13 full weeks. Then we can get following labor cost table, the resulting total labor cost would be around 52000 $ as shown in Table 11.

Name	$/Hour	Hours/Week	Weeks	Cost ($)
Yunfei	60	20	13	15600
Jingjing	60	20	13	15600
Jiabao	60	20	13	15600
Xiaoyi	60	20	13	15600
Total	60	80	13	62400

Table 11: Labor Cost

2. Material Cost

Name	Description	Manufacturer	Quantity	Price	Cost
Arduino UNO R3	Main control board	Arduino	2	¥164	¥328
HD44780 LCD	A display unit that uses liquid crystals to produce visible images	Raylid	2	¥7.5	¥15
Allegro ACS758	Current sensors for lightbulb and fan	Allegro MicroSystems	2	¥20	¥40
INA219	Current sensor for battery	Texas Instruments	1	¥10	¥10
SDD-7HA	Relay module: Input voltage: 3 - 5 V	XYF	7	¥10	¥70
LM 2575 ADJ	Switching regulator: Input voltage: 4.75 - 40 V	Jinkesheng	2	¥0.62	¥1.24
Bulb	Electrical appliance: 2.5 V, 0.3 A	Yuanning	5	¥1	¥5
Fan	Electrical appliance: 2.5V	KQU	1	¥1.86	¥1.86
Wind turbine	Generator: 5 V, 3 W	Gabosun	1	¥19.8	¥19.8
Hand crank	Generator: 9 V, 3 W	Qimeng	1	¥8.8	¥8.8
Power Adapter	220 V AC - 7.5 V DC	Dingsheng	1	¥10	¥10
Lithium battery pack	7.4 V, 13600 mAh	Baidong	1	¥134.8	¥134.8
Plastic Portable Box	Pack all components for display	Bainianhaohe	1	¥44.55	¥44.55
Sponge	Lining for PCB layer	Yunchuang	2	¥16	¥32
EVA Foam Board	Lining for display layer	Junhe	1	¥70	¥70
Total					¥644.5

Table 13: Material Cost

4.2 Schedule

WEEK	Yunfei Lyu	Jingjing Qiu	Jiabao Shen	Xiaoyi Han
2/19/2023	Form the team	Form the team	Form the team	Form the team
2/26/2023	Write Request for Approval (RFA) and contract information	Write Request for Approval (RFA) and contract information	Write Request for Approval (RFA) and contract information	Write Request for Approval (RFA) and contract information
3/4/2023	Write Proposal	Write Proposal	Write Proposal	Write Proposal
3/11/2023	Download software for programming and design	Purchase hardware for circuit and control	Learn how to code in Arduino	Learn how to code in Arduino

3/18/2023	Learn how to use kicad	Learn how to use kicad	Learn the basic operations of Arduino related to PID	Learn the basic grammar of Arduino about I/O stream
3/25/2023	Design power input circuit in Kicad	Design power control circuit in Kicad	Build the basic circuit and coding for the Arduino I/O.	Write basic codes for the Arduino I/O and charging/discharging logic for battery
4/1/2023	Continue designing power input circuit in Kicad	Continue designing power control circuit in Kicad	Add LCD display and improve the power-distribution part in our simulation	Code for power distribution and power/battery level display
4/8/2023	Design the circuit framework for multi-source power selection	Finalize the multi-source power selection circuit design and draw it on Kicad	Finishing the whole process of control subsystem in simulation	Finish the whole process of display subsystem in simulation
4/15/2023	Do the unit test for power subsystem	Do the small demo for power subsystem	Add LCD display and improve the power-distribution part in our simulation	Start to build the hardware part of Arduino, breadboard, LCD, and screen
4/22/2023	Connect the hardware and software together	Debug for the power subsystem in hardware	Load the control logic in Arduino	Load the display logic in LCD
4/29/2023	Do the physical design	Design a beautiful user interface	Connect the hardware and software together	Connect the hardware and software together
5/6/2023	Prepare for the presentation	Prepare for the presentation	Prepare for the presentation	Prepare for the presentation
5/13/2023	Prepare for the public display	Prepare for the public display	Prepare for the public display	Prepare for the public display
5/20/2023	Complete the final report	Complete the final report	Complete the final report	Complete the final report

5 Conclusion

5.1 Accomplishments

Our project successfully implements a dynamic power management system, efficiently distributing power among devices while ensuring stability in the power supply. Key accomplishments include:

- **Integration of Renewable Energy:** Our system integrates multiple energy sources to enhance sustainability and reduce reliance on traditional power, simulating various power input and load scenarios within an electrical grid. The setup includes a socket that acts as a stable arch power source, similar to a conventional power plant, a wind turbine for variable natural green energy, a hand crank for temporary manual power, a battery for energy storage, and fans and light bulbs to mimic basic loads with different power requirements.
- **Stable Power Supply:** Our system features a voltage stabilization system that ensures a constant power output regardless of fluctuations in input or load. Additionally, it includes a storage battery that captures any surplus electricity from external sources. This stored energy can be used to consistently power the system even when no external energy inputs are available.
- **User-Friendly Interface:** Our system is designed with a user-friendly interface that includes intuitive controls and real-time visual feedback, making it accessible for users of all ages. The visual feedback system displays the current power output of light bulbs and fans using a LCD screen and uses some LEDs to indicate which power source is active, and shows the charging status of the battery. User interaction is facilitated through various engaging activities such as manually cranking a handle, plugging and unplugging sockets, using a hairdryer to generate power for the wind turbine, and toggling switches to control the light bulbs and fans.
- **Educational Value:** Our project offers significant educational value by providing hands-on learning opportunities that help foster an early interest in and understanding of STEM concepts. It teaches children about series and parallel circuits, voltage stabilization and division, energy distribution and flow, and the principle of energy conservation. This interactive approach not only makes learning engaging but also aids in building a solid foundation in these critical scientific principles from a young age.

5.2 Uncertainties

- **Variability in Hand Crank Generator Output:** The hand crank generator exhibits resistance variability depending on the load, which complicates maintaining a steady cranking speed. Despite the presence of a voltage regulator that aids in stabilizing output, fluctuations in the hand-cranked voltage around the critical 5V threshold can induce frequent switching between battery and hand-crank power sources, potentially resulting in an unstable voltage supply. To mitigate these effects, implementing a robust voltage stabilization method or a buffer system is recommended to ensure a more reliable transition between power sources and reduce the impact of voltage fluctuations.

- **Stability of Arduino Digital Pin Outputs:** When powered by a battery, particularly under conditions where multiple outputs are active, the stability of the outputs from Arduino's digital pins can be compromised. This instability may lead to incorrect signaling to the relays, causing them to fail to switch correctly and potentially disrupting the operation of the entire system. A solution involves using a more stable power supply for the Arduino or incorporating additional power conditioning components. This would enhance the reliability of digital outputs, possibly through using power sources with higher capacity or more consistent output characteristics.
- **Interference from Wind Turbine in Proximity to Fans:** Operating a wind turbine in close proximity to other components, such as fans, can lead to interference due to the airflow from the turbine affecting the operation of these components. This is particularly problematic if the turbine's air output is directed towards fans, causing unintended interactions. Such airflow interference could alter the performance of the fans and affect system tests that depend on stable conditions to evaluate component functionality. To minimize this interference, it is advisable to design the system layout to maintain adequate physical separation between the wind turbine and sensitive components like fans. Additionally, employing directional barriers or shields to control airflow paths within the system could be beneficial.

5.3 Ethics

- **Public Safety**: Ensuring the safety of the public is paramount in any engineering project. The IEEE Code of Ethics emphasizes the importance of prioritizing safety, health, and welfare of the public in professional activities [7]. Misuse or malfunctions of the smart power routing system could lead to electrical hazards, such as shocks, fires, or system failures.Therefore, we will put up warning signs and implement comprehensive safety protocols during system development and usage during system development and usage. We will integrate fail-safe mechanisms and emergency shut-off features to minimize the risk of accidents, ensuring the system is both safe and reliable for all users.
- **Academic Integrity and Citation**: Maintaining academic integrity involves ensuring all research and development work is conducted honestly, without plagiarism, and properly credits sources of knowledge and inspiration. The IEEE Code of Ethics highlights the importance of honesty in all professional endeavors [7]. We will rigorously follow academic citation practices, crediting all external sources of information, data, and ideas used in the development of the smart power routing system. Tools and processes will be implemented to check for inadvertent plagiarism, ensuring that all project documentation and publications accurately reflect the contributions of external sources.
- **Environemtal impact**: The development and use of smart power routing systems

have potential environmental implications, including energy consumption and electronic waste. Efforts will be made to use sustainable materials and to design the system for easy recycling at the end of its life following the IEEE Code of Ethics [7].

5.4 Safety

- **Electric Shock Risk:** Handling live wires, especially when integrating manual generators and electrical outlets with 220 v power supply, poses a risk. The International Electrotechnical Commission(IEC) 60364 series sets forth standards for the electrical installations emphasizing the need for protective measures against electric shock and ensuring the safety of installations under both normal and fault conditions [8]. Therefore, we should follow these regulations to ensure all components are properly insulated and implementing fail-safes to disconnect power in case of a short circuit are essential.
- **Overheating and Fire Risk:** The IEC 62368-1 states that equipment must be designed to prevent the risk of fire and overheating, even under fault conditions, by implementing safeguards such as thermal protection and limiting energy sources [8]. In our system, components such as batteries and microcontrollers can overheat, especially under continuous operation or fault conditions. It is essential that we use components within their rated capacities and incorporating thermal cutoffs to mitigate this.
- **Mechanical Safety:** The hand-crank generators and pneumatic turbines involve moving parts. We can follow guidance from ISO 12100 series, "Safety of machinery - General principles for design - Risk assessment and risk reduction." to use protective casings and guards to prevent injury from moving parts [9].

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