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Development of Power Management System Device: An Energy Conservation and Safety

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Abstract: *This study aimed to evaluate the effectiveness of the proposed project, which is a development of power management system device. It focuses on the primary usage, functionality, applicability, durability and safety aspects of the project, as well as how it effectively assists people through innovative means. The project is tested out of 40 respondents that has knowledge regarding electricity, enough to understand the flow of the project its material used, functions, usage and how it works. Based on the comprehensive evaluation of the device the following key findings have emerged. First, the prototype exhibited exceptional functionality, earning an excellent rating. This indicates a high level of effectiveness in power management system that can detect electrical faults and the ability to react when high and low voltage occur. Second, the device exhibits versatility and adaptability, receiving high ratings for both residential and commercial applications. It effectively addresses specific needs, accommodates user requirements, and provides a safe and practical learning experience in the field of power management system. Third, the prototype was well-agreed by users, who were satisfied with its workability and the availability of expertise, materials, tools, and support resources. Fourth, the device was highly regarded by users for its durability, demonstrating strong resistance to deformation, high temperatures, and environmental factors. This resilient framework ensures the device longevity, making it suitable for long-term use. Fifth, the device was highly regarded by users for its emphasis on safety. By eliminating sharp edges, avoiding toxic materials, and incorporating safety features like adequate protection and clear instructions, the device prioritizes user well-being, making it suitable for educational environments.*

Keywords: Power Management system. Functionality, Durability, Safety

I. INTRODUCTION

Every industry, in every sector—oil and gas, power generation and distribution, offshore, industrial locations, and many more—needs electrical power. It is crucial for enterprises to control their electrical energy demand because of the rising cost of electricity, the world's reliance on energy resources, growing political and environmental consciousness, and strict restrictions. In order to provide consumers with dependable electrical energy, electric utilities must take certain crucial measures when developing their systems(Toshpulatov et al., 2020). The energy supply of every nation is crucial to its economic growth since energy commodities create jobs and increase productivity and income. Every social and economic activity we engage in on a daily basis is supported by energy(Onimisi, 2023). Supporting productive endeavors in both the formal and informal sectors is crucial. Because it impacts all facets of development—social, economic, and environmental—as well as livelihoods including water availability, agricultural production, population health, education, and gender concerns, it is also essential to sustainable development and the fight against poverty(Ekpo, 2022).

Household appliances are frequently made to function within a specified voltage range, unstable energy supplies pose serious threats to them. Voltage fluctuations can cause computers and refrigerators to malfunction, sometimes resulting in a short circuit or the failure of sensitive components(Lund et al., 2022). The most severe impact of unstable electricity is related to safety and health. Electrical instability can increase the risk of fires due to overheating or sparks from faulty wiring or overloaded circuits(Avordeh et al., 2024). These fires can cause extensive property damage and pose serious risks to personal safety.

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Thus, the goal of this suggested study is to create a power management system device that can handle low voltage instability and voltage spike, which have a greater impact on the system's overall power supply delivery. If the voltage source rating capacity exceeds its usual rating, this proposed research device can assess it and, if an irregularity is found, will operate as a stopping mechanism. Another feature of the proposed device is it has as design for automatic transfer switch that act a transfer mechanism to switch to grid power source and or power generator supply. The purpose of this study is also to raise awareness and provide more information on the dangers of high-power surges and abrupt increases in power voltage, which can damage electrical lines and cause property damage or even death. Essentially, the researcher is excited to work on a topic that will lead to the development of a novel, useful, and affordable technology.

II. REVIEW OF LITERATURE

Energy is now considered a human being's most necessity. Energy consumption is rising daily because of rising electric car usage and recent technological advancements. In practically every country, the amount of energy that is needed exceeds the amount that is produced. As a result, energy should be viewed as one of the fundamental support systems for any economy's expansion and a crucial component in assessing the development of any state or nation.

Power Management System

Power management system is a control system device able to act as safety device that will interfere with the flow of power supply so that it can protect when having voltage surge and low voltage supply. Energy management can be made easier and more automated in homes with the use of power management systems (PMS). They can improve convenience and comfort in the home while lowering total energy demand and moving more usage to off-peak hours. By enabling variable energy demand and making a home the end-use node of a smart energy system, PMS promotes the use of renewable energy sources and aids in the fight against climate change(Mascherbauer et al., 2022).

Voltage Surge

Often caused by lightning strikes, power grid switching, or large appliances turning on and off quickly, a "voltage surge" is a sudden, brief increase in electrical voltage on a power line. In essence, it is a power spike that can be significantly higher than the normal operating voltage and can damage electronic equipment if it exceeds the device's tolerance level. According to the National Electrical Manufacturers Association (NEMA), a power surge is a brief spike in an electric circuit's voltage, current, or power. Transients, also known as surges, are short-lived overvoltage spikes or disruptions on a power waveform that have the potential to harm, deteriorate, or destroy electronic equipment in any kind of building, whether it be residential, commercial, industrial, or manufacturing. R. Mason, (2021) deliberates that protection devices are installed with the aims of protection of assets and ensure continued supply of energy. Switchgear is a combination of electrical disconnect switches, fuses or circuit breakers used to control, protect and isolate electrical equipment.

Low Voltage

A low voltage supply at home can lead to a number of problems, such as flickering lights, broken appliances, decreased electronic efficiency, possible damage to appliance motors, a higher chance of electrical components overheating, and even possible safety risks because appliances may draw more current to make up for the low voltage (Guo et al., 2020)**.** A household's low voltage supply may be caused by a number of internal and external factors. An overloaded power grid, which happens when demand for electricity surpasses supply capacity, particularly during peak usage hours, is one frequent external reason. Voltage drops can also result from outdated or malfunctioning power distribution system infrastructure, such as undersized conductors or defective transformers. Additionally, transmission line resistance can result in voltage loss over long distances between the home and the power source. Internal problems such as weak connections, inadequate wiring, or undersized cables that are unable to support the necessary load might cause low voltage. Using too many high-power devices at once can overload the electrical system and make the issue worse. Storms and strong winds are examples of natural events that can interfere with the power supply and cause voltage

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instability. Maintaining a dependable and effective power supply in a home requires recognizing and resolving these issues.

Faulty Electrical Circuit

A malfunctioning electrical circuit in a home can have detrimental effects on functionality and safety. The danger of electrical fires, which are frequently brought on by short circuits or overheating because of damaged wires, faulty connections, or overloaded circuits, is among the most obvious consequences. Circuit breakers may trip frequently as a result of defective circuits, interrupting the power supply and creating annoyance(Zhang et al., 2023). Additionally, because they might not receive the correct voltage or current, such circuits could result in appliances operating inefficiently or failing completely. Another major risk connected to malfunctioning circuits is electrical shocks, which can be extremely dangerous for the safety of the home. Extended problems may lead to greater energy use, higher utility costs, and possible harm to delicate equipment from power surges or erratic current flow. Preventing these hazards and guaranteeing the dependability and security of the electrical system depend on quickly locating and fixing malfunctioning circuits(Chen, 2021).

III. CONCEPTUAL FRAMEWORK

This study is anchored in the published journal of (Thentral et al., 2021) " Implementation of protection circuit for over voltage and under voltage protection". This study identifies the development of an undervoltage and overvoltage protection. The majority of businesses and household appliances are highly costly and delicate. The AC mains supply's instability could cause damage to this. Losses in the electrical circuit may also result from it. Low power factors and significant power waste are the results of these losses. The power quality may be significantly impacted by the fluctuations, and many expensive and valuable pieces of equipment may be damaged. To safeguard the load, a tripping mechanism is therefore advised. The most common reasons for voltages below the authorized value include sudden increases in load brought on by system malfunctions, short circuit situations, and sudden increases in source impedance brought on by a circuit break. An abrupt drop in load in a circuit with a subpar or broken voltage regulator is what causes the voltage to rise above the rated levels. Additionally, faulty connections in the neutral wire or circuit damage may be the source of the overvoltage(Chaturvedi & Akshat, 2022).

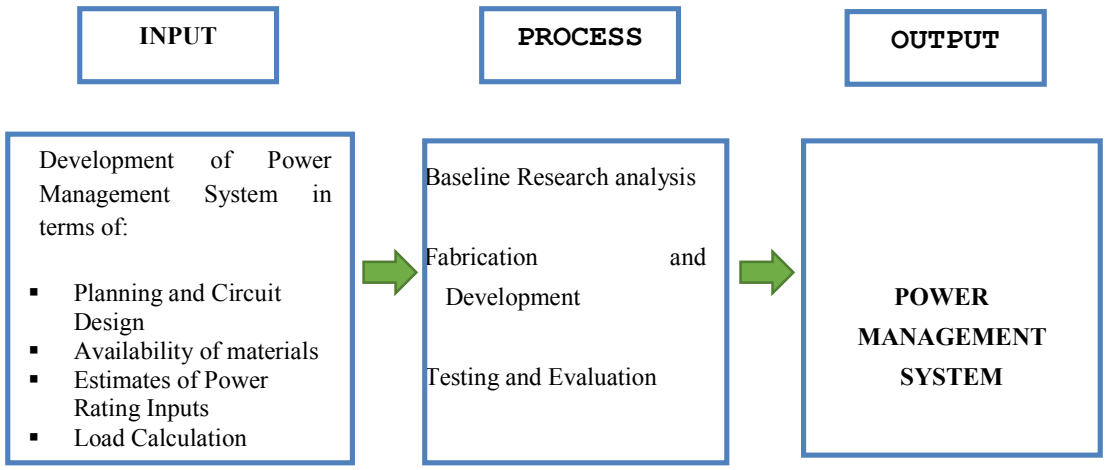

Figure 1 Conceptual Model of the Study

Planning stage of developing a Power Management System (PMS) device is crucial as it lays the foundation for the entire system's functionality and efficiency. During this stage, a thorough assessment of the system's objectives, requirements, and constraints is carried out. Planning process is understanding the power needs of the household or establishment where the PMS will be deployed. This involves evaluating the types of devices, equipment, and

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machinery that will be managed, alongside their respective energy consumption patterns. The load profile of the facility, which involves determining peak usage times, expected power demands, and fluctuations, is also an essential consideration. Additionally, the system must take into account environmental factors like temperature, humidity, and solar radiation, which can impact energy generation, especially for renewable sources.

Second box implies the research analysis and the innovative design and concepts. (Singh, 2021)Research data analysis is the crucial part of research which makes the result of the study more effective. The process stage in creating a Power Management System (PMS) device focuses on translating the inputs from the planning stage into actionable steps for design, development, and implementation. Prototyping and testing follow, where a functional model of the PMS is built and subjected to simulations or real-world conditions to ensure it performs as expected. Feedback from these tests helps refine the design and identify potential issues, such as delays in response times or inaccuracies in data processing. The process stage also includes ensuring compliance with safety and regulatory standards to make the PMS device market-ready. Finally, robust integration and scalability planning is conducted to ensure that the PMS can work seamlessly with existing power systems and accommodate future upgrades or expansions, ensuring a versatile and durable solution.

Third box indicates the output of the study. This indicates the finished product that can be utilized and ready for usage. This also undergo a series of testing and evaluation so that the product output is proven effective.

Statement of the Problem

This study aims to design and develop power management system device that is used as protection device of any electrical fault, or any power surges will occur. Specifically, it sought answers to the following questions:

What are the materials to be used in the development of Power Management System?

What processes need to be followed in order to create such a device?

What is the performance of the prototype device in terms of:

- Functionality,
- Durability,
- Service maintenance and,
- Safety,
- What is the formulated user's manual of the device?

Significance of the Study

The researcher believe that this study may add a greater help to house and establishment owners and offices in terms of power surge protection, and with auto detection for low power supply. Specifically, the findings of this study may benefit the following individuals or groups.

- **House and Establishments owners and Offices**. The study's findings can give them more understanding and pique their curiosity about how beneficial power management systems are for safeguarding electrical loads and averting any electrical issues that could cause major fatalities.
- **Researchers**. This study might offer pertinent data for their upcoming investigations into product analysis, design, development, implementation, and innovation.

Scope and Limitation of Study

The following guidelines are provided to help define the parameters for comprehending the goal and subject matter of this study:

- **Focus**. Designing, developing, testing, and assessing the proposed power management system device that will be used in homes and business buildings for more intelligent electrical power utilization is the primary goal of this project.
- **Respondents**. The respondents of the study are the house owners, establishment owners.
- **Place and Time**. This study will be conducted at San Francisco Surigao del Norte this academic year 2024-2025.

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Definition of Terms

The following terminology are operationally defined as follows to help with comprehension of the study's content and goal:

- **Power Management System.** a methodology that controls and manages power supply to ensure that demand is met, and that power is used efficiently and safely. It improves sustainability and energy efficiency, boosts productivity and operational performance, and makes sure that power capacity and demand are equal—even in the event that a generator fails.
- **Power Surge.** A power surge, sometimes referred to as a voltage spike, is an abrupt and notable rise in voltage that exceeds the normal flow of energy in the electrical circuits of your house or place of business.
- **Low Voltage.** Low voltage is the rated value are usually caused under unexpected rise in load due to faults in the system, during short circuit conditions and also rapid increase in source impedance due to lose connection in the circuit.
- **High Voltage.** High voltage is the rated voltage value are caused by a sudden decrease in load in a circuit having a poor or damaged voltage regulator. The over voltage may also be caused by a damage in the circuit or loose connections in neutral wire.

Project Design

The research methodology used in this study is developmental. The design process and the creation of the study's outcome both make use of the developmental technique.

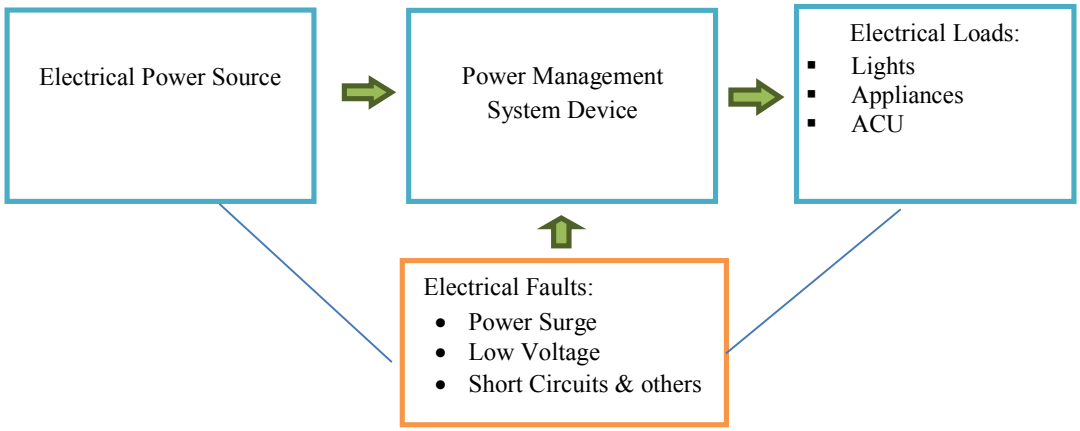

Figure 2 Research Design

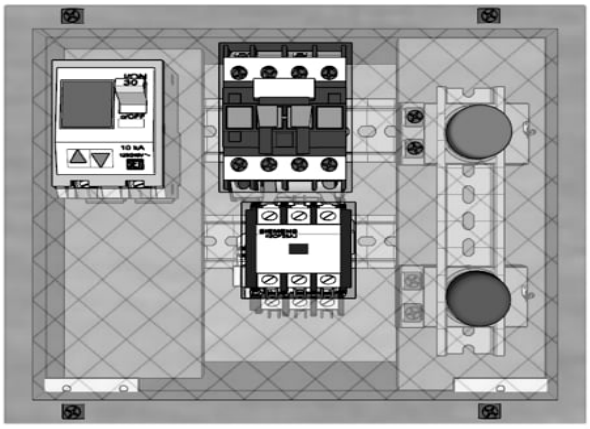

Figure 3 Technical Design

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Evaluation Procedures

Evaluation is a way to determine the acceptability of the proposed project. Selected people were asked to rate the performance of the device. These respondents were composed of selected residents and experts residing in San Francisco Surigao del Norte. Prior to the actual demonstration/evaluation of the device, the researcher explained the function of the device as well as its specification of the prototype. Before the evaluation sheet was given to the respondents, its content was discussed by the researchers. When the evaluation has been accomplished, the result was tabulated and computed to find the mean of every criterion as well as the overall mean. The respondents will then evaluate the said proposed project based on usability, quality of design, functionality, safety, and efficiency. Another evaluation sheet is provided where respondents can write their comments and suggestions for further improvement of the device.

IV. RESULTS AND DISCUSSIONS

This part presents the project description, capabilities and limitations, project test results, and the final evaluation.

Acceptability of the device in terms of Functionality

Criteria and Statement	Mean	Qualitative Description
A. Functionality		
Function of the device is meet as it expected.	4.25	**Excellent**
The device performs the task effectively.	4.32	**Excellent**
The device has a minimal error.	4.25	**Excellent**
The device can be enhanced or updated.	4.45	**Excellent**
The quality and consistency of the device's outputs	4.45	**Excellent**
Average	4.34	**Excellent**

The table assesses the "Functionality" criterion using five different claims regarding the device's performance and functionality. Every claim describes a distinct aspect of the device's functionality. The "Mean" column displays the average ratings or scores given to each statement. For example, Statement 1 received an average score of 4.25, Statement 2 received an average score of 4.32, and so forth. The mean score is the overall assessment of each statement's functionality. The "Qualitative Description" column provides a qualitative assessment or description of each statement based on its mean score. In this case, Statements 1 through 5 received the rating of "Excellent," indicating that they were well-reviewed and produced excellent work. According to this data, the device's functionality was evaluated favorably. For statements 1 through 5, which speak to the equipment's ability to fulfill tasks effectively and satisfy expectations, the device received an "Excellent" grade.

Acceptability of the device in terms of Applicability

B. Applicability	Mean	Qualitative Description
The device's effectiveness in specific real-world applications or environment.	4.52	Excellent
The device meets the needs of intended user group.	4.60	Excellent
The device withstands the specific environmental and usage conditions of its intended application.	4.45	Excellent
Measure how quickly and easily users can adopt the device, considering factors like training requirements and the user interface's intuitiveness.	4.35	Excellent
Level of maintenance required for the device and the availability of user support and resources.	4.45	Excellent
Average Mean	4.47	Excellent

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The respondents' opinions, which evaluate the "Applicability" criterion based on five different claims on the device's suitability and adaptability to different applications and user needs, are shown in the table. The "Mean" column displays the average ratings or scores given to each statement. For example, the average score for Statement 1 was 4.52, the average score for Statement 2 was 4.60, the average score for Statement 3 was 4.45, the average score for Statement 4 was 4.35, and the average score for Statement 5 was 4.45. The mean score is the overall assessment of each statement's applicability. The "Qualitative Description" column provides a qualitative assessment or description of each statement based on its mean score. In this case, statements 1 through 5 were both rated as "Excellent," indicating that they were exceptional and either met or exceeded safety standards. According to this table, the applicability of the gadget was deemed favorable. Statement 1 claims that the device works well in a certain real-world setting or application. received an "Excellent" grade, meaning it is appropriate for a certain use or function. According to Statement 2, the device satisfies the demands of the target user group and was given an "Excellent" grade, indicating that it can meet the needs and preferences of its users. The remaining criteria for the gadget were rated as outstanding, indicating that it meets all expectations for application.

Acceptability of the device in terms of Durability

D. Durability	Mean	Qualitative Description
1. The device withstands physical forces, including compression, tension, and torsion.	4.50	Excellent
2. The device's performance under various environmental stresses, such as temperature extremes, humidity, dust exposure, and water resistance.	4.45	Excellent
3. The materials used in the prototype behave under repeated use over time, which may include abrasion resistance and wear testing.	4.35	Excellent
4. Device performance under high and low temperature conditions.	4.50	Excellent
5. Device longevity and performance of the battery under typical usage conditions, including charge/discharge cycles.	4.50	Excellent
Average Mean	4.46	Excellent

Five different claims on the unit's capacity to tolerate high temperatures, resist deformation, and be well-designed are used in the table to assess the "durability" criterion. The "Mean" column displays the average ratings or scores given to each statement. For example, both Statements 1 and 5 received outstanding results. These demonstrate how each assertion's device durability is assessed generally and is shown by the mean score. The "Qualitative Description" column provides a qualitative assessment or description of each statement according to its mean score. In this case. Statements 1 through 5 were rated as "Excellent," indicating that they were highly acclaimed and had the best possible design. Based on the data in this table, it was concluded that the device's durability was favorable. Statements 1 through 5 focus on the device's ability to withstand physical forces like compression, tension, and torsion; its performance under different environmental stresses; how the prototype behaves under repeated use over time, including wear testing and abrasion resistance; and the battery's longevity and performance under typical usage conditions, such as charge/discharge cycles. The device received an "Excellent" rating, meaning that it showed the best resilience and maintained its shape under a variety of conditions.

Acceptability of the device in terms of Safety

Three particular claims are used in the table to assess the "Safety" criterion: the device has an emergency shutoff mechanism, there are no toxic substances present, and protection is provided. Mean: The "Mean" column displays the average rating or score for each statement. For example, the average score for Statement 1 was 4.15, the average score for Statement 2 was 4.20, and the average score for Statement 3 was 4.15. Statement 5 received a score of 4.15, whereas Statement 4 received an average score of 4.30. The mean score is the overall assessment of the safety of each statement.

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E. Safety	Mean	Qualitative Description
1. The device has an emergency shutoff mechanism, warning indicators, and user manuals for safety usage.	4.15	Very Good
2. Device absence from harmful substances, such as battery leaks or toxic materials.	4.20	Very Good
3. The physical design of the device to identify sharp edges, pinch points, or moving parts that could pose risks during use.	4.15	Very Good
4. The device potential electrical hazards, including short circuits, overloads, and proper grounding.	4.30	Excellent
5. The device's ability to manage heat during operation.	4.15	Very Good
Average Mean	4.19	Very Good

The "Qualitative Description" column provides a qualitative assessment or description of each statement based on its mean score. In this case, all five of the statements received the rating "Very Good," meaning that they were well-reviewed and believed to contain adequate safety measures.

Based on the information in this table, it was determined that the device was sufficiently safe. Statement 1, the device was rated as "Very Good" and features an emergency shutoff mechanism. This indicates that a shutdown mechanism built into the equipment would immediately stop it if it met any issues while in use. This is supported by Statement 2, which was rated as "Very Good" as well. The device's lack of dangerous components and battery leakage demonstrates that every aspect of safety was carefully taken into account during development to guarantee that the user would not suffer any harm. Statement 3 states that any moving parts, pinch points, or sharp edges that could be hazardous to use are identified by the device's physical design. This demonstrates the device's degree of safety as well as its ease of use. Statement 4 demonstrates how potential electrical hazards to the device, including overloads, short circuits, and proper grounding, are considered during the fabrication process. Making the device safer to use is one of the main objectives. Finally, the device's ability to regulate heat during operation is considered during the manufacturing process (statement 5). This will include the device's ability to withstand any room temperature and to continue to perform without worry in the event that it breaks or malfunctions.

V. SUMMARY

This study aimed to evaluate the effectiveness of the proposed project, which is a development of power management system device. It focuses on the primary usage, functionality, applicability, durability and safety aspects of the project, as well as how it effectively assists people through innovative means.

The project is tested out of 40 respondents that has knowledge regarding electricity, enough to understand the flow of the project its material used, functions, usage and how it works.

VI. FINDINGS

Based on the comprehensive evaluation of the device the following key findings have emerged:

1. Functionality Excellence:

The prototype exhibited exceptional functionality, earning an excellent rating. This indicates a high level of effectiveness in power management system that can detect electrical faults and the ability to react when high and low voltage occur.

2. Applicability Across Diverse Settings:

The device exhibits versatility and adaptability, receiving high ratings for both residential and commercial applications. It effectively addresses specific needs, accommodates user requirements, and provides a safe and practical learning experience in the field of power management system.

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3. Workability and Accessibility:
The device was well-agreed by users, who were satisfied with its workability and the availability of expertise, materials, tools, and support resources. While the tool's ability to provide valuable educational experiences received a slightly lower score, it presents an opportunity for further improvement.
4. Durability:
The device was highly regarded by users for its durability, demonstrating strong resistance to deformation, high temperatures, and environmental factors. This resilient framework ensures the tool's longevity, making it suitable for long-term use.
5. Safety User:
The prototype was highly regarded by users for its emphasis on safety. By eliminating sharp edges, avoiding toxic materials, and incorporating safety features like adequate protection and clear instructions, the device prioritizes user well-being, making it suitable for educational environments.

VII. CONCLUSIONS

In conclusion, studying power management systems (PMS) in residential and commercial establishments highlights their critical role in optimizing energy consumption, reducing costs, and enhancing sustainability. These systems enable efficient load management, peak shaving, and integration of renewable energy sources like solar panels, helping households and businesses lower electricity bills and carbon footprints. Smart metering, automated lighting, and HVAC controls further improve energy efficiency in these settings. However, challenges such as high upfront costs, user adaptability, and the need for regular maintenance may limit widespread adoption. Despite these barriers, the growing demand for energy-efficient solutions and advancements in IoT-based monitoring make PMS indispensable for modern buildings. Future developments should focus on affordability, user-friendly interfaces, and seamless integration with existing infrastructure to encourage broader implementation in both residential and commercial sectors.

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