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Exploring Multi-Output Power Station With Diverse Charging Input

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A B S T R A C T

The study explores the efficiency and versatility of a power station with multiple charging inputs—solar, AC, and car charging—and various output ports. This design ensures compatibility with numerous devices, making it ideal for outdoor activities, emergencies, and off-grid living. The modular construction allows for easy upgrades. Environmentally, it supports sustainable practices through renewable energy use, while economically, it offers long-term savings by reducing reliance on traditional power sources. User-friendly features and robust safety mechanisms enhance the experience. The prototype can support 12-volt appliances up to 60 amps, AC appliances under 500 watts, and Type-C devices up to 65 watts, with a USB port delivering 24 watts. This study is pivotal for advancing sustainable energy systems.

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INTRODUCTION

In this research, a multifunction hand-crank power station was developed. It has multi-purpose, portable, and lightweight capacities, setting it apart from previously developed devices. The main purpose of the research is to examine the efficiency and versatility of a power station equipped with multiple charging inputs (solar, AC, and car charging) and various output ports. This study focuses on designing a system that is compatible with a wide range of devices, making it useful for outdoor activities, emergencies, and off-grid living. The research addresses the problem of dependency on traditional power sources by proposing a solution that utilizes renewable energy, particularly solar power, to reduce reliance on non-renewable energy. By exploring a modular design, the power station can be easily upgraded, offering long-term economic benefits by reducing the need for grid-based power. It also supports sustainable practices, contributing to environmental preservation. The ability to charge various types of devices further increases its practicality and appeal. Ultimately, the study aims to advance sustainable energy systems by providing an efficient, user-friendly, and safe alternative to conventional power sources, catering to a diverse range of user needs and situations.

The need for sustainable and portable energy solutions has become increasingly critical in the modern era, driven by the necessity for reliable power in off-grid and emergency scenarios. Hand-crank power stations, a form of human-powered energy generation, represent a practical response to these needs by harnessing mechanical energy produced by manual cranking and converting it into electrical energy, capable of powering small electronic devices and providing a backup power source during outages. A typical hand-crank power station consists of a crank mechanism connected to a dynamo or alternator, which converts rotational mechanical energy into electrical energy through electromagnetic induction, with the generated electricity regulated and stored in a battery or used directly to power devices. Modern designs often incorporate additional features such as USB ports, built-in batteries, LED lights, and digital displays to enhance functionality and user convenience.

owever, past studies have highlighted several problems with hand-crank power stations, including low efficiency and limited power output, making them suitable only for small devices. The physical effort required for cranking can lead to user fatigue, and poor ergonomic design can exacerbate discomfort . Additionally, many models lack alternative charging options, relying solely on manual cranking. Durability issues, such as the rapid wear and tear of mechanical components and insufficient build quality, further impact their reliability. Inadequate energy storage and inefficient charge retention reduce their effectiveness as a power source. Moreover, complex interfaces and the absence of clear indicators for charge status and power output hinder user experience. High costs limit accessibility, and compatibility issues with modern devices present additional challenges. These factors have constrained the broader adoption and development of hand-crank power stations.

Addressing these challenges involves improving efficiency, design, durability, and user interfaces, along with integrating better energy storage solutions and increasing market awareness. These efforts aim to make hand-crank power stations more viable and user-friendly, enhancing their role in providing sustainable and portable energy solutions. With the increasing need for power in remote locations, during recreational activities, or in off-grid scenarios, hand-crank power stations offer a promising solution. Based on the literature, hand-crank-based battery is not new since there are studies reviewed by the researchers to identify the pattern of development of the device. Also designed is a battery charger for a portable human-powered generator, which is physiologically designed for males and can generate 100w using feet cranking motions. However, despite the numerous advantages and potential applications, several general and specific issues need to be addressed to enhance the efficiency, durability, and adoption of hand-crank power stations.

LITERATURE REVIEW

A hand-held tool for converting mechanical energy produced by human beings into electrical power is a hand-crank generator. The generator mechanism usually contains a handle (crank). As the user turns the crank, electricity is generated through mechanical energy that can be used to charge batteries or power devices connected to it.

When it comes to emergency sources of energy, options are very scanty. Hand-cranked systems are perhaps the simplest, most dependable, and among the oldest ways of generating energy. This technology could be used to power mobile devices, hence enabling communication and other important services. The research by E. Max and J. Berman has illustrated that hand-cranked generators have proved effective in providing electricity to areas with limited grid access, such as remote regions. This paper aimed to design and build a multi-purpose mechanical energy charger that can be used in emergencies and in the development of environmentally friendly technology. Design presentation is such that any person with similar components can create a portable manual phone charger. Previously, efforts were made to design devices liked this by other people but all of them do not have some qualities highlighted. Some chargers need built-in power-storing components. Advancements in hand crank technology are geared towards improving efficiency and power output. Research explores design optimization and the use of advanced materials to enhance generator performance. Integrating solar panels with hand cranks for a hybrid charging solution is gaining traction. This approach offers greater flexibility and the potential for higher power generation, catering to a wider range of devices.

Commercially available hand-crank power banks typically lack AC outlets. Existing products focus on USB outputs for charging low-power devices like smartphones. However, research suggests a growing interest in user-friendly and versatile solutions, particularly for off-grid scenarios and emergency preparedness. In the provided design, the user turns the handle at 200 r.p.m., and the battery will charge. Overload protection and automatic shut-off mechanisms are essential to prevent equipment damage and user injury when it reaches 50 degrees Celsius. In general, charging a phone requires 3.6 to

5 volts dc and 180 to 700mA. A good size for this device is important because it is intended to be used in cases of emergency where people would need to charge their phones while on the move. The articles before did not meet this limitation since they had massive chargers requiring separate bags for carrying them. Technology is of great importance to disaster relief efforts, especially for people who live in areas where electricity is accessible. More research should be conducted on how to make the user experience better. One way of doing this is by refining hand-crank design ergonomics and even considering adjustable power output levels as part of it.

Hand-crank power banks are an emerging sustainable energy source. The technology has the potential to become a key player in addressing the limitations in terms of power output, user experience and possibly integrating with renewable sources for a more sustainable future that caters to a wider audience, promotes energy independence, and environmentally friendly practices

METHODOLOGY

The study employed a combination of design and testing methods focused on optimizing both the input and output performance of the power station.

For the charging inputs, solar, AC, and car charging methods are evaluated to ensure maximum energy efficiency and compatibility. Solar panels are tested under various weather conditions to assess their reliability, while AC and car inputs are analyzed for their charging speed and efficiency.

Regarding output ports, the system is tested with a range of devices, from 12-volt appliances to Type-C and USB-powered devices, ensuring that each port can deliver the necessary wattage (up to 60 amps for 12-volt appliances, 500 watts for AC appliances, 65 watts for Type-C devices, and 24 watts for USB). This is done by monitoring performance under different loads and conditions to confirm consistent power delivery.

The modular design is examined for ease of upgrade, ensuring that components can be replaced or improved without extensive reconfiguration. Safety mechanisms, such as overcharge protection and surge protection, are incorporated and tested to prevent malfunctions and ensure the robustness of the system.

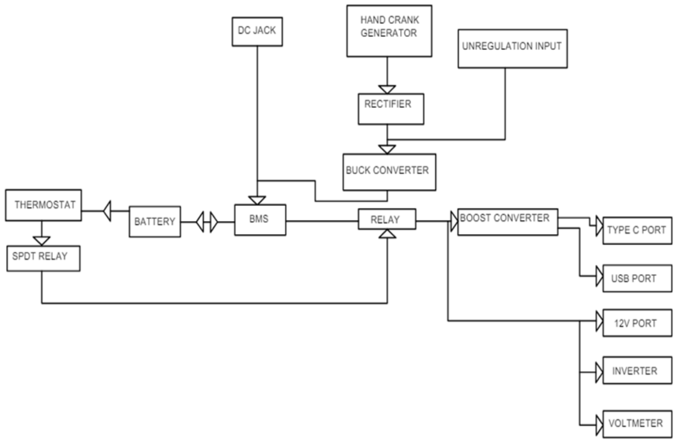

Figure 1: Block Diagram of the System

Figure 1 is the block diagram of the system. The power bank can be charged through its DC jack with a regulated 14.2v, via solar in its unregulated port, or by using its hand-crank terminal. The unregulated voltage from the solar or hand-crank generator is then regulated by the buck converter. The regulated power from the DC jack goes directly to the BMS. Once all inputs are at 14.2v, the BMS controls the battery charging rate, storing energy until needed, and the power IC's convert the 12.8 Vdc to the required power.

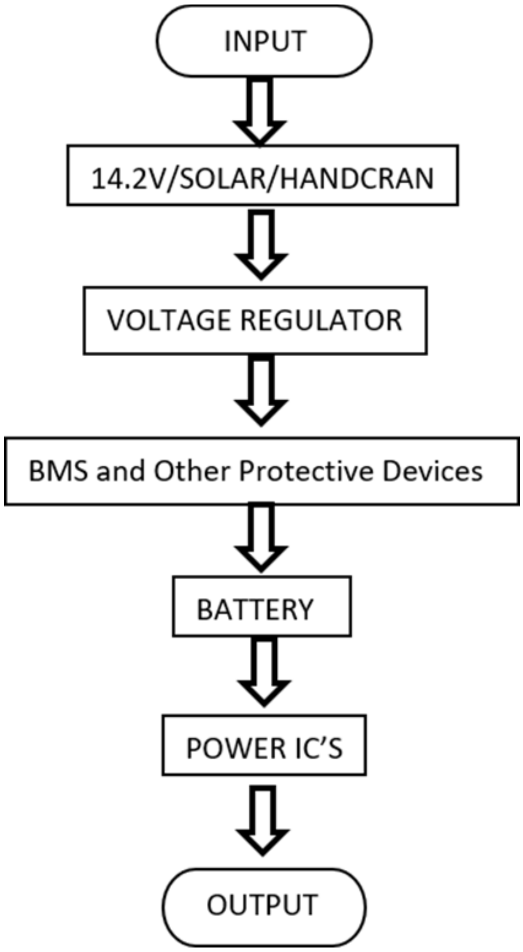

Figure 2. Flow Chart of the System

Figure 2 is the flow chart of the system. The power bank can charge by a regulated 14.2v on its DC jack or solar in its unregulated port or on its hand-crank terminal. After that, the unregulated voltage from the solar or the hand-crank generator will be regulated by the buck converter. The power from the regulated DC jack will go straight to the BMS, and then if all input is at 14.2v, the BMS will control the charging rate of the battery. It will store the energy that needs to be released, and the power ICs will convert the 12.8vdc to the needed power.

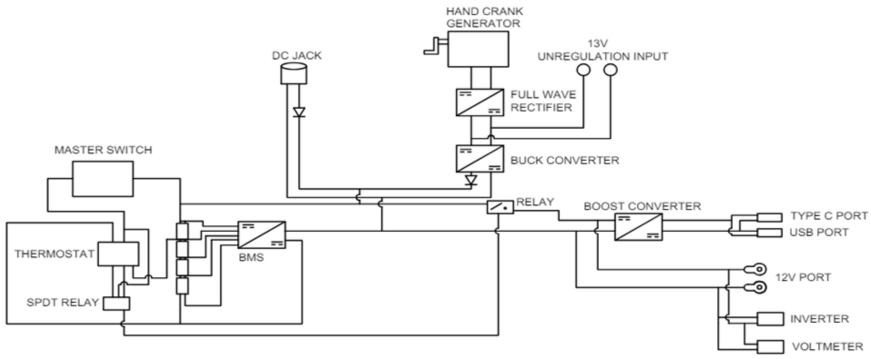

Figure 3. Schematic Diagram of the System

Figure 3 is the schematic diagram of the system. The power bank offers versatile charging options, allowing it to recharge through a regulated 14.2v input on its DC jack, harness solar energy via its unregulated port, or utilize its hand-crank terminal. In the case of solar or hand-crank charging, the unregulated voltage is carefully managed by the buck converter. The regulated power from the DC jack seamlessly feeds into the Battery Management System (BMS). Once all inputs stabilize at 14.2v, the BMS takes charge, skillfully controlling the charging rate of the battery. The battery acts as a reservoir, storing the accumulated energy until it is required for use. Finally, the power IC's efficiently convert the stored 12.8vDC to the specific power requirements, ensuring a reliable and tailored power output.

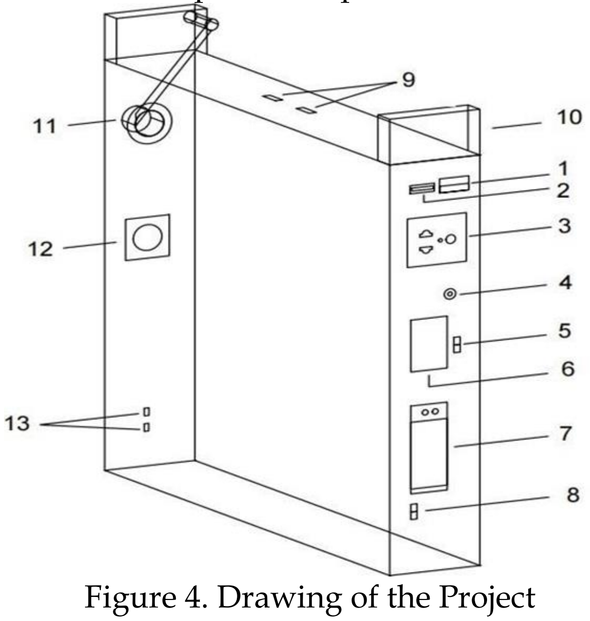

Figure 4. Drawing of the Project

Figure 4 is the system design. The (1) type c port is used to power the type c devices that use 5v3amp, 9v3amp, 12v3amp, and 20v3.25amp. The (2) USB port is used to power the USB devices that use 5v3.4amp, 9v2.5amp, and 12v2amp. The (3) AC outlet powers the appliances that need AC power; it can give up to 280 VA of pure sine wave power. The (4) DC jack is where the regulated power from the outlet goes. The (5) AC master switch is used to turn on and off the AC power to save power. The (6) inverter voltmeter shows the voltage going in the inverter. The (7) system voltmeter analyzes the battery status based on its voltage. The (8) master switch is used to turn on and off the whole power bank, (9)12v out, (10) handle, and (11) hand crank handle. The (12) system fan is used to circulate air inside the system, and the (13) unregulated port accepts any 14v to 46v input.

RESULT AND DISCUSSION

Table 1. Performance output of AC port

Battery Voltage	Load	Sine Wave Form	Outlet Voltage
12.8 V	0 Watts	Good	225 V
12.6 V	34.5 Watts	Good	230 V
12.5 V	57.5 Watts	Good	230 V
11.5 V	313.9 Watts	Good	215 V

Table 1 shows that the system voltage produced 12.8 Volts with 0 Watts for its starting value, and the sine wave displays a good performance. Also, when 12.6 Volts was rated, 34.5 Watts was the outcome for a 230 Volts AC supply. The same of a 12.5 Volts, which displayed an amount of 57.5 Watts for an outcome of good sine wave resulting in a 230 Volts supply. Lastly, 313.9 Watts was produced when 11.5 Volts was generated and resulted in a voltage of 215 volts, which is already a sign of a good sine wave rating.

Table 2. Performance output of AC port

Trial No.	Load	Battery Voltage	Outlet Voltage	Time Duration (Minutes) (100% to 0%)
1	60 W Fan	12. 8 V	230 V	272
2	60 W Fan	12. 8 V	230 V	273
3	60 W Fan	12. 8 V	230 V	268
4	60 W Fan	12. 8 V	230 V	271
5	60 W Fan	12. 8 V	230 V	274
6	60 W Fan	12. 8 V	230 V	272
7	60 W Fan	12. 8 V	230 V	277
8	60 W Fan	12. 8 V	230 V	274

Table 2 shows that the output voltage varies depending on the time consumed. It shows that different data were gathered upon testing it. The different data includes the battery running on it based on their time consumption. This supplied a varying level of data when it was tested for its own specific duration.

Table 3. Performance output of USB port

Power Source	**Time (83%-88%)**
Outlet 45 W Adaptor	2:29
Power Bank 24 W Module	4:37

Table 3 represents the outcome of the USB socket. With the use of an outlet that was timed for 2 minutes and 29 seconds, a smartphone was utilized for charging and gathered a result from 83% to 88% charging time. On the other hand, the use of hand-crank power bank provided a charging time of about 4 minutes and 37 seconds with the same battery percentage.

Table 3. Performance output of USB port

Trial No.	**Quantity of Phones that can be fully charged from 0%-100%**
1	13
2	14
3	12
4	14
5	12

Table 3 represents the outcome of the USB socket. With the use of an outlet that was timed for 2 minutes and 29 seconds, a smartphone was utilized for charging and gathered a result from 83% to 88% charging time. On the other hand, the use of hand-crank power bank provided a charging time of about 4 minutes and 37 seconds with the same battery percentage.

Table 4. Number of Phones (5000 mAh) that can be energized through USB port

Trial No.	**Quantity of Phones that can be fully charged from 0%-100%**
1	13
2	14
3	12
4	14
5	12

Table 4 presents the total number of phones that can be fully charged, ranging from 0%-100%.

Table 5. Number of laptop (65 wHr) that can be energized through type C port

Trial No.	**Quantity of Laptop that can be fully-charged from 0%-100%**
1	3
2	4
3	4
4	3

5	3

Table 5 presents the total number of laptops that can be fully charged, ranging from 0%-100%.

Table 6. Efficiency of hand-crank generator

Speed	**Power**
200 rpm	8.3 W
150 rpm	4.8 W
120 rpm	4 W

Table 6 provides the efficiency of a hand-crank generator based on different levels of speed and power in calculating the ampere rating of the hand crank. With an increasing amount of amperage starting from 120 rpm with a rating of 0.28 amperes to 150 rpm for a slightly higher current output of 0.33 ampere until the peak speed with a 200 rpm was generated, a total of 0.57 ampere was evaluated. With this, the total amperage increases for a higher generated speed of the system.

Table 7. Charging time of the System

Charging time (Minutes)	**Charged %**
265	100
270	100
268	100
266	100
258	100

Table 7 shows different trials in which a system can be charged from 0%-100%.

Table 8. Efficiency of Unregulated Plug

Input Voltage	Power
16 V	35 W
20 V	44 W
30 V	44 W

Table 8 provides the efficiency of unregulated plug based on the input voltage and power. It shows that when the input power is 44 W, the input voltage can be 20 V and 30 V. This is because the limit input current that can be processed is 3 Amperes to avoid overload.

CONCLUSIONS AND RECOMMENDATIONS

The research on the multiple charging input and output power station demonstrates significant advancements in efficiency, versatility, and practical application across various scenarios. The device's ability to utilize multiple inputs—solar, AC, and car charging—along with its multiple output ports ensures broad compatibility with numerous devices. This makes the power station particularly valuable for outdoor activities, emergencies, and off-grid living. Its modular design facilitates easy upgrades, supporting sustainable practices through renewable energy use and offering long-term economic savings by reducing dependency on traditional power sources. User-friendly features and robust safety mechanisms further enhance the overall user experience, establishing this project as a crucial component in advancing sustainable and resilient energy solutions.

The developed multifunction hand-crank generator exhibits robust performance by supplying power to various appliances and devices. Specifically, it can support 12-volt appliances with ampacity below 60 amps, maintaining acceptable voltage levels even when ampacity reaches 24 amps. The AC port can deliver up to 500 watts, with voltage drops occurring only at 280 watts, while the Type-C and USB ports efficiently handle devices with specific ratings. The power bank's efficient charging capability, at a regulated input in 270 minutes and an unregulated input at 16 volts, highlights its practicality and effectiveness.

To further enhance these features, several recommendations can be made for future researchers working on similar themes. One key recommendation is to use a battery with larger capacity, which would extend the operational duration and optimize performance. Additionally, customizing and combining power bank modules can reduce components and costs, particularly through the employment of a microcontroller. Creating a custom PCB would also contribute to a more professional appearance and streamlined design. Finally, improving the device's durability and aesthetics by developing a more durable and economically viable design would enhance its overall outlook.

ADVANCED RESEARCH

While this study presents significant advancements, it has certain limitations that warrant further investigation. One primary limitation is the reliance on manual cranking for power generation, which can cause user fatigue and limit long-term usage. Future research could explore integrating alternative charging mechanisms, such as kinetic or piezoelectric energy harvesting, to complement manual cranking and enhance user convenience. Furthermore, optimization of energy storage solutions by investigating advanced battery technologies could improve storage capacity and efficiency. Developing ergonomic solutions to reduce user fatigue and improve the user experience during prolonged use is also essential. Additionally, exploring the incorporation of smart technologies, such as IoT connectivity, could enable remote monitoring and management of the power station. Investigating ways to further reduce production costs without compromising quality would make the power station more accessible to a broader audience.

By addressing these limitations and exploring these research avenues, future studies can continue to enhance the functionality, efficiency, and userfriendliness of hand-crank power stations, contributing to the broader adoption of sustainable and portable energy solutions.

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