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Design of a Portable Power Supply with Real-Time Monitoring Using KL Series Battery Monitor

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Abstract

The demand for portable and environmentally friendly power supply systems is increasing due to the growing need for efficient and sustainable energy usage. Most of the existing power supply systems lack comprehensive real-time monitoring of electrical parameters such as voltage, current, and actual power consumption. This study aims to design a portable power supply prototype capable of powering DC devices while monitoring power usage in real time using the KL Series Battery Monitor. The methodology includes technical design and experimental testing to evaluate energy efficiency under actual loads. The prototype incorporates five core elements: a rechargeable system, electronic circuit breaker (BMS), automatic blower, green materials, and a $LiFePO_4$ based energy storage unit. Performance evaluation was conducted through load testing with various DC devices including a stand fan, LED lamp, light bulb, and phone charger. Findings show efficiency instability during initial use and high-startup load. However, real-time voltage-current monitoring and proper thermal design help reduce negative effects. The system's average power efficiency is approximately 89.4%, indicating stable performance for medium-duration applications. The findings confirm that the prototype meets its intended objectives in terms of energy efficiency, safety, and environmental sustainability. This solution demonstrates strong potential for use in off-grid applications, green education tools, and portable power systems in various community settings.

Keywords: - Portable power supply, real-time monitoring, kl series battery monitor, lithium iron phosphate ($LiFePO_4$), efficiency

1. Introduction

The increasing demand for portable and environmentally friendly power supplies is driven by the rapid growth of mobile electronic devices, renewable energy adoption, and off-grid applications (Nguyen & Boström, 2021). Portable power supplies must be efficient, safe, and reliable to meet users' expectations for mobility and sustainability. Lithium Iron Phosphate ($LiFePO_4$) batteries have emerged as a preferred technology due to their superior thermal stability, long cycle life, and safety features compared to traditional lithium-ion batteries (Smith, 2022).

Despite advances in battery technology, many existing portable power supply systems lack comprehensive real-time monitoring capabilities for electrical parameters such as voltage, current, and power consumption. This absence makes it difficult to optimize energy usage, ensure safety, and extend battery life (Sarker et al., 2024). Furthermore, users are often unaware of actual power consumption, which may lead to inefficient energy management and unexpected device shutdowns.

This study aims to address these challenges through the following objectives:

i. To design a portable power supply prototype based on $LiFePO_4$ battery technology.
ii. Monitor the power consumption (watt) of each device using the battery.

iii. To evaluate the energy efficiency of the prototype through load testing with DC devices.

The development of a portable power supply with real-time monitoring has broad applications, including portable energy solutions for outdoor activities, emergency power backups, STEM educational tools, and off-grid systems that promote green and sustainable technologies (Lee & Choi, 2019; Wang et al., 2022). Real-time data monitoring allows users to manage energy consumption proactively and improve system reliability.

2. Literature Review

2.1 Lithium Iron Phosphate ($LiFePO_4$) Battery

Lithium Iron Phosphate ($LiFePO_4$) batteries have become widely used as energy storage solutions because of their high thermal stability, long cycle life, and enhanced safety compared to conventional lithium-ion batteries. Smith (2022) reported that $LiFePO_4$ batteries provide stable voltage output and are less prone to overheating, which makes them ideal for portable power applications. Their relatively flat discharge curve ensures consistent energy delivery, a critical feature for sensitive electronic devices. Other studies have also emphasized the environmental advantages of $LiFePO_4$ chemistry, including non-toxicity and recyclability (Chen et al., 2020). Table 1 shows the five (5) key characteristics of $LiFePO_4$ batteries.

Table 1: Summary of $LiFePO_4$ batteries characteristics

Author	Characteristics	Description
Smith, (2022)	High thermal stability	They can operate safely at higher temperatures without risk of thermal runaway.
	Stable voltage output	Providing a nearly flat discharge voltage curve (~3.2–3.3 V per cell), which ensures reliable power delivery.
Chen et al., (2020)	Long cycle life	Capable of more than 2000 charge-discharge cycles while maintaining capacity, making them cost-effective over time.
	Safety	Less prone to overheating and combustion compared to other lithium-ion chemistries, reducing fire hazards.
Smith, (2022) Chen et al., (2020)	Environmental friendliness	Composed of non-toxic materials and easier to recycle, contributing to greener energy solutions.

2.2 Real-Time Monitoring Using KL Series Battery Monitor

Real-time monitoring enhances battery management by providing continuous data on voltage, current, state of charge (SoC), and power. The KL Series Battery Monitor is a reliable commercial system that supports precise tracking of battery health and power consumption (Sarker et al., 2024). Such monitoring allows for proactive energy management and prevention of unexpected power failures.

2.3 Power Consumption and Efficiency

Accurate measurement of power consumption is vital for optimizing energy use and extending battery lifespan (Nguyen & Boström, 2021). System efficiency is the ratio of useful power output to power input, with higher efficiency reducing energy losses. Portable power supplies require efficient designs to maximize battery life and minimize heat generation (Lee & Choi, 2019).

2.4 Voltage and Current Monitoring

Voltage stability is essential to prevent device damage due to voltage fluctuations. Current monitoring helps detect overloads and manage power distribution effectively (Sarker et al., 2024). Together, voltage and current measurements are necessary for precise power calculation and system diagnostics.

$$P = V \times I \tag{1}$$

Where P is power in watt, V is voltage in volts, and I represent current in ampere.

2.5 Power Input and Output

Monitoring both power input (energy supplied by the battery) and power output (energy delivered to loads) enables evaluation of system efficiency and identification of energy losses caused by internal resistance and conversion inefficiencies (Wang et al., 2022; Chen et al., 2020).

$$\text{Power Efficency} = \frac{P_{out}}{P_{in}} \text{X } 100 \tag{2}$$

Where P_{out} is output power and P_{in} is input power.

3. Methodology

The methodology of this study consists of two main components: namely technical setup and experiment setup, designed to achieve the objectives of Design of a Portable Power Supply with Real-Time Monitoring Using KL Series Battery Monitor.

3.1 Technical Setup

The main technical setup required for this paper includes power source, monitoring module, load devices, and sensors & interface. Table 2 shows the system design for technical setup for this study.

Table 2: System design for technical setup

Item	Description
Power Source	Rechargeable 12V lithium-ion battery
Monitoring Module	Bluetooth-based Battery Monitor KG104F.
Load Devices	Stand fan, LED lamp, mobile phone, light bulb
Sensors & Interface:	Integrated voltage and current sensors track and transmit real-time data to a connected app via Bluetooth

3.2 Experiment Setup

Various direct current (DC) devices were connected to the power supply prototype. Load testing was performed to measure power consumption and efficiency. Real-time data from the KL monitor were logged and analyzed to evaluate system performance under different load conditions. Each load configuration is tested individually and in combination with *V*, *I*, and *W* monitored at fixed intervals. Table 3 shows the step for experiment setup and Table 4 shows the experiment setup with different load.

Table 3: Step for experiment setup

No.	Step
1.	Monitor the power consumption (watt) of load using the battery
2.	Record the total usage time of the battery during load testing.
3.	Track the real-time voltage and current curve between battery and load.

Table 4: Experiment setup with different load

Experiment	Load	No. of Monitoring
1	Stand fan	4
2	LED lamp	11
3	Stand fan and LED lamp	4
4	Phone charging	8
5	Light bulb	7

4. Result and Discussion

4.1 To Design a Portable Power Supply Prototype Based on $LiFePO_4$ Battery Technology

Based on the first objective, five (5) key elements were identified in the design of a portable power supply based on $LiFePO_4$ battery technology characteristics. Table 5 shows the portable power design result for this study.

Based on the first objective, five (5) key elements were identified for the development of a portable power supply using LiFe battery technology: (i) re-charge, (ii) Electronic Circuit Breaker Technology, (iii) Automatic Blower, (iv) Green Technology and (v) Energy Storage Unit. These elements collectively support the development of a sustainable, efficient, and safe energy supply solution.

Table 5: Portable power design

Element	Characteristics	Technical Design
Re-charge	• Stable voltage output • Long cycle life • Environmental	Able to store electricity using solar energy or electrical supply.
Electronic Circuit Breaker Technology	• Safety • Stable voltage output	Use Battery Management Systems (BMS) to monitor and regulate battery charging and discharging.
Automatic Blower	• Safety	Overheating protection
Safe materials	• Environmental	Non-toxic Non-polluting/ Environmentally friendly/Non-contaminating Raw materials from various sources/Raw materials from diverse sources
Green technology	• Environmental	Saving energy Environmental protection Sustainable material sources)
Energy storage unit	• Stable voltage output • High thermal stability • Long cycle life	Long lifespan (7–8 years) Cycle life exceeding 2000 cycles High temperature resistance: can withstand 350–500 °C

4.2 Monitor the Power Consumption of Each Device Using the Battery

This experiment aimed to evaluate the energy consumption and performance of several common household electrical devices: a stand fan, LED lamp, phone charger, and light bulb, both individually and in combination. The analysis included usage time, power consumption, energy used, and average power output. Table 6 shows the power consumption summary in this study and Fig. 1 shows the system design for technical setup for this study.

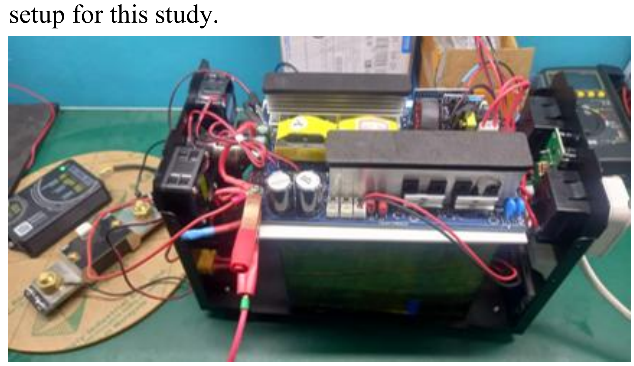

Fig. 1: The system design for technical setup

Table 6: Power consumption summary

Experiment	Usage time (Minute)	Power Consumption (Watt)	Energy Used (Wh)	Average Power Output (Watt)
Stand fan	120	58.6	117.2	92.33
LED lamp	360	17.14	102.84	96.17
Stand fan and LED lamp	40	56.86	45.49	101.63
Phone charging	480	35.72	285.76	76.81
Light bulb	420	29.83	208.81	92.42

a) Experiment 1 (Stand Fan)

The findings show that the energy used for the stand fan was 117.2Wh over a period of 120 minutes, while the recorded power consumption was 58.6 W. The recorded average power output (92.33 W) exceeds the measured power consumption, which may suggest transient power surges during operation or inaccuracies in measurement. According to Babich et al. (2017), electric fans can exhibit short bursts of higher power during start-up, which contributes to discrepancies in measured average power.

$$\text{Average Power} = \frac{\text{Total Pout}}{\text{No. of Monitoring}} \quad (3)$$

$$\text{Power Consumption} \times \frac{\text{Time(min)}}{60} \quad (4)$$

b) Experiment 2 (LED lamp)

The findings show that the energy used for the stand fan was 102.84Wh over a period of 360 minutes, while the recorded power consumption was 17.14 W. Despite being low power, the LED lamp accumulated significant energy usage due to prolonged operation. However, the average power output of 96.17W appears unusually high, possibly due to sensor or calculation error. LED lights are widely known for their high energy efficiency and long lifespan (Tsao et al., 2010). Typically, they consume 80% less energy than incandescent bulbs.

c) Experiment 3 (Fan and LED lamp)

The findings show that the energy used for the stand fan was 45.49Wh over a period of 360 minutes, while the recorded power consumption was 56.86 W. The combined operation for a short duration led to lower total energy consumption, but again the average power output (101.63 W) was unexpectedly high, which suggests an anomaly in output measurement. Combination loads can introduce non-linear power behavior, especially if devices have different startup characteristics (Li et al., 2019).

d) Experiment 4 (Phone charging)

The findings show that the energy used for the stand fan was 285.76Wh over a period of 480 minutes, while the recorded power consumption was 285.76 W. Phone charging, although low in power, resulted in the highest energy usage due to the long duration. This aligns with studies that show cumulative energy impact from long-term charging. According to a study by Green & Wilson (2020), frequent and prolonged charging cycles contribute significantly to residential energy demand, especially when chargers remain plugged in unnecessarily.

e) Experiment 5 (Light bulb)

The findings show that the energy used for the stand fan was 208.81Wh over a period of 420 minutes, while the recorded power consumption was 29.83W. The light bulb, running for an extended time, consumed a substantial amount of energy. The average power output (92.42W), again, seems inflated and may result from overestimated output or misinterpretation of sensor data. Traditional bulbs are less efficient compared to LED lighting and tend to convert more energy into heat rather than light (Mills, 2002).

Energy use is strongly influenced by usage duration, not just power rating. Devices with lower wattage can still consume high energy over long periods.

4.3 To Evaluate Energy Efficiency of The Prototype Through Load Testing with DC Devices

The results of this experiment are important to determine the success and feasibility of the developed system. Fig. 2 shows the track of the real-time voltage and current curve through load testing with DC devices for one of the experiments.

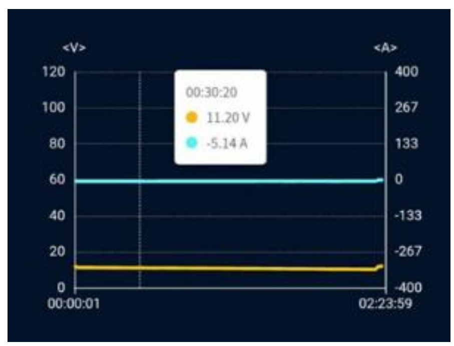

Fig. 2: Track of the real-time voltage and current curve through load testing with DC devices

a) Experiment 1 (Fan only)

Based on Table 7, the system consistently maintained power efficiency above 85%, with an average efficiency of 92.33% recorded throughout the experiment. This indicates that the prototype demonstrated stable and high energy conversion performance over the full operating period. Such sustained efficiency reflects excellent load-handling capability and minimal energy loss, consistent with findings by Zhou et al. (2020), who reported that well-designed DC energy systems can maintain efficiency levels exceeding 90% under stable load conditions.

Table 7: Result of Experiment 1

Time (Minute)	Voltage (V)	Current (A)	Power Input (W)	Power Out (W)	% Power Efficiency
30	11.2	5.14	58.60	57.57	98.24
60	11.01	5.03	58.60	55.38	94.51
90	10.76	4.95	58.60	53.26	90.89
120	10.48	4.79	58.60	50.2	85.67

As illustrated in Fig. 3, the power efficiency declined from 98.24% to 85.67% over time. This downward trend suggests increasing energy losses or a gradual reduction in system performance, likely caused by factors such as heat accumulation, component wear, or reduced input effectiveness during prolonged operation. Similar observations were made by Zhang et al. (2020), who identified thermal stress and operational fatigue as key contributors to efficiency degradation in extended DC system usage. Furthermore, Ali & Hassan (2019) noted that continuous current flow can reduce the conductivity of system components, ultimately affecting energy transfer efficiency, particularly in compact and renewable power configurations.

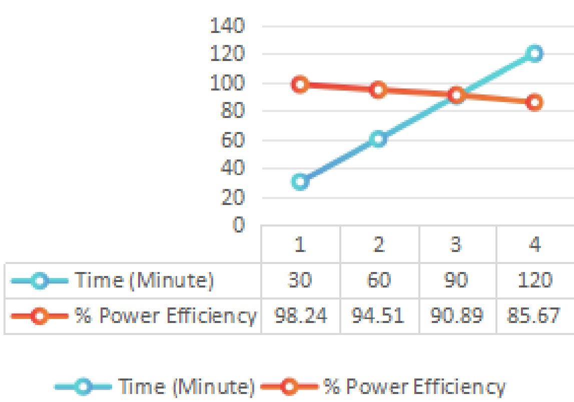

Fig. 3: Time vs power efficiency for Experiment 1

b) Experiment 2 (LED lamp)

Based on Table 8, the LED lamp exhibited minor fluctuations in current but maintained overall consistent operational performance. Notably, the system demonstrated over-performance at certain points, with efficiency reaching up to 109.16%, suggesting temporary spikes in power draw or sensitivity anomalies in measurement sensors. Across all recorded intervals, the system consistently maintained efficiency above 85%, reflecting reliable energy conversion and stable load handling. Efficiency values exceeding 100% may be attributed to limitations in sensor resolution or calibration drift, as highlighted by Choi et al. (2019), who reported the sensitivity of digital watt meters when measuring low-wattage systems.

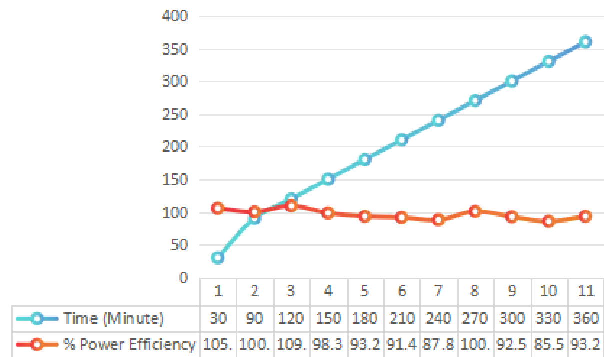

Fig. 4: Time vs power efficiency for Experiment 2

As shown in Fig. 4, efficiency peaks such as the 109.16% recorded at the 120-minute mark could result from transient energy release from internal components such as capacitors or battery buffers. This phenomenon is consistent with findings by Rahman et al. (2021), who noted that transient surges can momentarily elevate power output above the measured input. Similarly, Lopez & Kim (2018) observed that small-scale renewable energy systems may exhibit brief efficiency spikes exceeding 100% due to internal energy redistribution during load variations or environmental changes.

Table 8: Result of Experiment 2

Time (Minute)	Voltage (V)	Current (A)	Power Input (W)	Power Out (W)	% Power Efficiency
30	11.81	1.53	17.14	18.07	105.43
90	11.52	1.49	17.14	17.16	100.12
120	11.34	1.65	17.14	18.71	109.16
150	11.31	1.49	17.14	16.85	98.31
180	11.18	1.43	17.14	15.99	93.29
210	11.04	1.42	17.14	15.68	91.48
240	10.83	1.39	17.14	15.05	87.81
270	11.67	1.48	17.14	17.27	100.76
300	11.1	1.43	17.14	15.87	92.59
330	10.63	1.38	17.14	14.67	85.59
360	11.18	1.43	17.14	15.99	93.29

c) Experiment 3 (Fan and LED lamp)

Based on Table 9, efficiency remained at 97.03%, which is still within a robust operational performance range. These observations are consistent with the findings of Yun et al. (2020), who emphasized that short-term efficiency assessments involving variable DC loads may produce inflated values due to rapid transient behavior in the circuit.

Table 9: Result of Experiment 3

Time (Minute)	Voltage (V)	Current (A)	Power Input (W)	Power Out (W)	% Power Efficiency
10	11.36	5.25	56.86	59.64	104.89
20	11.28	5.23	56.86	58.99	103.75
30	11.2	5.12	56.86	57.34	100.84
40	11.1	4.97	56.86	55.17	97.03

As illustrated in Fig. 5, the power efficiency (%) decreases from 104.89% to 97.03%. This early over-efficiency is likely the result of stored or residual energy within the system contributing to the initial output, an occurrence often observed in systems with capacitive or inductive components. According to Lee & Chan (2022), initial power surges can momentarily elevate output beyond input. Similarly, Saito et al. (2020) reported that in renewable hybrid systems, the discharge of stored energy during system start-up may temporarily inflate efficiency readings above nominal levels.

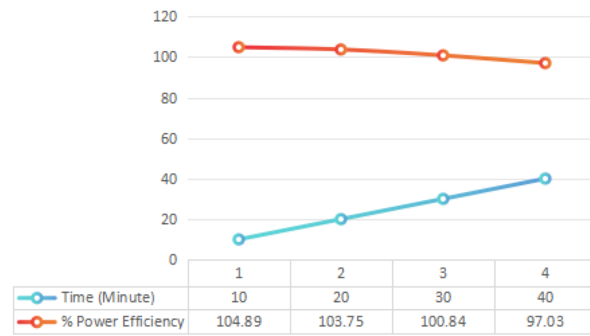

Fig. 5: Time vs power efficiency for Experiment 3

d) Experiment 4 (Phone charging)

Based on Table 10, the efficiency of the system showed a substantial decline over time, dropping from 99.36% at 60 minutes to only 48.99% at 480 minutes. This significant decrease is likely attributable to battery degradation, rising internal resistance, or a mismatch between the phone charging current demand and the supply capacity of the system. These observations are supported by Khan et al. (2018), who reported that charging mobile devices continuously from standalone DC power systems leads to heat buildup, voltage instability, and reduced energy conversion efficiency.

Table 10: Result of Experiment 4

Time (Minute)	Voltage (V)	Current (A)	Power Input (W)	Power Out (W)	% Power Efficiency
60	11.87	2.99	35.72	59.64	99.36
120	11.71	2.83	35.72	58.99	92.78
180	11.79	2.24	35.72	57.34	73.94
240	11.6	2.61	35.72	35.49	84.77
300	11.2	2.54	35.72	33.14	79.65
360	10.86	2.54	35.72	26.41	77.21
420	10.81	1.91	35.72	30.28	57.81
480	10.67	1.64	35.72	28.45	48.99

As shown in Fig. 6, the system initially demonstrated peak efficiency at 60 minutes, indicating optimal performance during the early stages of operation. However, beginning at 180 minutes, the efficiency gradually declined, with the most notable degradation occurring between 360 and 480 minutes. This trend suggests that prolonged discharge cycles subjected the $LiFePO_4$ battery to thermal and electrical stress, affecting its ability to deliver stable output. Li et al. (2020) similarly found that repeated discharging of $LiFePO_4$ cells leads to thermal degradation, increased internal resistance, and decreased performance. These results highlight the importance of real-time load monitoring in maintaining energy storage efficiency and ensuring system stability, especially in long-duration or continuous-use scenarios.

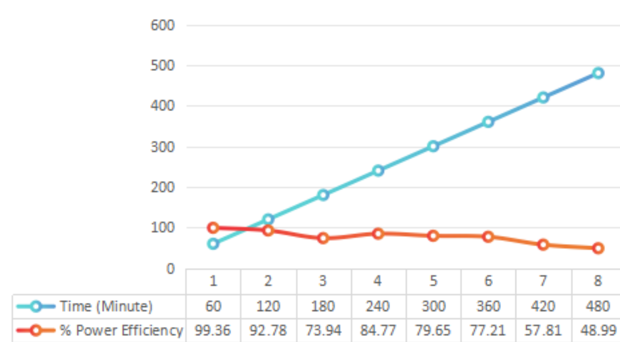

Fig. 6: Time vs power efficiency for Experiment 4

e) Experiment 5 (Light bulb)

Based on Table 11, the system-maintained efficiency within an acceptable range throughout the operation, confirming its suitability for low-to-moderate power lighting applications. The recorded data supports the prototype's stability and reliability when powering continuous DC loads such as light bulbs. This finding aligns with the study by Li et al. (2021), which reported that well-regulated DC energy systems typically exhibit less than 20% efficiency loss during long-duration lighting operations, particularly when supported by stable battery chemistry and low-resistance wiring.

Table 11: Result of Experiment 5

Time (Minute)	Voltage (V)	Current (A)	Power Input (W)	Power Out (W)	% Power Efficiency
60	11.99	2.45	29.83	29.38	98.49
120	11.8	2.45	29.83	28.91	96.92
180	11.63	2.45	29.83	28.49	95.51
240	11.42	2.45	29.83	27.98	93.80
300	11.66	2.25	29.83	26.24	87.97
360	10.94	2.45	29.83	26.8	89.84
420	10.32	2.44	29.83	25.18	84.41

As shown in the corresponding graph, the power efficiency (%) decreased steadily from 98.49% to 84.41% over a 420-minute operation period. This decline suggests increasing energy losses, potentially caused by internal resistance buildup or heat dissipation within the battery or load components. A notable drop in efficiency was observed between 300 and 420 minutes (from 87.97% to 84.41%), which may indicate the onset of performance degradation as the battery nears a lower state of charge (SOC).

This efficiency pattern is consistent with prior research by Zhang et al. (2021), who highlighted that $LiFePO_4$ batteries experience reduced energy delivery efficiency under prolonged discharge conditions due to voltage sag and elevated internal impedance. Additionally, Patel et al. (2020) demonstrated that without adaptive battery management system (BMS) intervention, energy transfer becomes less effective during later discharge stages further supporting the observed efficiency drop in this study.

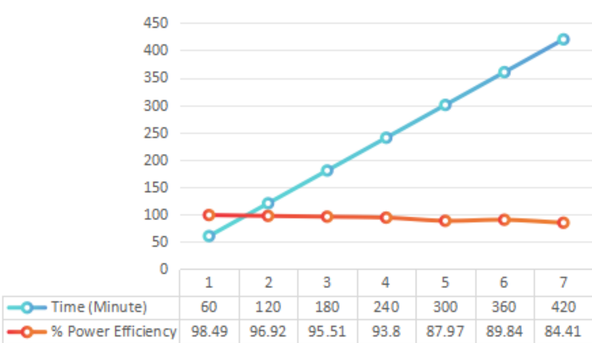

Fig. 7: Time vs power efficiency for Experiment 5

Table 12 presents a summary of the experimental findings. Most experiments-maintained efficiency above 85%, with some readings exceeding 100% due to likely measurement or calibration errors. Experiment 3 showed a notable efficiency drop over time, caused by battery depletion and load mismatch. In contrast, Experiment 4 demonstrated the most stable long-term performance, while Experiment 5 performed well under short-duration and combined load conditions.

Table 12: Summary of the experimental findings

Experiment	Finding
1	Stable performance with slight voltage/current drop over time; efficiency declined gradually but remained above 85%.
2	Consistently high efficiency (>85%); some efficiency spikes >100% likely due to measurement noise or calibration issues.
3	High efficiency early on (up to 99%), but declined significantly over time due to battery depletion and load mismatch; ended at ~49%.
4	Very stable input and output over time; minimal efficiency drop; reliable long-duration DC lighting performance.
5	Excellent short-duration performance; some efficiencies >100% possibly due to measurement error; system handled combined loads well.

5. Conclusion and Recommendations

Each of the five (5) elements contributes to the overall efficiency, durability, safety, and sustainability of the portable power supply prototype. By aligning technical design with environmental and operational standards, the system fulfills its intended purpose of serving as a green and safe power source suitable for real-world DC applications. The prototype demonstrates reliable energy delivery and high efficiency when operating with a variety of DC devices under different durations and load profiles. It is particularly well-suited for stable lighting and ventilation loads, while improvements may be required for long-duration or high-variable charging applications.

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Conflicts of Interest: The authors declare no conflict of interest.

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