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Design and Development of Battery Energy Storage System for Portable Electricity Supply

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ABSTRACT

The demand for portable power sources has been on the rise, particularly for supplying electricity to mobile food vendors and small-scale enterprises that operate during the night. With portable power sources, these merchants can sell freely in crowded areas without the concern of electricity availability for their cooking equipment and business lighting. This article presents the design and development of a portable battery energy storage system (BESS) intended for use by mobile culinary businesses. A portable BESS comprises a battery pack, a power inverter, and a transfer switch, all integrated into a compact unit, along with a separate battery charger. The battery utilized is of the lithium-ferro-phosphate (LFP) type, which provides benefits such as high energy density, lightweight design, and a long lifespan. The design process for the portable BESS begins with an estimation of the daily electricity demand of the electrical installation,then followed by determining the required storage capacity of the battery pack and the ratings for the power inverter and transfer switch. The specifications for the BESS are 0.768kWh/220V/50Hz/1000W. Functional tests have been conducted, revealing that the BESS can be fully charged in 3 hours and can power five 19-W LED lights for up to 6.5 hours.

Keywords*: Battery Energy Storage System; Lithium-Ferro-Phosphate Battery; Portable Electricity Supply*

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INTRODUCTION

The demand for portable power sources has recently increased, particularly for supplying electricity to mobile culinary vendors and small-scale businesses that operate at night. By utilising portable power sources, merchants can sell freely in crowded areas without the concern of electricity availability for their cooking equipment and lighting their business premises. Additionally, these power sources are essential for mobile government services, such as vehicle tax payment units, mobile driver's licence renewals, and mobile public libraries.

Despite facing high operational costs, many people continue to use portable engine generators for their domestic and business needs. Studies in Nigeria by Babatunde et al. (2020) and Zubair et al. (2022) indicate that numerous Nigerians have transitioned to using portable engine generators due to the inadequate quality of electricity from local utility companies. Similarly, many individuals in India rely on portable engine generators for both domestic and business purposes, as reported by Jakkana et al. (2026). Conversely, in Indonesia, the use of portable engine generators is rare because the electricity supplied by the state electricity company (PLN) is generally satisfactory, and the operational costs of the generators are significantly higher than using PLN electricity. However, in some areas, pressurised kerosene lamps are still commonly used by small businesses, as noted by Anto et al. (2026), Krismadinata et al. (2017), and Khayam et al. (2023).

Researchers have shown increasing interest in small-scale photovoltaic (PV) systems for supplying electricity to small businesses. Azriyenni et al. (2023) developed a portable PV system with a peak capacity of 100 watts to provide electricity to small enterprises, utilizing a lead-acid battery for energy storage. Bin Mohd Yusoff et al. (2022) made a 20W-capacity portable solar generator powered by lithium-ion batteries, which can also serve small businesses for electrical needs. Applied research on portable PV power generators has been documented by Manfaluthy (2021), who donated a lighting system that included an LED light, a battery unit, and a PV module to recharge the battery for a mobile food vendor in Bekasi, Indonesia. Additionally, Rombekila & Buang (2023) installed a simple solar power generation system to provide lighting for a small business cart in Papua Province, Indonesia. Some researchers propose the use of rechargeable batteries to supply electrical power to small-scale enterprises. During the day, these batteries are charged using electricity from the utility grid, while at night, they power electrical equipment at the merchant's business location. Susilawati et al. (2021) developed a portable generator based on a 12V lead-acid battery to provide electrical power to a small kiosk at tourist sites in Lombok, Indonesia, utilizing a single-phase inverter with a step-up transformer to achieve an alternating voltage of 220 V, 50 Hz. Mahyastuty et al. (2025) designed a power source based on a 12V/60Ah lead-acid battery for a mobile coffee vendor. Anto et al. (2025) employed a lithium-ferro-phosphate battery-based power source rated at 48V/3.5 kWh to supply electricity for a food truck.

Rechargeable battery-based portable power sources are particularly practical for small-scale businesses operating at night. Compared to portable engine generators, this technology is more environmentally friendly, as it does not emit greenhouse gases or harmful exhaust gases. Furthermore, it operates quietly, minimising disturbances to customers' activities. Traders can charge the batteries during the day using electricity from the utility grid or other energy sources like PV modules, discharging the batteries at night to support their business needs.

While lead-acid battery-based power sources are advantageous over portable engine generators, their adoption is still limited by the large dimensions, weight, and short lifespan of the batteries. The potential for portable battery-based power sources will increase with the introduction of lightweight batteries that are more compact and have longer lifespans.

The advancement of battery technology has led to the development of lithium-ferro-phosphate (LFP) batteries, which are characterised by their high energy density, lightweight design, and long lifespan. These batteries are increasingly used as a power source in battery-based electric vehicles, as evidenced by the research of Sophy-Mahfoudi et al. (2024), Akyildiz et al. (2025), and Lu (2024). Furthermore, LFP batteries have been incorporated into energy storage systems (ESS) to enhance the performance of electrical power systems, as discussed by Aslam et al. (2025) and Gatta et al. (2016). They also serve as a medium for storing electrical energy in solar power plants, as noted by Chen et al. (2024) and Rey et al. (2023).

In this study, we designed and developed a portable ESS based on LFP batteries specifically for mobile food vendors. We have named this equipment the Portable Battery Energy Storage System, or Portable BESS, for short. While our primary focus is on mobile food vendors, the design approach we employed for the Portable BESS can be adapted to meet various other needs requiring portable energy storage solutions.

Principles of Portable Battery Energy Storage System

The battery energy storage system (BESS) is quite old technology. This technology has been developed since 1991 with the first commercial use of lithium-ion batteries by the Sony company (Li et al., 2018) (Shaibani & Majumder, 2022).

A battery is essential to a BESS because it stores electrical energy for use when needed. BESS utilizes various types of batteries, including redox flow, sodium-sulfur, lead-acid, and lithium-ion batteries. Among these, lithium-ion batteries are the most commonly used in BESS. They offer several advantages over other battery types: they are lightweight, have a high energy density, and exhibit high efficiency during charging. Additionally, lithium-ion batteries have a long life cycle and a low self-discharge rate, which allows them to maintain their full charge better than other batteries. However, it is important to consider some significant disadvantages of lithium-ion batteries, such as the risk of explosion if misused, potential damage from complete discharge, and sensitivity to high temperatures (Wang et al., 2025) (Mylenbusch et al., 2023) (He et al., 2024).

Table 1. LFP Battery Cell Characteristics

Parameters	**Value**
Nominal voltage (V)	3.2
Energy density (Wh/kg)	150
Maximum charging voltage (V)	3.65
Maximum continuous charging current	0.2C
Discharging cut-off voltage (V)	2.5
Maximum continuous discharging current	1C
Working temperature (^oC)	-20 ~ 55
Recommended operating SOC	10% ~ 90%

There are five types of lithium-ion batteries: lithium cobalt oxide ($LiCoO_2$), lithium manganese oxide ($LiMn_2O_4$), lithium nickel manganese cobalt oxide ($LiNiMnCoO_2$, or NMC), lithium iron phosphate ($LiFePO_4$), and lithium titanate ($Li_4Ti_5O_{12}$). Among the five, $LiFePO_4$ (LFP) batteries are the most widely used because they have good temperature stability during the discharging process (Evro et al., 2024) (Assi

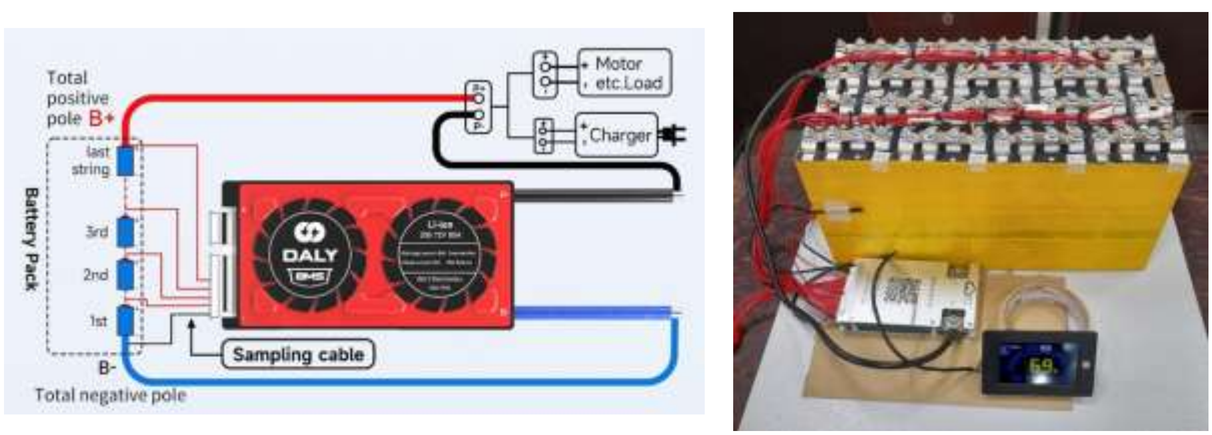
& Amer, 2025).

In a BESS application, an LFP battery commonly consists of multiple cells connected in parallel and series configurations to form a battery pack. The characteristics of an LFP battery cell are detailed in Table 1. The energy stored in a battery is quantified using the State-of-Charge (SOC) value, where a fully charged cell has an SOC of 100%, and an empty cell has an SOC of 0%. During charging, the maximum voltage reaches 3.65 volts, and the highest allowable current is 0.2C. Conversely, in discharging mode, the continuous maximum current that can be drawn from the battery is 1C, while the minimum voltage at the battery cell terminals is 2.5 volts. Figure 1 shows that LFP battery cells usually come in two types of packaging: cylindrical and prismatic.

A battery pack must include a battery management system (BMS) that monitors the battery condition, balances the cell voltages, protects against overcharging, and extends the battery's lifespan. Figure 2(a) displays the wiring diagram of the battery pack with the BMS (Daly, 2026). Note that there are two cables connecting each battery cell terminal to the BMS for measuring battery cell voltage. A battery pack equipped with the BMS is depicted in Figure 2(b).

(a) (b)

Figure 1. LFP Battery Cell Packaging, (a) Cylindrical, (b) Prismatic.
(Source: *www.google.com*)



(a) (b)

Figure 2. (a) Wiring Diagram of Battery Pack and BMS, (b) Set of Battery Pack, BMS and LCD Screen Informing Battery Pack Conditions

The components that comprise a BESS include (1) a battery pack equipped with a BMS, (2) a power inverter, (3) a transfer switch, and (4) a battery charger. The battery pack, made up of several LFP battery cells arranged both in parallel and in series, functions as a storage unit for electrical energy. The power inverter converts DC power from the battery pack into AC power, which is necessary for driving electrical appliances at the small-scale enterprise's premises. The transfer switch manages the operational modes of the BESS, specifically the discharging mode and the charging mode. The battery charger is responsible for recharging the battery pack. The battery pack, power inverter, and transfer switch are assembled, wired, and enclosed in a compact package, while the battery charger remains separate from this package. Figure 3 shows the electrical circuit diagram of the BESS.

The operation of the BESS is clarified through the wiring diagram presented in Figure 3. Within the single package, the battery pack, power inverter, and transfer switch are located together. The transfer switch features two contact arrangements: S1 and S2, both designed with mechanical interlocking to ensure they cannot close simultaneously. When S1 is closed, S2 is kept open, and vice versa. In charging mode, the S2 contact arrangement is closed, allowing the output terminals of the battery charger to connect to the positive and negative terminals of S2. The battery charger operates with standard residential AC power sources, specifically a single-phase 220-V, 50-Hz voltage supply. For discharging mode, the S1 contact arrangement is closed, connecting the battery pack to the power inverter. Consequently, the power inverter supplies power to electrical appliances at the small-scale business premises. Vendors can switch the transfer switch to charging mode during the day to replenish the BESS's battery pack and later revert to discharging mode to use the BESS to power their electrical appliances.

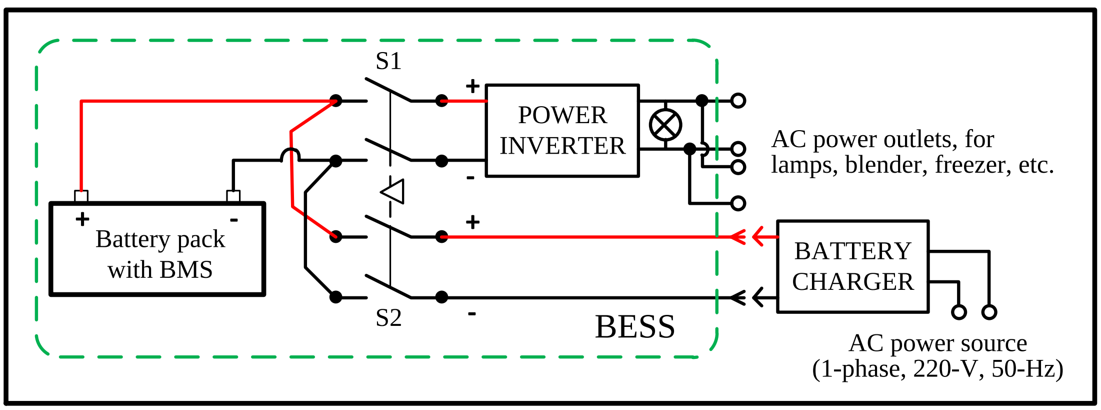


Figure 3. BESS Wiring Diagram.

METHODS OF RESEARCH

The research commenced with the calculation of the total daily electricity demand (TDED) of an electrical installation using the tabulation method. This method involves entering the electrical equipment to be operated by the vendor and the duration of its use into a table to determine the total daily electrical energy consumption. The TDED concept necessitates daily charging, which means the BESS must be recharged after use.

After calculating the TDED, the next step is designing the battery pack. This involves assessing the required capacity, selecting the type of battery cell, and determining the number and configuration of the cells. Once the battery pack design is complete, the specifications for the power inverter, transfer switch, and battery charger are established. Following the design phase, the main components of the BESS are procured. The next step is the assembly of the BESS components into a compact unit. Finally, functional testing of the BESS is conducted, which includes tests for both charging and discharging modes.

The storage capacity of a battery pack (Q) is calculated using the following equation:

$$Q = \frac{E}{DOD \times \eta} \tag{1}$$

In Equation (1), Q is in watt-hours (Wh), E is the TDED, in Wh, DOD is the depth-of-discharge of the LFP battery pack, typically at 80%, and η is the battery efficiency, typically at 95%.

The number of battery cells needed to assemble a battery pack (N) is calculated using the following equation:

$$N = \frac{Q}{Q_{bc}} \tag{2}$$

In Equation (2), Q_{bc} is the watt-hours (Wh) rating of the battery cell.

The configuration of the battery cells that comprise a battery pack is influenced by the types and ratings of battery chargers available on the market, given that we do not produce a specific battery charger tailored for any particular battery pack. This strategy helps reduce the development time of the BESS.

Once the battery pack design is finalized and the specifications for the battery charger are established, the next phase involves determining the specifications for the power inverter and the transfer switch. The configuration of the battery pack and its maximum output power dictate the specifications of the power inverter. For the transfer switch, we utilize a single-phase changeover switch rated for 400V/50Hz/63A. Note that the BESS development employs a transfer switch specifically designed for AC electrical installations.

RESULT AND DISCUSSION

The design of the BESS began with calculating the total daily electricity demand (TDED) of the food vendor business premises during its operating hours. The TDED is calculated using the tabulation method shown in Table 2. The electrical appliances include five 19-W LED lights operated for 6 hours. From Table 2, the TDED is 475 Wh.

Table 2. Electricity Demand of Food Vendor Premises

No.	Electrical Appliances	Power (W)	Duration of Use (h)	Electricity Consumption (Wh)
1.	LED lights (5 x 19W)	95	6	475
	Total Electricity Demand			475

By entering E = 475 Wh, DOD = 0.8, and η = 0.95 into Equation (1), we obtain the battery pack storage capacity Q = 625 Wh. We have chosen the prismatic LFP battery cell with 30 Ah (or 96 Wh) storage capacity to construct the battery pack. Using Q = 625 Wh and Q_{bc} = 96 Wh in Equation (2), we obtain that the number of LFP battery cells required is 7. We then raise the value to 8 cells to consider ease of battery charger selection. We then use the 8S configuration to build the battery pack, meaning eight cells are connected in series.

Based on the battery pack configuration, we have selected a battery charger that produces an output voltage of 25.6 V with an output current of 10 A. Furthermore, we have selected a power inverter with input voltage specifications of 24 VDC and output power of 1000 W. Table 3 provides detailed specifications for the main BESS components.

Table 3. Specifications for Main BESS Components

No.	Main component	Specifications
1.	Battery pack	Type of battery cell: $LiFePO_4$, 3.2V/30Ah Number of cells and configurations : 8 cells, 8S configuration Nominal voltage : 25.6 V Storage capacity : 768 Wh
	BMS	Type of battery cell and configuration : $LiFePO_4$, 8S Maximum charging current : 40 A Maximum discharging current : 60 A
2.	Power inverter	Input voltage : 24 VDC Output voltage: 220V/50Hz, pure sine wave Output power: 1000 W
3.	Battery charger	Input voltage: 220V/50Hz Output voltage: 25.6 V Output current: 10 A
4.	Transfer switch	Contacts configuration: Single-phase changeover switch Nominal voltage: 400V/50Hz Nominal current: 63 A

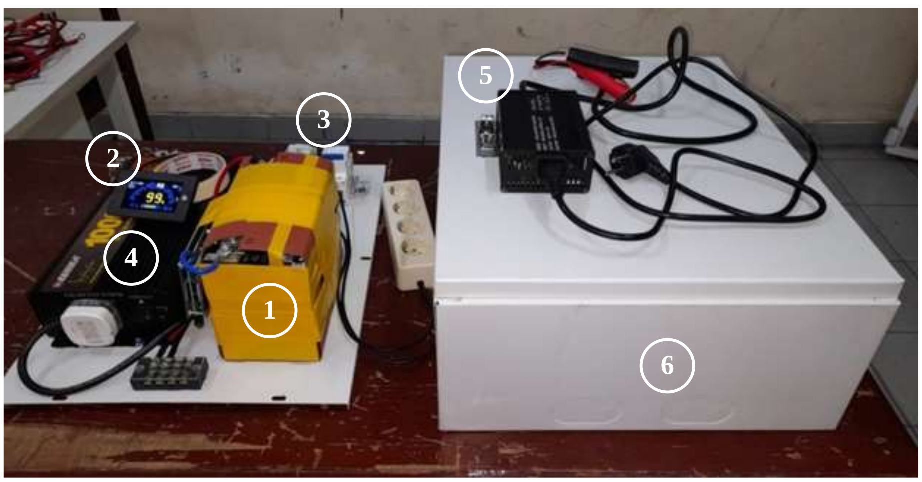


Figure 4. Main BESS Components.

Figure 4 shows the main components of the portable BESS prior to assembly. Component 1 is an 8S battery pack with a capacity of 0.768 kWh, which is already equipped with a BMS. Component 2 is an LCD unit that functions to display the conditions of the battery pack. Component 3 is the transfer switch, while Component 4 is the power inverter. Component 5 is the battery charger, which has a charging voltage of 25.6 V and a charging current of 10 A. Component 6 is a steel box measuring 600mmx400mmx250mm, which is used to package the portable BESS.

Figure 5 depicts the portable BESS packaging after assembly, along with a battery charger positioned on the top side of the BESS package. An LCD unit on the front of the BESS packaging shows important information about the battery pack, such as its state of charge (SoC), voltage, charging current, and discharging current. A charging socket is also available to connect the internal battery pack of the BESS to the battery charger. The AC power generated by the BESS can be accessed through two discharging sockets, which output an AC voltage of 220V at 50Hz. A red indicator light signals that the BESS is in discharging mode. This light does not activate when the SoC of the battery pack falls below the minimum threshold set within the BMS or when the BESS is in charging mode. Additionally, the transfer switch unit is located inside the BESS enclosure and can only be accessed by opening the enclosure door. For identification purposes, the developed BESS is specified in Table 4 and described as a 0.768 kWh/220V/50Hz/1000W portable BESS.

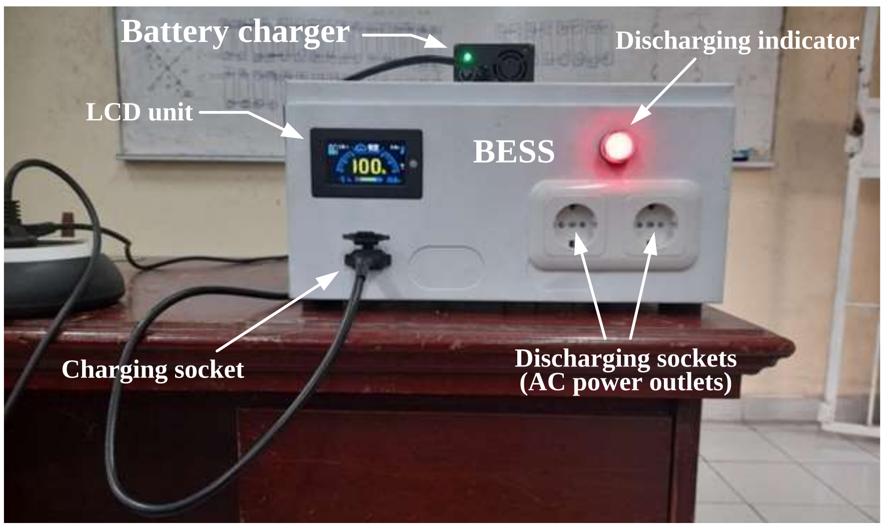
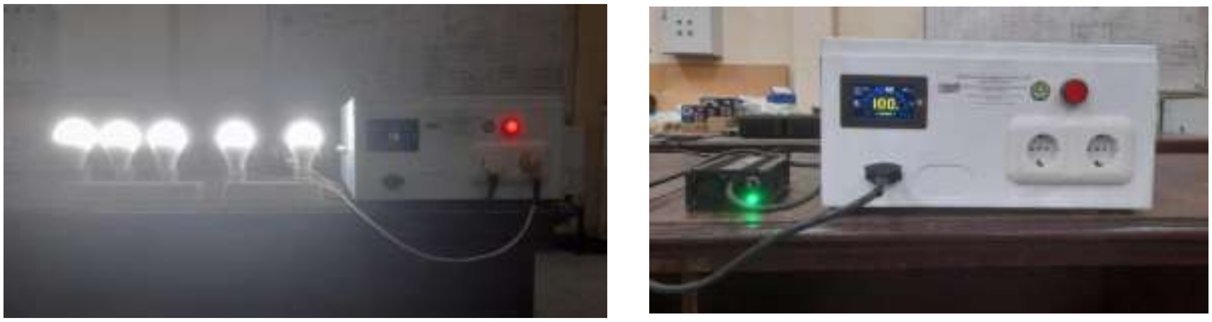


Figure 5. Portable BESS and Battery Charger.

Table 4. Specifications of Portable BESS

Parameters	Value
Storage capacity	0.768 kWh
Output voltage	220 V, 50 Hz
Output power	1000 W

We have conducted functional tests on the portable BESS, including discharging and charging tests. For the discharging test, the transfer switch handle is positioned at the discharging mode. The test was conducted by loading the fully charged portable BESS with five 19-W LED lights. The test lasted until the BMS cut off the current drawn from the battery pack. Figure 6a shows the electrical setup for the portable BESS discharging test. A red indicator lamp illuminated throughout the test but turned off as the BMS interrupted the discharging current. The results from the discharging mode test indicated that the portable BESS could power the LED lights for up to 6.5 hours. Figure 6b presents the electrical installation of the portable BESS charging test. For the charging test, the transfer switch handle was positioned at the charging mode, and the battery charger was connected to the battery pack through the charging socket. During the test, the SoC of the battery pack was increasing until it reached 100%, at which point the BMS automatically cut off the charging current. The results indicated that the charging process took 3 hours to complete.



(a) (b)

Figure 6. Functional Test Setup, (a) Discharging Mode, (b) Charging Mode.

Comparison between Portable BESS and Portable Engine Generator Operational Costs

The fabrication cost of a 0.768kWh/220V/50Hz/1000W portable BESS is Rp 6,000,000. This amount is 1.71 times higher than the cost of purchasing a 1000-W gasoline portable engine generator, which is Rp 3,500,000. Operating under the same conditions as the portable BESS, a 1000-W engine generator consumes approximately 2.5 liters of fuel per night. With gasoline priced at Rp 15,000 per liter, the fuel cost for the engine generator amounts to Rp 37,500 per night, totaling Rp 1,125,000 per month. Additionally, maintenance expenses for the engine generator average Rp 40,000 per month. Therefore, the total operational and maintenance expenses for the 1000-W gasoline generator are Rp 1,165,000 per month. The operational cost for the 0.768kWh/220V/50Hz/1000W portable BESS is determined by its charging cost, based on the PLN electricity tariff for residential use, which is Rp 1,444.70 per kWh (PLN, 2024). The monthly charging cost of the portable BESS (B_{chg}) is calculated using the following equation:

$$B_{chg} = \frac{30Q_n}{0.8} \times 1444.7 \tag{3}$$

In Equation (3), Q_n represents the rated storage capacity of the battery pack in kWh. By substituting Q_n = 0.768 kWh into Equation (3), the monthly charging cost is calculated to be Rp 41,607.36. The portable BESS incurs no maintenance costs, so its operational expenses are solely determined by the battery charging costs.

The above analysis indicates that although the procurement cost of a portable BESS is higher than that of a portable engine generator, its operational cost is significantly lower. Based on the calculations from the previous paragraph, the combined procurement and operational expenses of a 1000-W gasoline engine generator will equal those of a 0.768-kWh portable BESS after 3 months of use. After this period, the food vendor will incur costs of Rp 1,165,000 per month for operating and maintaining the generator, in contrast to only Rp 41,607.36 per month for operating the 0.768-kWh portable BESS. This analysis indicates that, despite the higher initial investment in a portable BESS, its lower operational expenses make it more economical overall compared to the engine generator. Additionally, a significant advantage of using a portable BESS is that it does not produce noise and smoke pollution, thereby enhancing the comfort of food vendor customers.

CONCLUSION

An efficient and effective electricity supply technology for mobile food vendors is described in this article. This technology employs a portable battery energy storage system (portable BESS) specifically for lighting purposes at food vendor business locations. The portable BESS comprises a compact package that includes a lithium-ferro-phosphate (LFP) battery pack, a power inverter, a transfer switch, and a separate battery charger unit for recharging the battery pack. The specifications of the portable BESS are as follows: 0.768 kWh, 220 V, 50 Hz, and 1000 W. The battery charger unit is rated at 25.6 V and 10 A.

The portable BESS has undergone various tests, including both discharging and charging modes. A discharging test with a load of five 19-W LED lights demonstrated that the portable BESS could power this load for up to 6.5 hours. This performance assures food vendors that the portable BESS can adequately support their daily operations, which typically last for 6 hours. Additionally, a charging test with a 25.6 V/10 A LFP battery charger revealed that the portable BESS could be fully charged within 3 hours.

When compared to portable engine generators, the portable BESS offers advantages such as lower operational expenses and the absence of noise and smoke pollution during operation.

Despite the successful functionality of the developed portable BESS, its procurement entails significant costs, as we currently integrate the main components without manufacturing some or all of them. To reduce the procurement costs of portable BESS, several strategies can be implemented: (1) developing portable BESS with standardized sizes; (2) self-producing key components of the portable BESS, such as the BMS, power inverter, and battery charger; and (3) developing a bidirectional AC-DC converter capable of charging the LFP battery through standard household AC power sources while also discharging the LFP battery to supply typical household electrical loads.

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