Real Time Energy Management System for LiFePO4 Portable Generator Using Smart BMS

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Abstract. The portable generator is a type of power supply system that contains a battery to maintain power to provide power to electronics in the event of a power surge or outage. This paper presents energy management system for a portable generator uninterruptible power supply using LiFePO4 battery and smart Battery Management System. The portable generator potential to replace the petrol generator that noisy and not environmentally friendly. The designed of a portable generator consist of: LiFePO4 battery, 2000watt inverter, 5V 2Ampere DC-DC converter, ob board charging system, and android app. Portable generators have been applied to household electronic equipment.

Keywords: LiFePO4, BMS, portable generator

1 Introduction

Electricity is one of the things that human needs nowadays [1]. Everyday electronic devices used must use electrical energy, for example, cellphones, laptops, and other portable electrical appliances. It is one of the greatest inventions humanity has ever made because it plays such an important role in socio-economic and technological development [2]. Electricity can be transmitted by alternating current (AC) or direct current (DC) [3]. Alternating current is the form drawn from the electrical outlets in your home or office. It consists of a sinusoidal voltage source and can use continuous voltage (and current) flow direction changes to generate a DC magnetic component. Current flowing in a fixed direction and voltage with a fixed polarity, suitable for short-distance transmission. Direct current is the form that is stored in batteries. It has limited usage and relies on AC power. The direct current (DC) microgrid has attracted great attention because it provides substantial safety, cost-effectiveness, energy efficiency, and reliability [4].

In order to sustain power and deliver electricity to devices in the case of a power surge or loss, a portable generator is a sort of power supply system. [5]. Data centers, phone exchanges, and numerous industrial process control and monitoring systems are among the sensitive electronic loads that are powered by its uninterruptible power

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supply systems, which are separate AC power sources. These applications need access to reliable electricity. The following voltages are provided by portable generator solutions for sensitive electrical loads to create a reliable interface between utilities and sensitive loads: 1) Is devoid of any power disturbances and complies strictly with the load's stringent limits; 2) Can be utilized in the event of a power breakdown within the permitted tolerance [6].

Essential Parts of a portable generator system include the following main components: 1) on-board AC to DC charging system, 2) Inverter, 3) Storage system (batteries), and 4) electronic system that switches the load back and forth from the inverter and utility power [7]. The different kinds of static portable generator based on IEC standard 62040-3 specifies three main types: offline-passive stand-by, line-interactive and online–double conversion [8], [9]. The passive stand-by is the simplest UPS topology, also known as offline. An offline portable generator operates in two modes of operation, inverter mode. Since the inverter usually is off while the load is powered directly from the input grid, and the other is the backup mode, the UPS will switch to inverter operation and draw energy from the battery [10]. Figure 1 illustrates the topology of portable generator passive stand-by/offline.

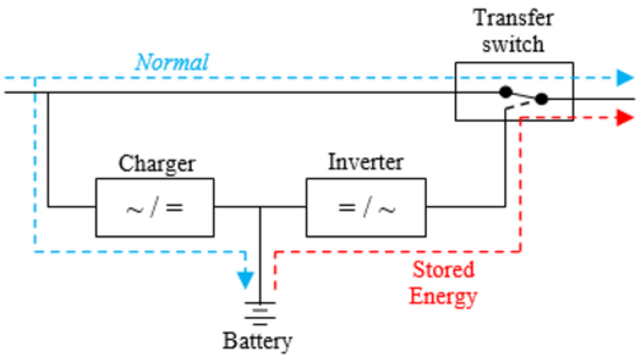

Fig. 1. Passive stand-by

In normal mode operation, the load receives main power via a filter that eliminates certain disturbances and offers some voltage control (IEC 62040 specifies forms of power regulation) [11]. The inverter operates in standby passive mode. In battery-backed mode, the inverter and battery will intervene to restore the power after a brief transfer of less than ten ms to assure continuous power to the load in the event that the AC input voltage is beyond the UPS's predefined tolerance or utility power fails. The UPS will operate on battery power until utility power is restored or the battery backup period has passed, at which point the load is connected to the AC input once more (normal mode) [12].

Since this portable generator operates without an actual static switch, it takes time to transfer the load to the inverter [13]. While this time is acceptable for specific individual applications, it is incompatible with the performance required by more demanding and sensitive systems. Additionally, the frequency is not tuned, and there is no bypass.

A portable generator's main component that stores and provides electricity during a power outage is a battery. [14]. Due to their benefits as an energy storage system, including their long cycle life, low self-discharge rate, compact size, lightweight, quick charging capabilities, and wide temperature range, lithium-ion (Li-ion) batteries are becoming more popular. [15], [16]. The lithium iron phosphate battery (LiFePO4 battery) or LFP battery (lithium ferrophosphate) is a form of lithium-ion battery that uses a graphitic carbon electrode with a metallic backing as the anode and lithium iron phosphate (LiFePO4) as the cathode material. [17]. They offer higher power output, quicker charging, less weight, and a longer lifetime than the more conventional cobalt-based Li-Ion batteries. Additionally, the batteries are safer and will not blow up under pressure. Compared to lead-acid batteries and other lithium batteries, lithium iron phosphate batteries have several advantages. Improved discharge and charge efficiency, longer life term, no maintenance, maximum safety, and lightweight, to mention a few. Due to its extended lifespan and lack of maintenance, LiFePO4 batteries are not the most affordable ones on the market. The comparison of various battery technologies is shown in Table I [18], such as lead acid, lithium iron phosphate (LiFePO4), lithium nickel manganese cobalt oxides NMC, and lithium nickel cobalt aluminum oxides (NCA).

Table 1. Li-on Battery Comparison.

Specification	**Lead Acid**	**$LiFePO_4$**	**NMC**	**NCA**
Nominal Voltage	2	3.2	3.6 – 3.7	3.6 – 3.7
Typical operating range (V/cell)	1.6-2.4	2.5 – 3.65	2.5 – 4.2	2.5 – 4.2
Specific Energy (Wh/kg)	30 – 50	90 - 150	150 - 220	200 – 260
Typical energy (Wh/kg)	0.2C	0.5C	0.5C	0.5C
Typical Discharge Rate	0.1-0.5C	1 – 2C	1 – 2C	1C
Charge temperature (oC)	-20 – 50	0 – 55	0 – 50	0 – 50
Discharge temperature (oC)	-20 – 50	-40 – 80	-20 – 50	-20 – 50
Cycle life (100%DOD)	200 - 300	2500 – 12000	500 – 2000	500 – 2000
Thermal runaway temperature (oC) and comment	100 - 150	270	210	150
	Plastic container gets soften and melt	Very safe even if fully charged	High charge promotes thermal runaway	High charge promotes thermal runaway

Battery Management System (BMS) is an electronic component that must be used to protect the LiFePO4 battery during operation [19]. Lithium iron phosphate (LiFePO4) has voltage, temperature, and current ranges in which it can safely operate. Cells falling below or above these ranges are detected and controlled by the BMS. This keeps the battery safe and protects it in the long run [20]. Another critical safety feature of BMS is cell balancing [21]. Individual cells within a battery pack do not function the same. One cell can be weaker or more potent than others, charging or discharging faster than others in the chain. The BMS helps monitor and control the charge demanded by each cell in the chain, ensuring that the SoC is evenly distributed [22].

2 Methodology

The development of hardware and software devices is carried out in the electrical engineering laboratory of the Malang State Polytechnic. The hardware of the portable generator consists of 1) LiFePO4 battery 12V 100Ah, 2) DC-AC inverter 2000watt, 3) on-board charging system 10A, 4) DC-DC converter 5V 2A, 5) Display monitoring system, and 6) Data logger system. Then, the android app monitoring system shows: 1) voltage battery cell, 2) the working voltage, 3) current, 4) State of Charge (SoC), and 5) temperature.

The experiment procedure of this development research is developing hardware, developing software, testing the product, and recording real-time data using a data logger. The parameter data collected are the system's voltage, current, and temperature. All of the data is recorded on an SD card module, and the real-time data showing on the android app. The design of a portable generator block diagram and energy management system is shown in figure 2.

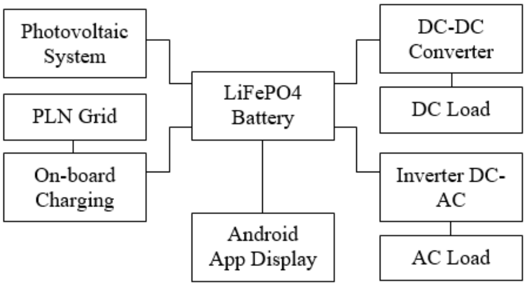

Fig. 2. Portable Generator Block Diagram

This portable generator and charging system uses 12VDC standalone photovoltaic solar energy. This system will constantly charge the LiFePO4 battery with solar charge controller MPPT 40A. The solar charge controller manages the power entering the LiFePO4 battery from the solar array, ensuring that the batteries are not overcharged throughout the day. On the other hand, there is also on-board charging 10A, which can be connected to the PLN grid.

3 Results And Discussion

This test includes a steady state load test. Test these parameters: input voltage, output voltage, input current, output current, and State of Charge (SoC). This analysis can reveal the need for the average use of portable generators in everyday life. Tabel II shows the specification of a portable generator that has been developed.

Table 2. Specification of Portable Generator.

Item	**Type**
Portable Generator Details	Static Portable Generator
BESS	LiFePO4 12V 100Ah
BESS Module	4
Input Voltage	220VAC & 12VDC
Output	220VAC, 12VDC, And 5V VDC
Total output power	2000 Watt
Portable Generator Efficiency	90%
Display	Android App

Battery packs used in portable generator applications must be small, have high volumetric energy, and have high power densities. The form factors (size, shape, and weight) are not a significant limiting factor when LiFePO4 batteries are utilized for grid storage because there is more space available. One more battery pack in the shape of a container may be added to the current packs if the power generating and storage system needs to be expanded. The lifespan of Li-ion batteries in automotive applications ranges from 6 to 8 years before the warranty expires and a replacement is necessary.

The energy management system of the portable generator has been generated and shown on the hardware and android app displays. The data on energy consumption were processed by Battery Management System installed on the battery pack. Then the data is sent to the android application via the Bluetooth network. The android monitoring app was developed with blynk software. Figure 3 shows the android app display of a portable generator. This application displays all the battery parameters used in the generator in real-time, including voltage, current, and battery temperature.

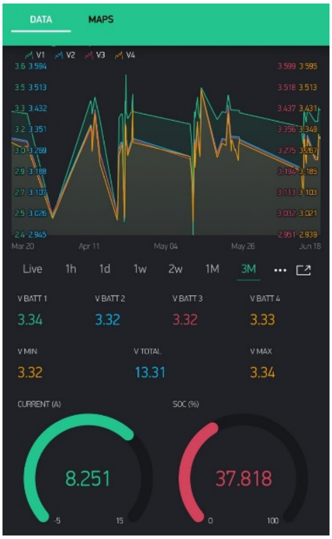

Fig. 3. Android app display of portable generator

3.1 Battery

T The LiFePO4 battery pack of a portable generator is 12V 100Ah, consisting of 4 series and one parallel LiFePO4 prismatic cell. Figure 4 shows the actual capacity of the battery pack. The battery was tested using 120watts of 12VDC lamp 10A continuous current discharge.

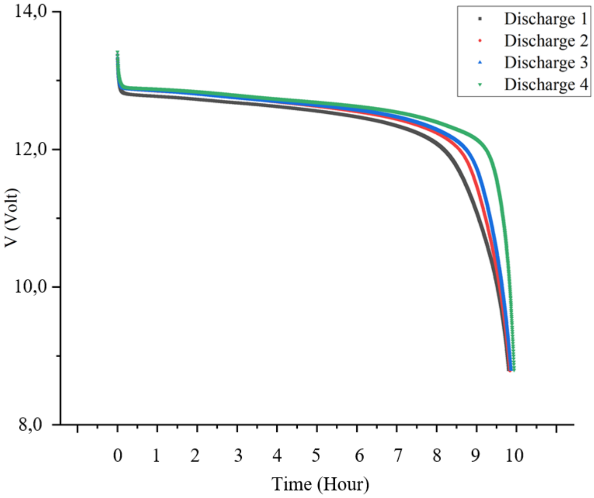

Fig. 4. Real capacity test of battery pack

3.2 Battery Management System (BMS)

The LiFePO4 battery pack's Battery Management System (BMS) that used is 12 Volt 100 Ampere. It is made up of embedded algorithms and electrical circuits that run the battery pack securely and effectively. The monitoring and control modules of the BMS may typically be divided into two categories. The monitoring module includes all the measurements or estimations of particular crucial battery pack characteristics that are necessary to track the state of charge of the battery system. The Control module or User may also share data with the Monitoring module. Measurement (data acquisition), estimating parameters, and defect identification and diagnosis are some of the Monitoring module's crucial tasks.

Because these conditions might put the batteries in danger, the Battery Management System (BMS) function has to be safeguarded from overvoltage, overcurrent, and overtemperature situations. Table 3 displays the parameter settings for the Battery Management System (BMS).

Table 3. Parameter Setting of Battery Management System (BMS).

Parameter	**Setting**
Cell Overvoltage	3,65 Volt
Cell Undervoltage	2,2 Volt
Pack overvoltage	14,6 Volt
Pack undervoltage	8,8 Volt
Temperature	-5° – 65° C
Charge overcurrent	60 Ampere
Discharge overcurrent	100 Ampere

3.3 Inverter DC-AC

A portable generator's inverter is crucial for converting direct current (DC) to alternating current (AC). Inversion is the process of changing alternating current (AC) from direct current (DC). The inverter has an astable multivibrator, a frequency reduction circuit, and Darlington pairs that condition the signal for the power transistors, which decide the system's power rating. The astable multivibrator creates a square wave (AC voltage) at the required frequency. A will A voltage regulator is also present for controlling DC power. The voltage supplies the different parts and serves as a conduit between them and a transformer to increase the output voltage to the necessary amount.

3.4 Charging Methode

This portable generator uses two ways of charging that is using onboard charging, which can be connected to PLN electricity, and the other hand using input from the standalone solar power plant. The onboard charging system has a 10-ampere maximum current, requiring 10 hours of charging time when the battery is empty. Then, the standalone solar power plant consists of a 300Wp photovoltaic and MPPT solar charge controller 40Ampere. The onboard charging system monitoring data is shown in figure 4.

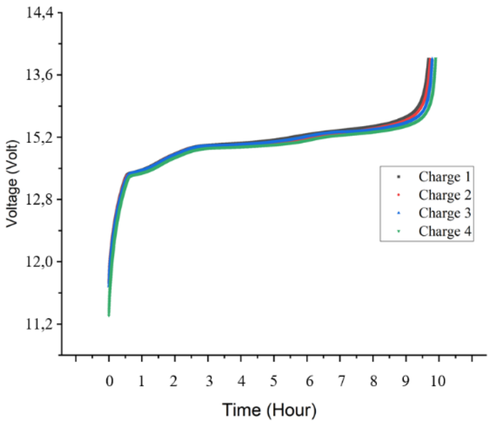

Fig. 5. On-board charging monitoring

The real-time current charging from the photovoltaic system shows in figure 5. It compares light intensity vs. the current charge battery, and the maximum charging current is 10,5 Ampere.

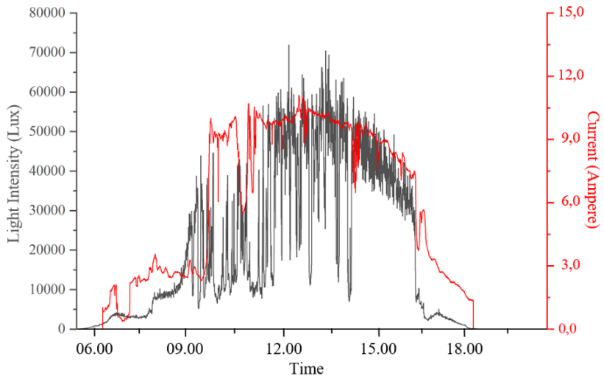

Fig. 6. the real time monitoring light intensity and charging current

The charging current to the battery is by the intensity of sunlight that entering to the solar panel system. The higher the light intensity, the greater the battery charging current [23], according to the illustration in Figure 5.

3.5 Energy Monitoring System

Energy consumption of portable generators used in home appliances. The monitoring system of the portable generator uses an android app, which can process data in real-time. Portable generators are used for lighting systems and household appliances such as cell phone chargers, charging laptops, electric stoves, fans, and vacuum cleaners. The specification power and average daily usage of each electric home appliance are shown in Table IV.

Table 4. List of Elextric Home Appliances.

Name	Power (Watt)	Average daily usage (Hour)
cell phone charger 1	15	4,47
cell phone charger 2	10	4,09
Laptop charger	65	3,74
electric stoves	1200	2,83
fans	38	3,74
vacuum cleaners	600	0,18
lighting systems	30	11,4

The portable generator was tested for one month using several home electronic devices. Battery power usage data is recorded in real-time using the android application, compared to the data recorded on the battery analyzer display in the portable generator. The data on the average capacity usage of portable generators in 1 month is shown in Figure 5.

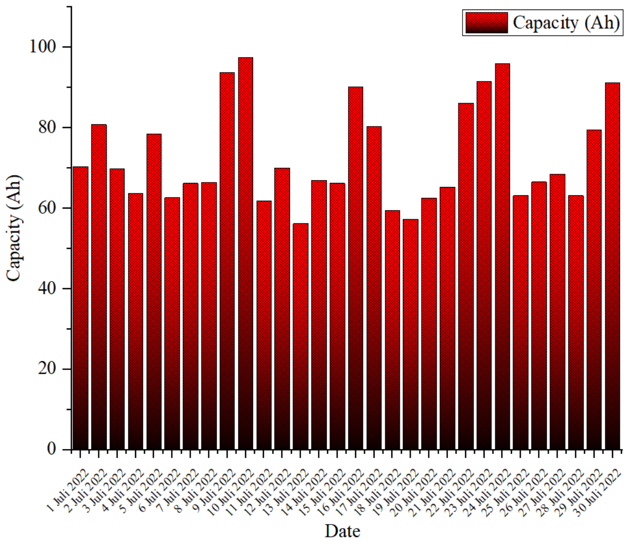

Fig. 7. The realtime average capacity usage

Figure 7 shows the use of portable generators within a month. The data is recorded in the data logger contained in the android application, then converted into a graph. The graph shows the battery capacity usage from day to day. Loading using the light system is carried out daily for an average of 11.4 hours. Then, use two cell phone chargers with an average time of 4.47 hours and 4.09 hours. A laptop charger is used daily with an average time of 3.74 hours. The fan is used with an average time of 4.74 hours. And the last vacuum cleaner is not always used, with an average time of 0.18 hours per month.

4 Conclusion

To determine the requirement for a portable energy storage system must first be determined the power requirements that will be used. Then it is described in a product schematic which includes the need for a battery energy storage system, inverter, converter, charging system, and several other supporting components. These need to be done, so there is no imbalance between the specifications of the developed portable generator and the existing power requirements. This research provides an overview energy management system of the portable generator LiFePO4 battery.

Based on the real monitoring data, the total capacity usage during one month is 2191,35Ah. Therefore, the total power usage during one month is 26,29kWh. The average of capacity daily used is 73Ah. Minimum energy use in one month occurs on Wednesday, July 13, 2022, with a usage capacity of 56Ah or around 974Wh. Meanwhile, the highest energy use in one month occurs on Sunday, July 10, 2022, with a usage capacity of 97.4Ah or around 1.6kWh.

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