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A Monitoring System of Battery $LiFePO_4$ for Assessment Stand-Alone Street Light Photovoltaic System Based on LabVIEW Interface for Arduino (LIFA)

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ABSTRACT

The paper presents monitoring and assessment system of battery $LiFePO_4$ performance that applied on a stand-alone photovoltaic system. A stand-alone photovoltaic system is constructed by photovoltaic module 50 Watt Peak, Pulse Width Modulation solar controller, battery module $LiFePO_4$ battery (12 Volt 21 Ah), and street light 10 watt. To overcome the data acquisition, a simple monitoring system has been designed using LabVIEW Interface for Arduino. The voltage divider, current sensing type ACS712, temperature and humidity sensor, and light intensity sensor were used to collect the data. The data processed by a dual microcontroller (ATmega-2560 and ATmega-328) and LabVIEW software on Personal Computer. The assessment of stand-alone photovoltaic system includes battery $LiFePO_4$ performance (State of Charge, voltage, and current) during charging and discharge condition, the power efficiency, and environmental condition (temperature, humidity and solar radiation). In the discharge condition, voltage battery and State of Charge decreased about 40% after 12 hours operated. In the charge condition, the current battery fluctuated in the range of 0.10 A-1.95 A and the State of Charge increased up to 25% after 8 hours operated. It indicates that the power of the battery has always lacked.

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1. INTRODUCTION

Street lights are fundamental part of the street, road, or highway to ensure sufficient visibility at night vision in order to increase the safety and decrease the crash rate. The street lights illuminate more than 13 hours every day endanger huge amount of electrical power consumption that related to high cost [1]. This issue has attracted the researcher to use photovoltaic modules as an alternative power source that offers low operational cost [2], clearer, less emission and no fossil fuel [3]. In addition, the PV stand-alone for street light system model needs a battery to store the electric power from photovoltaic module and supply the energy to the street light.

As a vital component, there are many kinds types of battery for the PV stand-alone for street light system such as lead acid [4]-[6], Lithium-ion [5]-[6], and $LiFePO_4$ [4], [7]. It should be noted that different kind of battery will give different performance [8]. Comparing these three kinds of battery, $LiFePO_4$ battery became a strong candidate because it has the longest life cycle up to 6000 cycles [9], non pollution property [10], and it was less reactive with the electrolyte at high temperature [11]. $LiFePO_4$ is a rechargeable battery that has C-$LiFePO_4$ or carbon on the cathode and carbon intercalated with lithium on anode. This battery has high theoretical capacity 170 mAh g^{-1} [12]. It runs effectively in the temperature range of 25^{o}C-

45^{o}C and current range of 0.33 C to 2C [13]. However battery performance will be decreased as the time goes. The lifetime of a battery will be longer when it always operated in the safe operating area. Improper charging and discharging process will decrease the battery's performance and shorten the lifetime [8]. Battery monitoring was necessary in order to elude the battery from over charge, over discharge, and over heat that could damage the battery. As a result, a comprehensive monitoring of the battery was significant to do.

Monitoring of the battery was done by many researchers and deal with many methods, such as HOMER software [3], using a single chip microcomputer and DS2438 [14], using Lab VIEW on PC [15,16]. However, some of battery monitoring did not have weather monitoring and light intensity. Others research have been carried out that the weather and light intensity will influence PV performance [17]-[18] and so does the battery. The paper presented a novel solution to assess the battery $LiFePO_4$ performance that applied on a stand-alone PV system with implant a temperature and humidity monitoring.

2. RESEARCH METHOD

The monitoring and assessment system (MAS) of Battery $LiFePO_4$ constructed both hardware and software to assess the stand-alone PV system. The schematic of MAS is shown on Figure 1.

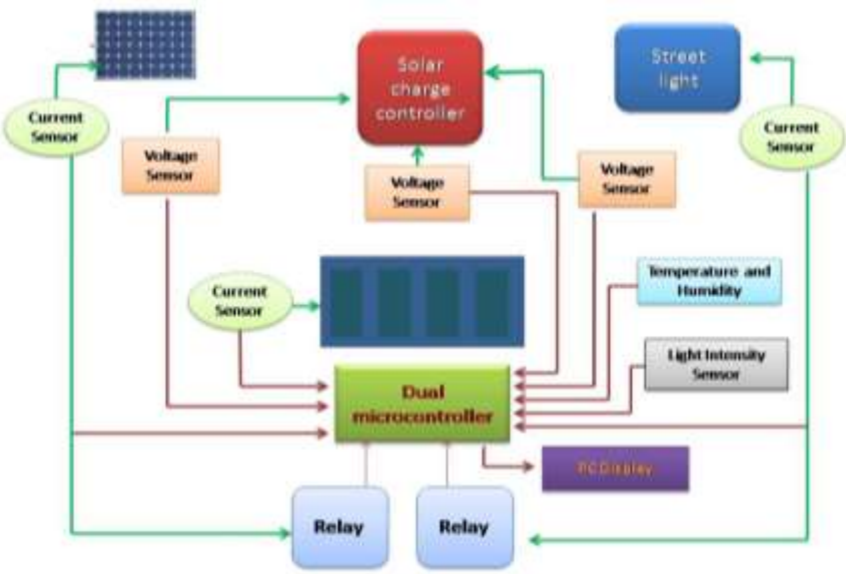

Figure 1. The design of monitoring system for assessment battery $LiFePO_4$

2.1. Stand-Alone PV Street Light System

The MAS was implanted to evaluate stand-alone PV street light system which designed including photovoltaic (PV) 50 watt peaks, battery $LiFePO_4$ module smart UNS (12 Volt, 21 Ah), solar charger type PWM and LED for lighting system. PV module was used to convert solar energy to electrical energy and charging electricity to the battery. It was produced by Sunbe Solar type SPM 50-12 with dimension 800 x 500 x 35 mm, which has maximum power voltage (V_m) 17.2 Volt and maximum power current (I_m) 2.91 A. Furthermore, electrical energy was stored on the battery module $LiFePO_4$ 12 volt, 21 Ah (252 Wh). LED type 10 watt was used as a load system for the battery discharging.

2.2. Measurement and Assessment System (MAS)

2.2.1. Sensor

The MAS of battery LFP was constructed by current sensor (3 ea), voltage sensor (3 ea), temperature and humidity sensor and light intensity sensor. The ACS-712 based on hall-effect system were used as current sensor. The voltage sensor type ADC voltage divider that can be operated until 25 volt is selected for the MAS. Furthermore, sensor for environment monitoring included temperature and humidity, type DHT 11 that operated for the measurement on range 20-90% of humidity and temperature 0-50^{o}C. The solar radiation was measured using light intensity sensor (LDR 7 mm diameter).

2.2.1. Microcontroller

Both main controller ATmega-328 and ATmega-2560 were used to control the system. ATmega-328 was used to control LDR and DHT 11, while the ATmega-2560 was used to control voltage divider, ACS 712, and relay module. This method was chosen to avoid the memory leakage. These kinds of microcontroller have many advantages such low cost, able to run on different platform, easy assembly due to the constitution of the modules, and open source [19]. The research proposed dual microcontroller to reduce data acquisition bouncing. The schematic of main controller is shown on Figure 2.

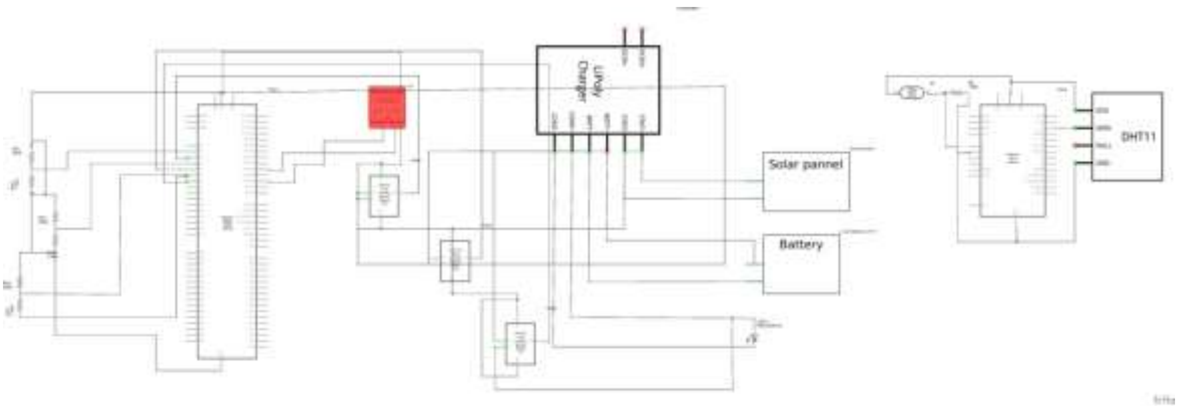

Figure 2. Schematic diagram of main controller

2.3 State of Charge (SOC) Algorithm

The vital information for assessment of battery lithium is State of Charge (SOC) that inform battery condition during charging and discharging. The coulomb counting method was used to calculate SOC of the battery during charging and discharging process which follows equation [20] :

$$SOC(t) = SOC_0 - \frac{1}{C}\int Idt \quad (1)$$

Herein, SOC(t) is charging state of this time and SOC_0 is State of charge condition of the battery before used. C is the maximum battery capacity (Ah), I is current of this time and dt is special grid. SOC_0 is calculated based on voltage of battery. The relationship between voltage of battery and SOC is shown on Figure 3.

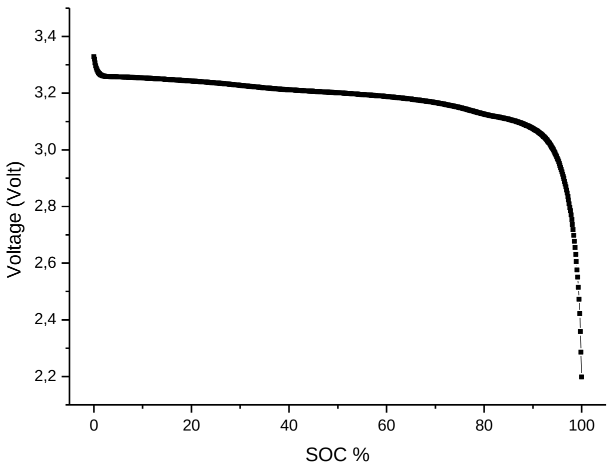

Figure 3. Relationship between SOC and voltage battery

The SOC data (Figure 3) were observed using battery analyzer type BST8-3 on 1C of discharging condition. The relationship of SOC and voltage of battery is used as the data refference of SOC_0 on this research. The SOC subroutine (Figure 4) calculated SOC_0 of battery based on battery voltage.

2.4. LabVIEW Interface for Arduino (LIFA)

LabVIEW Interface for Arduino (LIFA) is a toolkit that can be downloaded freely which allows a LabVIEW developer to control and acquire the data from microcontroller. LIFA helps LabVIEW software easily communicate and move the information from Arduino pins. LabVIEW became more productive when collaborate with Arduino because they have interactive tools that help the user to build complex tasks, design, and interact with the system through graphical programming [19]. The flowchart of program was shown on Figure 4.

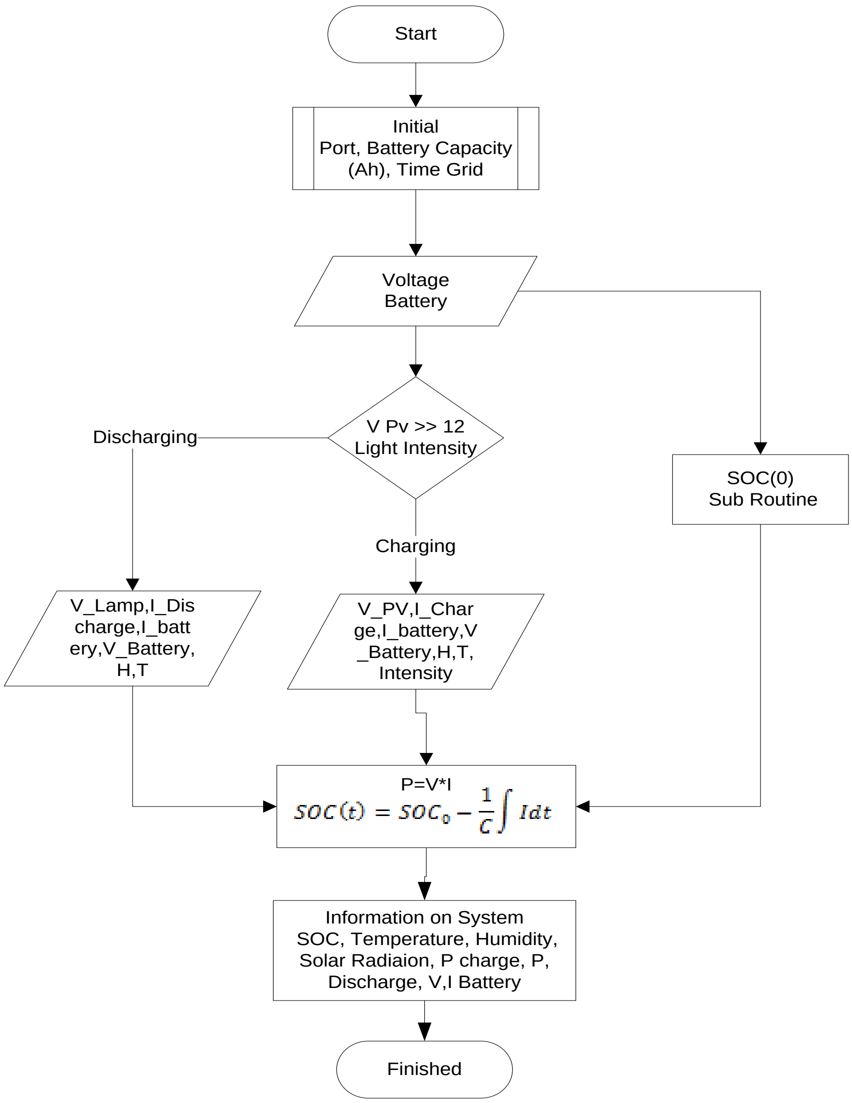

Figure 4. Flowchart of the program

2.5. Calibration System

The assessment of battery $LiFePO_4$ system was calibrated each part of the system include temperature and humidity system and the light intensity sensor. Table 1 shows the comparison of temperature/ humidity between DHT 11 and actual condition. The Light Dependent Resistor (LDR) sensor was calibrated to obtain the light intensity in unit of Lux by comparing the ADC data of LDR with the Lux meter. The light bulb was varying the intensity to obtain the data and the result was made a curve to find the relationship between ADC and Lux meter (Figure 5).

Table 1.Comparison of temperature/humidity between DHT 11 read and actual

Temperature Humidity	Average± Standard Deviation	Actual	Error (%)
Temperature	26,2 ±0,45°C	26°C	1.71%
	28,8±0,84°C	28°C	2.91%
	31,0 ±1,00°C	30°C	3.23%
	31,8 ±0,84°C	32°C	2.63%
	34,6±0,55°C	34°C	1.58%
Humidity	59,4±1,34 %	60 %	2,26 %
	55,4 ±0,84 %	57 %	2,06 %
	54,2±1,14 %	55 %	1,54 %
	51,0 ±1,00 %	52 %	1,39 %
	48,8 ±0,84 %	51 %	1,71 %

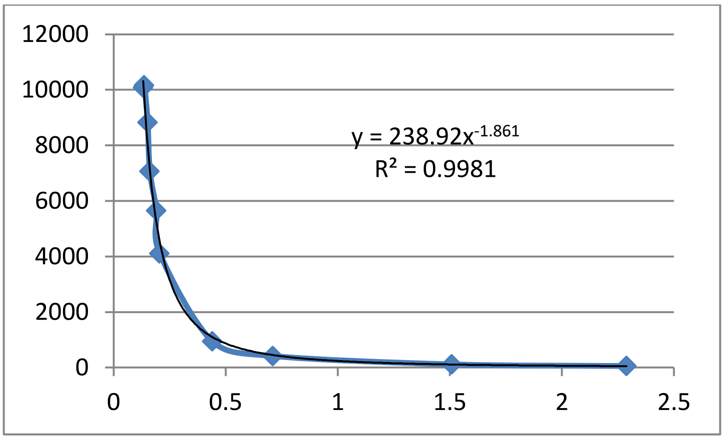

Figure 5. Lux measurement vs. LIFA read

The voltage data of ADC has been converted to to light intensity (Lux) value using a regression technique that through this following Equation;

$$\text{Light intensity (lux)} = 238.9 \text{ x } (\text{LDR read})^{-1.86} \tag{2}$$

3. RESULTS AND ANALYSIS

3.1. Graphic User Interface

The monitoring system of $LiFePO_4$ battery on stand-alone street light photovoltaic system has been designed using LabVIEW Interface for Arduino (LIFA). Figure 6 is a Graphic User Interface (GUI) front panel of the data measurement during monitoring process. It consists of graphs and numeric indicators for monitoring the voltage, current, and power from the photovoltaic module, street light, and battery. Subsequently, it showed the bar and numeric indicator for State of Charge (SOC). Temperature (^oC) and humidity (%RH) condition were easily monitored through displayed in graph, bar, and numeric indicator. The light intensity can be monitored through Lux meter and numeric indicator. In addition to show the real-time data, the table was also displayed. All data acquisition was converted to table in excel automatically and easy to convert on the graph. In this research, the data were obtained every 20 second. Thus, the oscillation of the power, voltage, and current were clearly revealed. This result gives complete information about the actual condition in battery, photovoltaic module, street light, light intensity, ambient temperature and humidity.

Another battery monitoring system was focused on observed battery condition during charging and discharging with coulomb counting method and a Local Area Network: LAN by Nic DAQ-9188 and module NI9335, NI9227, NI9211, NI9401[15]. Unfortunately, this monitoring system did not complete with light intensity and environment monitoring. The result also did not display the PV and load graph [15]. In addition, our previous work has done battery monitoring using LabVIEW Interface for Arduino (LIFA), but only showed the voltage and current information [16].

Figure 6. Front panel of Measurement and Assessment System (MAS) of LFP battery on a stand-alone PV

3.2. Performance Test

The stand alone photovoltaic street light was placed at Universitas Negeri Sebelas Maret Surakarta, Indonesia (7°33'23.9"S 110°51'18.6"E). In this research, the photovoltaic was assembled with 20^{o} slope to make sure that the rain drops flow easily on the photovoltaic surface that is showed in Figure 7. The charging process was conducted during daylight about 8 hours and the discharging process during the night about 12 hours. But, the effective charging was only 3 hours from 11 am to 2 pm. This condition indicates that the light intensity becomes the biggest factor that influences the PV performance during charging.

(a) (b)

Figure 7. Performance test (a) during charging; (b) during discharging

The performance of LFP battery has been observed for 3 days included the trend of battery, PV, and street light performance during 3 days monitoring that was showed in Figure 8. The “peak” patterns present their performances during charging and “flat” patterns present their performances during discharging. In addition, since the battery was supplied by the photovoltaic module, the performance of the battery during charging was greatly influenced by photovoltaic module. The power of battery is always under the power of PV. In the morning, the power of PV and battery were low, but they gradually increase and reach the maximum point at midday. However, the power of PV and battery were slowing down after midday and reach the minimum point in the night. The power of street light during discharging remains constant.

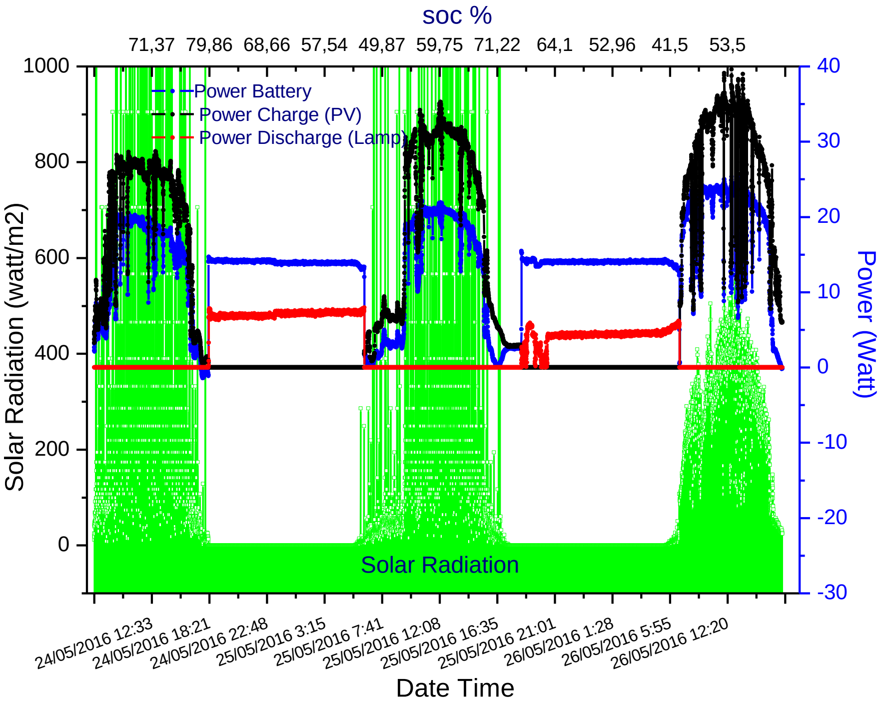

Figure 8. Battery performance during charging and discharging

4. CONCLUSION

The monitoring system of $LiFePO_4$ battery on stand-alone street light photovoltaic has been implemented based on LabVIEW Interface for Arduino (LIFA). This continuum comprises PWM solar charge controller and several sensors for measuring a set of parameters that integrated to double microcontroller ATmega-328 and ATmega-2560. The data has been delivered to personal computer through USB port therefore the result can be displayed on the LCD in real time. The GUI front panel in LabVIEW has been set to display the measurement result in graphical and numerical data of a package power, voltage, and current from the PV, battery, and street light. In addition, State of Charge (SOC) battery, light intensity, and weather condition were also displayed. These results have been transferred automatically to excel in order to facilitate the user to save and convert the data to graph. In this research, the current of $LiFePO_4$ battery during charge fluctuated depending on light intensity and weather condition.

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