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Diterbitkan: 2021-08-03

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Individual Battery Monitoring System using IoT in Electric Vehicle Prototype

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Abstract*—This research objective is to design and develop an individual monitoring system of a battery in an electric vehicle. The methodology of this research is problem identification, literature review, determining the target, analysis and problem solving using various method. The result shows implementation of sensor for individual battery and send the data as a display and to the IoT cloud. The calibration has been done to the device with 1.5% accuracy. The calibration factor for all battery has been calculated and implemented. The pulse charging system has been used to improve the lead acid battery condition. Data verification has been done with the measurement outside the prototype.

***Keywords*—electric vehicle, sensor technology, IoT, automotive, calibration, lead acid battery.**

I. Introduction

There are several ways to minimize the consumption of fossil fuel, to reduce the noise emission and to reduce the pollutant. The example of the solutions are alternative fuels and alternative types of drive. Alternative fuels can be used with Natural Gas, methanol, Hydrogen and Electric Fuel. (Fig.1.)

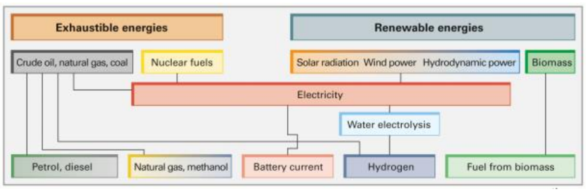

Fig 1. Renewable energy chart [1]

The condition of the battery with total voltage monitoring system is not complete to determine the condition of battery. The battery should be monitored in comprehensive ways, not only the whole system of the battery, so we can focus on which cell from the battery should be repaired. The one of main system of an electric vehicle is battery system. The electric energy stored in a battery and be monitored with a control module.

According to the cost efficiency, the lead acid battery still have wide user in vehicle application [2]. Lead acid battery have an energy sources from chemical reaction on two types of electrodes in a sulfuric acid fluids. The common reaction of lead acid battery is on Fig. 2.

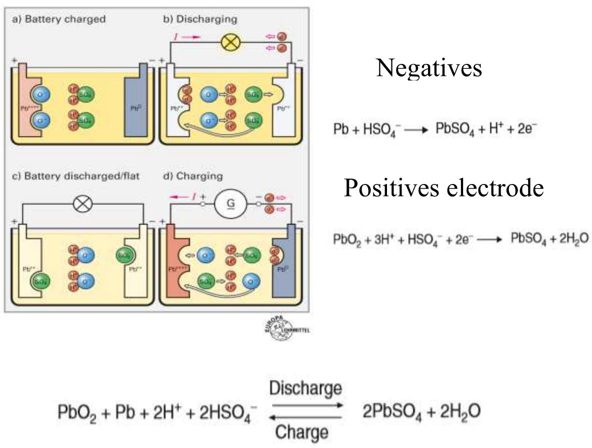

Fig. 2. Electrochemical process during charging and discharging [1]

The example subsystem of battery management system is voltage detection, Current detection, temperature and internal resistance [3]. The critical system of battery on an EV is Battery Management System (BMS).

The main function of BMS are: data acquisition, safety protection, state measurement, battery charging and discharging, cell balancing, thermal management, delivery data for user interfaces, prolonged battery life and battery components communication [4].

With controlling the BMS, Pilatowicz, G (2016) make a smart system in a micro hybrid vehicle with error 124mV in a static pulse and dynamic driving. This system is accurate to ensure the vehicle reliability, prolong service life and reduce warranty cost [5].

Android based battery monitoring system has been developed by Menghua (2017). Menghua monitored the Li-ion battery and display the result using android application [6]. The proposed system will use for lead acid battery and use the ThinkSpeak® cloud platform.

II. METHODOLOGY

A. Research Design

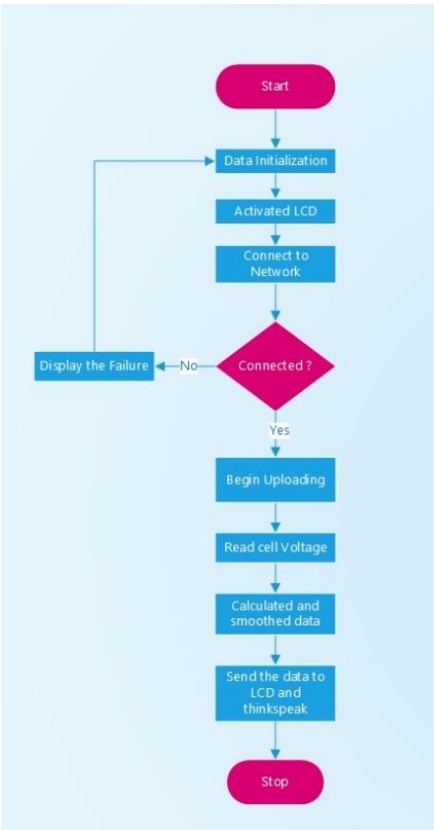

Fig. 3. Voltage monitoring research design.

The program flowchart on Fig. 3. shows the concept to set a program and send the data to the microcontroller through USB cable. The microcontroller using IDE program software.

B. Electric Vehicle (EV) Prototype

The specification of EV's is on Table 1. It designed for 2 passengers only.

TABLE 1
EV SPECIFICATION

Parameter	Units	Value
Motor Type	-	BLDC (Brushless) 500W 48V
Battery	-	MF 48V 20Ah
Maximum Torque	Nm	7.7
Maximum RPM	RPM	2800
Maximum Speed	Km/h	12
Differential Type	-	Hypoid bevel gear with independent drive shaft
Controller Type	-	Programmable with regenerative brake system

C. Voltage Measurement Circuit

The voltage measurement circuit have 2 main function such as to measure and send the data into LCD Display and to measure and send the data into IoT platform through wireless communication boards (ESP8266).

The function of LCD is to display the result of voltage measurement as shown in Fig. 4, this process will be done using I2C module. If the systems do not use the I2C module, the cable requirements will increase.

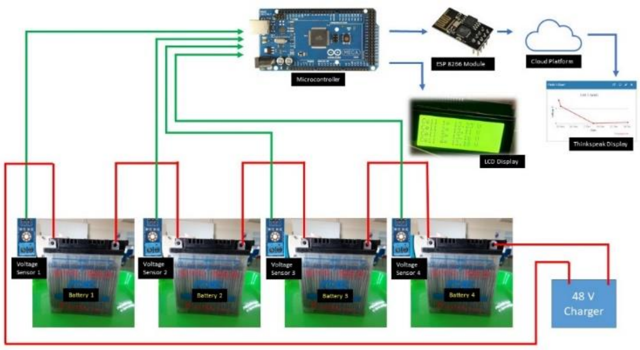

Fig. 4. Voltage monitoring circuit

D. Battery Preparation

The batteries that be used in this study are lead acid type batteries. It has 5Ah capacitance and 12 Volt voltage system. Each battery consists of 6 cells, every cell has ± 2.1 volt. The battery filled up with the electrolyte (H2SO4) until the service indicator (Fig. 5). The total number of all battery in this system is 4 batteries. Each battery have is own open terminal voltage value (Fig. 6).

Fig. 5. Lead acid battery

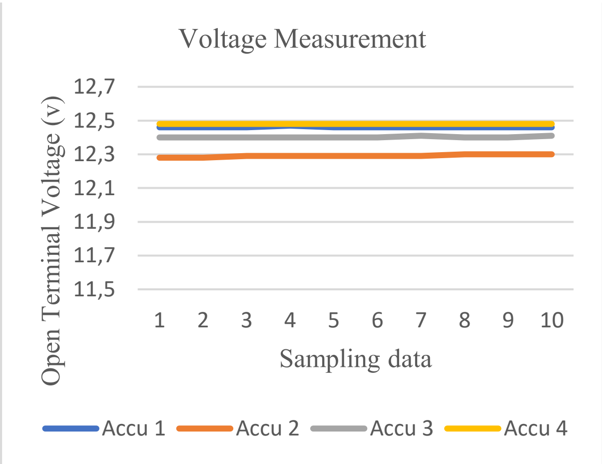

Fig. 6. Open terminal voltage

III. Result and Discussion

In this study, the voltage sensor is the important key to support the battery monitoring system. The Voltage measurement circuit consist of 4 voltage sensors which connected to each battery as shown in Fig. 7.

The voltage sensors locate on console box and connect to the battery with cable. Each battery has a specific sensor. The microcontroller receives the analog sensor data and calculate the data. The result of this data calculated, and the microcontroller send the data into LCD display through I2C module and send to the IoT cloud through ESP8266 module.

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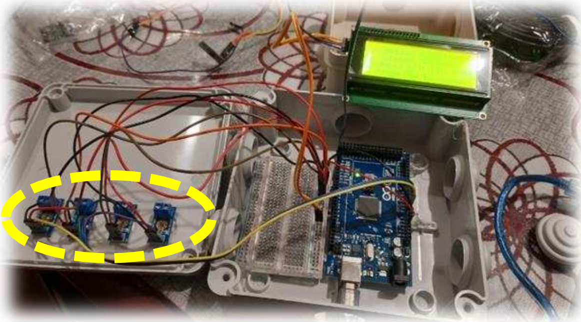

Fig. 7. Experimental setup of voltage monitoring system

The differences were found between sensor reading and voltage measurement devices (Fluke 325) with accuracy 1.5% (Fig. 8) [7]. The first step to solving the problem is validate the result of the sensor. The sensor reading also have result differences. The method of this study is using averaging method on microcontroller program and then calibrate the result to get closer to voltage measurement devices.

Fig.8. Comparison of voltage measurement by using sensors arrangements and Fluke voltage measurements.

The sampling data that be used on this study is 300 samplings. Each data has a delay 10 ms. The serial data issued from microcontroller is sent to the serial monitor on Microsoft Excel Program. This function is to capture the value of the data and calculated it through excel function, such as: averaging, maximum data, minimum data and trendline formula.

Fig. 9 shows the differences between sensor reading and voltage measurement device reading. The result of LCD display is always changing, to solve this problem we use averaging method. Cell 1 used as an example to average process.

To solve the differences between averaging data and fluke 325 measurement data, this study tries to find the equation. To make the equation, the data reading is not only at 10 V but in the 12 V and 14 V point. The methodology is using a stable voltage source and set the value until fluke 325 product shows the voltage value 10 V, 12 V and 14 V. the data is on linear line equation (Fig. 10 and Table II).

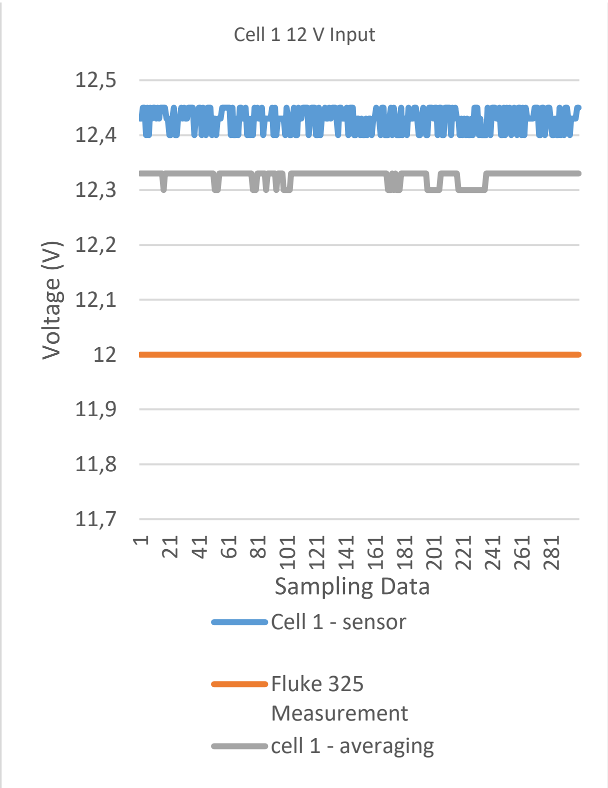

Fig. 9. Cell 1 with 12V input

After reading the data in various voltage and all cell of the battery, the next process is to find the linear equation for calibration. According to experimental data, the result of all cell calibration factor is on Fig. 10 and Equation (1).

TABLE II
ALL CELL MEASUREMENT

Input Voltage (V)	Cell 1	Cell 2	Cell 3	Cell 4	Average
10.0	10.28	10.39	10.43	10.38	10.37
12.0	12.33	12.40	12.47	12.51	12.42
14.0	14.53	14.55	14.57	14.58	14.56

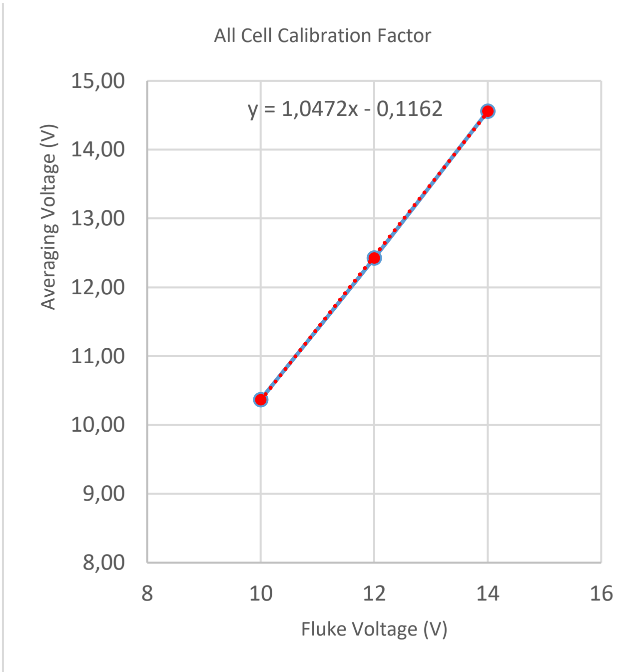

Fig. 10. All cell calibration factor

$$Sr_A = 1.0472\, Fr - 0.1162 \quad (1)$$

Whereas:
SrA = Average Reading
Fr = Fluke Reading

The IoT implementation can be done using ESP8266 module. It send the data through internet connection and display the data to the web-based display. Wherever the observer is, the data could be read as long as there is an internet connection. The IoT system consist of microprocessor, voltage sensor and ESP module (Fig. 11).

Fig. 11. IoT result for free Thinspeak platform

IV. CONCLUSION AND RECOMMENDATION

Based on the planning, literature and experiment data, the conclusion of this study are:

- The monitoring system has been designed and implemented as a prototyping. The monitoring system send the data as a display and to the IoT cloud. The display shows the individual cell voltage, so the defect cell could be determined.

- The calibration has been done to the fluke 325 with accuracy 1.5% thus for 10V system the device has 0.15V error. Without calibration, for the 10 V measurement the error varies between 10.25-10.33 V. The calibration factor for all measurement data is Vmeasure =1.0472*Vout-0.1162

Recommendations (Next Step):

- The Implementation of Charging with temperature factor influence
- The Implementation of another pulse signal to recovery the battery

ACKNOWLEDGMENT

The author would like to thank to Mr. Dena Hendriana., BSc., M.Sc., Ph.D and Mr. Ary Syahriar,. Ph.D,. DIC. and all Lecturers for their collaboration on this research.

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