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To cite this article: A E Mulyono et al 2018 IOP Conf. Ser.: Mater. Sci. Eng. 432 012057

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Abstract. Indonesian battery consortium for solar cell battery has made several battery prototypes and ready to be tested in a real system. Monitoring performance of battery prototype, while it is running in real system is necessary in order to study its behavior. The results are important to be used for improvement of the battery prototype itself. Accurate monitoring of battery performance can be obtained by fitting the instrumentation with the application and condition which are monitored. Generally the system for monitoring battery performance only measures electrical current and voltage, meanwhile for further development, it is also important to measure another variables like internal and ambient temperature of the battery pack. Therefore development of battery performance data acquisition system for monitoring battery performance inside solar cell system is acquired. Battery voltage and current will be measured using a DC voltage sensor based on voltage divider, and using non-invasive current sensor WCS1800, respectively. Temperature inside battery pack and ambient temperature are measured using thermocouple type K, and BME280, respectively. All measured variables are pooled to the microcontroller and then they are transmitted to the display screen. This system is expected to be used for monitoring battery performance accurately.

1. Introduction
In battery research and development, monitoring performance of battery prototype while it is running in real system is necessary. This because its behavior in real system is important to be known for further improvement of the battery prototype itself. Accurate monitoring of battery performance can be obtained by fitting the instrumentation with the application and condition which are monitored. Nowadays several companies have already provided battery monitoring product or data loggers. But their product cannot fulfill the requirement from the consortium (Indonesian battery consortium for solar cell battery), for example temperature monitoring is not included in their system. To fulfill the team requirement, the system should be customized.

Several researcher has also made their own customized battery or solar monitoring system [1–16]. However all their system were made to communicate with PC (Personal Computer with windows
as Operating system). This paper will describe a new approach for data acquisition system that replacing the role of PC in another researcher’s system by using android-based device as display screen and data logger. Android device based application can be easily made by using app Inventor while making PC-based application cannot using app inventor. Moreover Android-based device offering more flexibility in data flow management than PC-based device.

2. Experimental method

Generally the system consists of two main sub-system, namely, a system for measuring the variable which is called “Measurement System” and a system for displaying the data on display screen and for logging the data into internal memory of Android-based device which is called “Display and Logging System”. Block diagram for this system can be seen in Figure 2. Measurement System is placed inside the panel of Solar Cell system, while Display and Logging System can be placed remotely from Measurement System, for example, can be placed inside the building. Physical illustration of the system can be seen in Figure 1.

![Illustration of the integrated system for solar street lamp.](image)

Variables that measured in this system are voltage, current and temperature. Voltage will be measured using simple voltage divider with the ratio 1:5. Current will be measured using WCS 1800 which output is already in the voltage. Temperature inside the battery is measured using thermocouple type K that will be interfaced using module MAX6675. Ambient temperature is measured using BME280.

Figure 2 shows that voltage and current is interfaced to microcontroller (arduino Nano) via module ADC (Analog to Digital converter) ADS1256 which has 24 bit full resolution (23 bit if used single ended mode) and this module using SPI (Serial Peripheral Interface) protocol to communicate with Arduino Nano. Module MAX6675 for thermocouple and BME280 are also communicate through SPI protocol with arduino Nano. All the data that has been collected by arduino Nano then will be transmitted to the other side of the system through module HC12 (radio communication module), Nano communicate with HC12 via UART protocol.

On the other side of system, another HC12 receive the information and then forward the information to microcontroller (arduino Mega), based on the datasheet, the communication range between a pair of HC12 is maximum 1.8 km Line of Sight. From this microcontroller information were forwarded to
display screen via bluetooth communication. Finally the information would be displayed on display screen, 10 inch Android-based device, Chuwi Hi10 Pro. The Graphical User Interface (GUI) was made using App Inventor, beside displayed, information are also logged by this device.

Figure 2. Block diagram for battery monitoring system for solar cell system.

Figure 3. (a) Voltage sensor verification experiment, (b) current sensor verification experiment.
Figure 4. (a) Photo of voltage sensor verification experiment, (b) Photo of current sensor verification experiment.

In this paper, the system was tried to be applied in lab scaled, not in real solar cell system yet because it was still under development. Voltage and current measurement verification was done using Variable Power Supply Zhaoxin RPS3005DB. Voltage and Current verification experiment was done separately to make sure the value that measured by the sensor did not affect each other. Figure 3 below illustrate how the experiments was done, Figure 4 is the documentation of experiment. Temperature Measurement data validity was referred from its datasheet.

After passed the verification step, the system was tested on the simulation of solar cell system which is replaced solar cell module with variable power supply in solar cell system. The other part of solar cell system is still same which is consist of solar charger controller, battery and load. The illustration of this experiment can be seen in Figure 5.

Figure 5. Simulation of solar cell system experiment.

3. Result and discussion
Results from voltage and current sensor verification step can be seen in Figures 6(a) and 6(b). Figure 6 describes the relationship between voltage and current that was measured by the prototype vs. value
that was given by verification device (Zhaoxin RPS3005DB). It showed that relationship between input value from verification device and the value that read by prototype was tend to be linear. Specifically, mathematical relationship that obtained from this experiment can be written as in equation [1–5].

\[
P = a \cdot X + b \tag{1}
\]

\[
\begin{bmatrix}
\text{Load Voltage} \\
\text{Battery Voltage} \\
\text{Solar Cell Voltage} \\
\text{Load Current} \\
\text{Battery Current} \\
\text{Solar Cell current}
\end{bmatrix}
\]

\[
a = \begin{bmatrix}
0.003 & 0 & 0 & 0 & 0 & 0 \\
0 & 0.003 & 0 & 0 & 0 & 0 \\
0 & 0 & 0.003 & 0 & 0 & 0 \\
0 & 0 & 0 & 0.009 & 0 & 0 \\
0 & 0 & 0 & 0 & 0.0091 & 0 \\
0 & 0 & 0 & 0 & 0 & 0.0087
\end{bmatrix} \tag{2}
\]

\[
X = \begin{bmatrix}
\text{ADC value for Load Voltage} \\
\text{ADC value for Battery Voltage} \\
\text{ADC value for Solar Cell Voltage} \\
\text{ADC value for Load Current} \\
\text{ADC value for Battery Current} \\
\text{ADC value for Solar Cell current}
\end{bmatrix}
\]

\[
b = \begin{bmatrix}
-96.865 \\
-121.8 \\
-128.65 \\
-38.980 \\
-37.703 \\
-36.434
\end{bmatrix} \tag{3}
\]
When $P$ are physical value that want to be read, $X$ are ADC value that readed by the prototype, $a$ and $b$ are constant that obtained from experiment. This equation was used for translating ADC value to information that shown by display system.

![Documentation from simulation of solar cell system experiment](image1)

(a) ![Documentation from simulation of solar cell system experiment](image2)

(b)

**Figure 7.** Documentation from simulation of solar cell system experiment (a) without data acquisition system (b) with data acquisition system.

![Screenshot of display screen](image3)

**Figure 8.** Screenshot of display screen.
Figure 9. Screenshot of data logging results.

Figure 10. Documentation of solar cell system experiment and logging system while running.

Results from simulation of solar cell system experiment can be seen on Figure 7. Screenshot for display and data that had been logged by the logging system during experiment can be seen on Figure 8 and 9. Documentation of Display and Logging system while running can be seen in Figure 10. It can be seen from Figure 7 until 10 that the system worked well. The data that were measured from Measurement System could be successfully displayed and logged by Display and Logging System.

Voltage measurement range from this device is 0-25 Volt, current measurement range is 35 until 35 Ampere. Thermocouple in this prototype has range from 0-1024 degree Celsius, and BME280 for environment temperature can measure from -40 until 85 degree Celsius. The advantage of this prototype compared to other reference is in ADC unit, and its software is in Display and Logging System. The ADC that used in this device is 24 bit which is give more resolution than other reference that used
ADC less than 24 bits [5, 7, 14, 16–18]. Software that was used to build an application in Display and Logging System is MIT App Inventor, which is free and easy to use, meanwhile software that was used by reference are not free [2, 4, 6, 8–10, 13, 14, 19]. This experiment had successfully proved that data acquisition using Android-based device can be implemented for monitoring battery performance inside solar cell system.

4. Conclusion

The system for monitoring battery performance which used an Android-based device has been developed. Voltage, current, and temperature were successfully measured by the prototype. The data from measurement system to display system can also successfully be transmitted. The Graphical User Interface for displaying information also works well. The logging system is also works fine. Overall the system works fine, but it is still have several deficiency such as, its prototype casing, its capacity algorithm verification, the determination of real maximum distance, etc.

Acknowledgment

We would like to express my gratitude to PTM-BPPT and Indonesian Consortium for Solar Cell Battery for their sponsorship and loaning of the equipment. This work is partially supported from the grant for the New and Renewable Energy Research Consortium for Lithium Battery Development as Energy Storage of Solar Electricity Power funded by the Indonesian Ministry Research and Technology.

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