Development of battery performance data acquisition system for monitoring battery performance inside solar cell system

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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.

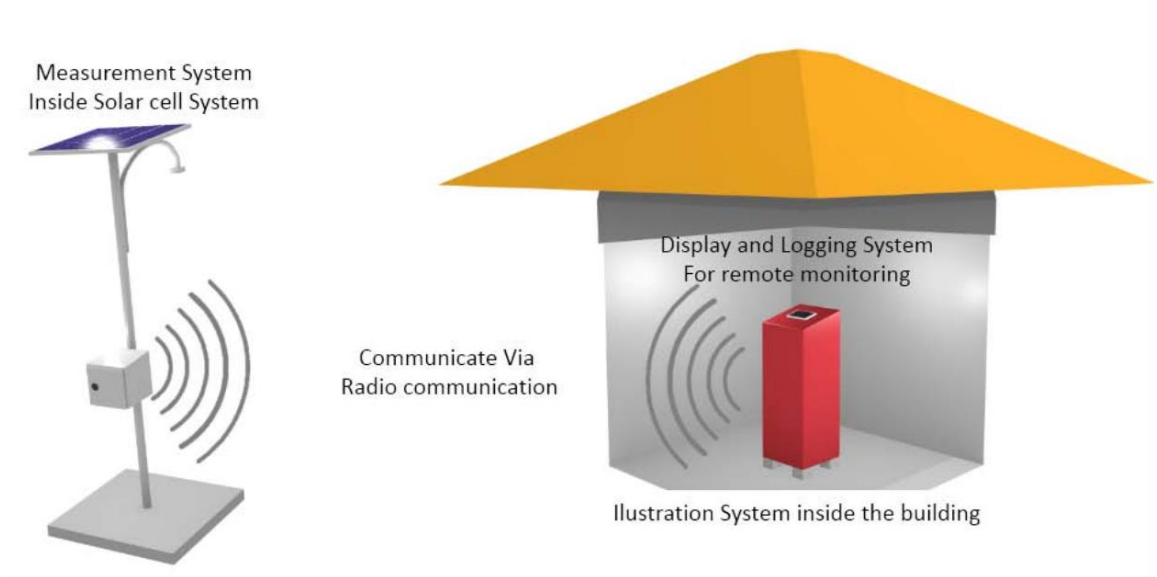


Figure 1. Illustration of the integrated system for solar street lamp.

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.

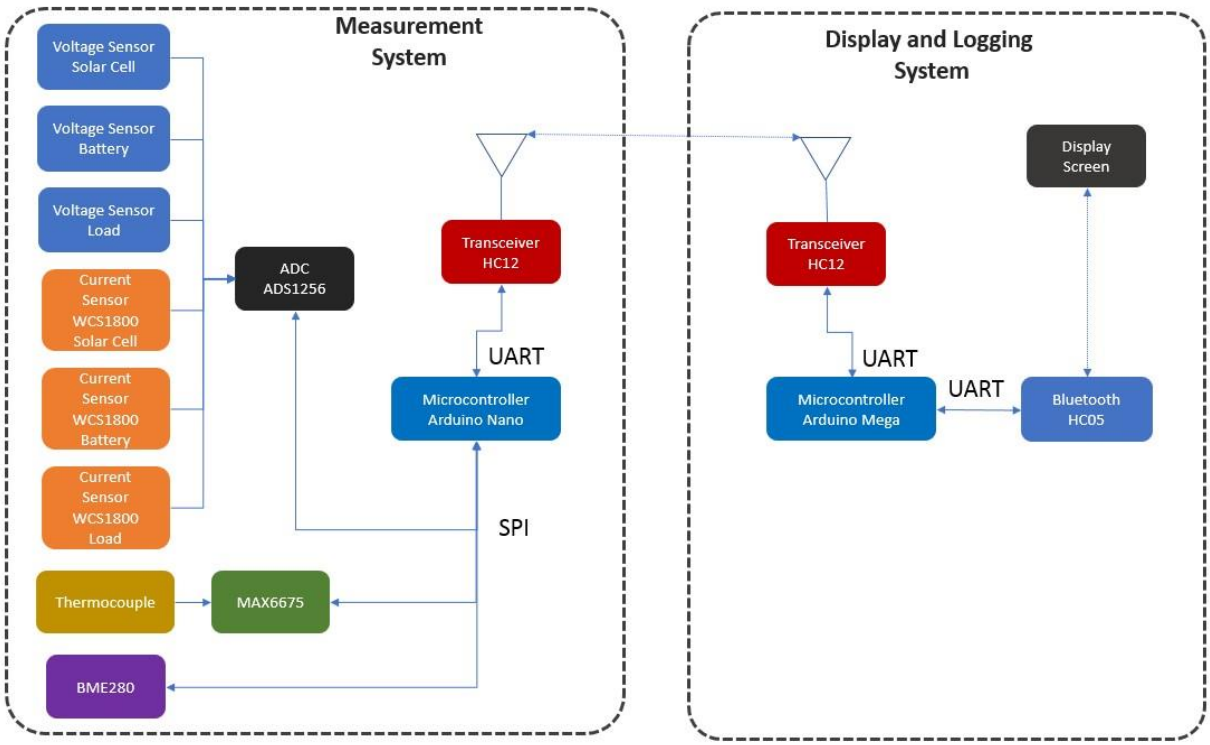
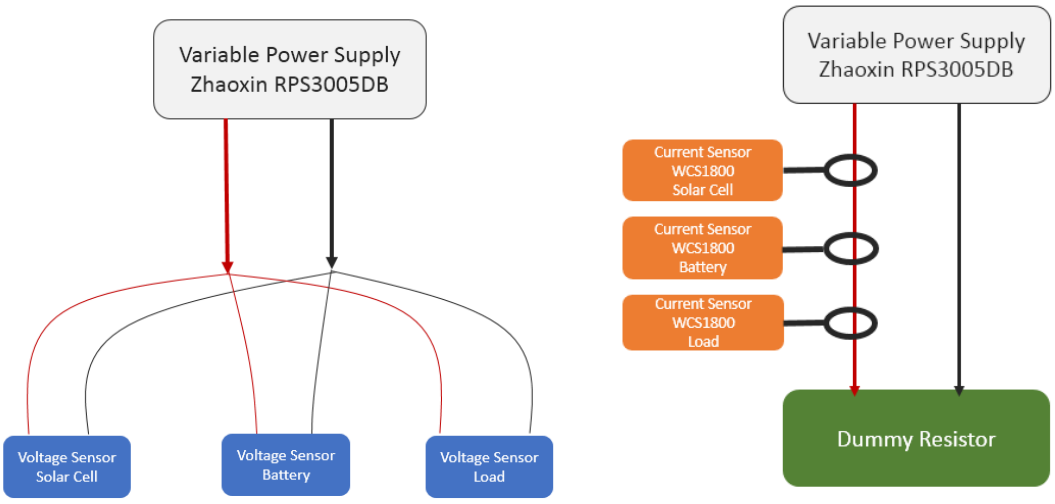
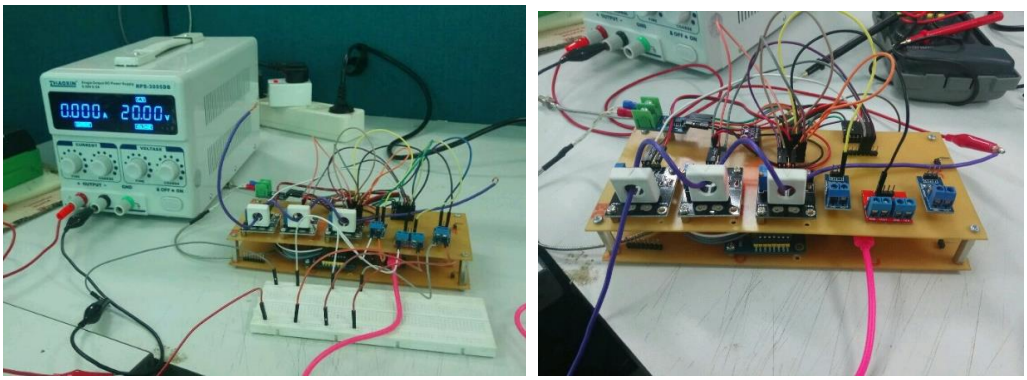


Figure 2. Block diagram for battery monitoring system for solar cell system.



(a) (b)

Figure 3. (a) Voltage sensor verification experiment, (b) current sensor verification experiment.



(a) (b)

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.

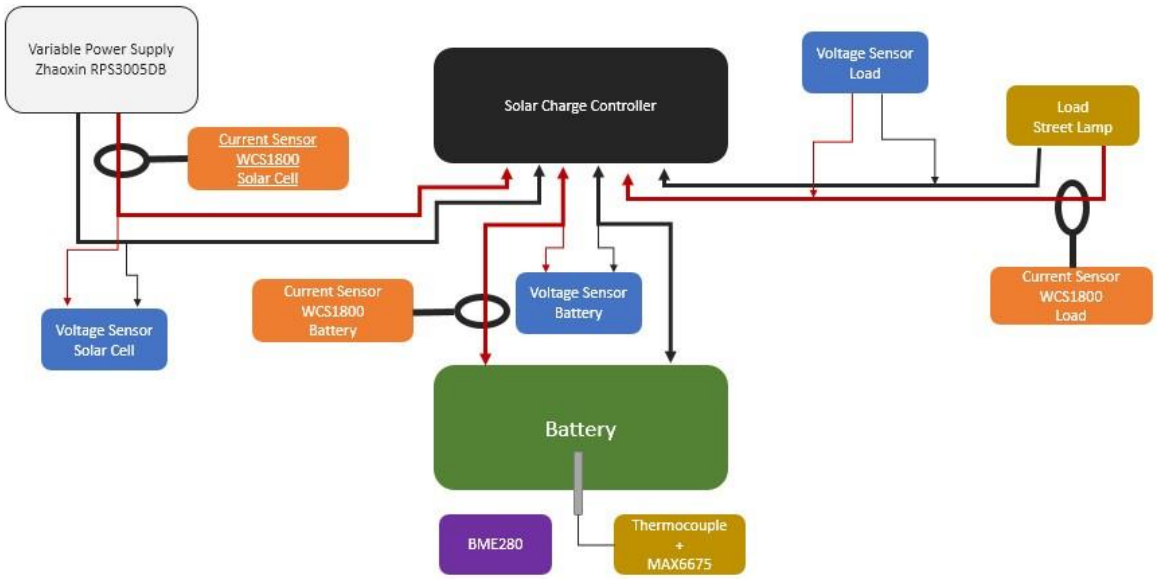


Figure 5. Simulation of solar cell system experiment.

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 givenby 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].

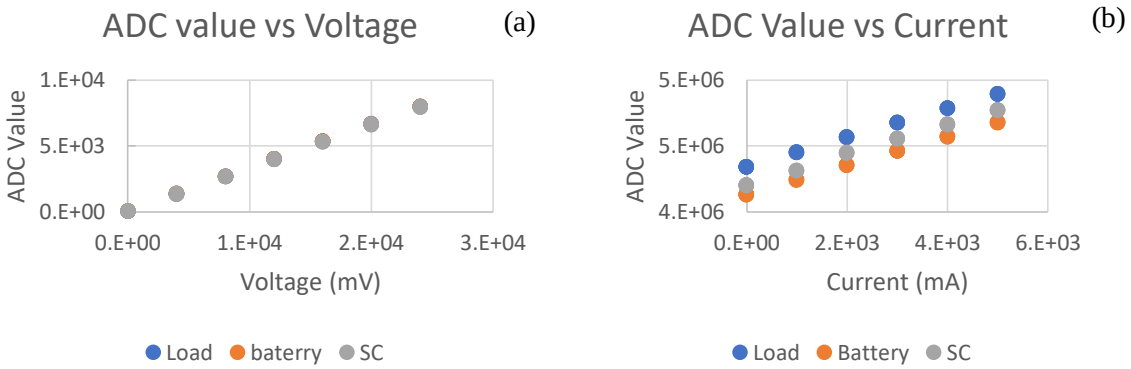


Figure 6. (a) Data plot for voltage sensor verification experiment (b) Data plot for current sensor verification experiment.

$$\boldsymbol{P} = \boldsymbol{a}.\boldsymbol{X} + \boldsymbol{b} \tag{1}$$

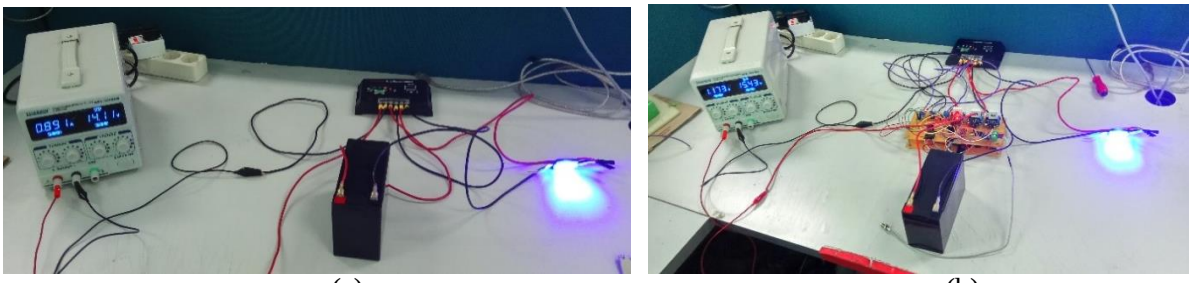
$$\boldsymbol{P} = \begin{bmatrix} Load\ Voltage \\ Battery\ Voltage \\ Solar\ Cell\ Voltage \\ Load\ Current \\ Battery\ Current \\ Solar\ Cell\ current \end{bmatrix} \tag{2}$$

$$\boldsymbol{a} = \begin{bmatrix} 0{,}003 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0{,}003 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0{,}003 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0{,}009 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0{,}0091 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0{,}0087 \end{bmatrix} \tag{3}$$

$$\boldsymbol{X} = \begin{bmatrix} ADC\ value\ for\ Load\ Voltage \\ ADC\ value\ for\ Battery\ Voltage \\ ADC\ value\ for\ Solar\ Cell\ Voltage \\ ADC\ value\ for\ Load\ Current \\ ADC\ value\ for\ Battery\ Current \\ ADC\ value\ for\ Solar\ Cell\ current \end{bmatrix} \tag{4}$$

$$\boldsymbol{b} = \begin{bmatrix} -96{,}865 \\ -121{,}8 \\ -128{,}65 \\ -38.980 \\ -37.703 \\ -36.434 \end{bmatrix} \tag{5}$$

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.



(a) (b)

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

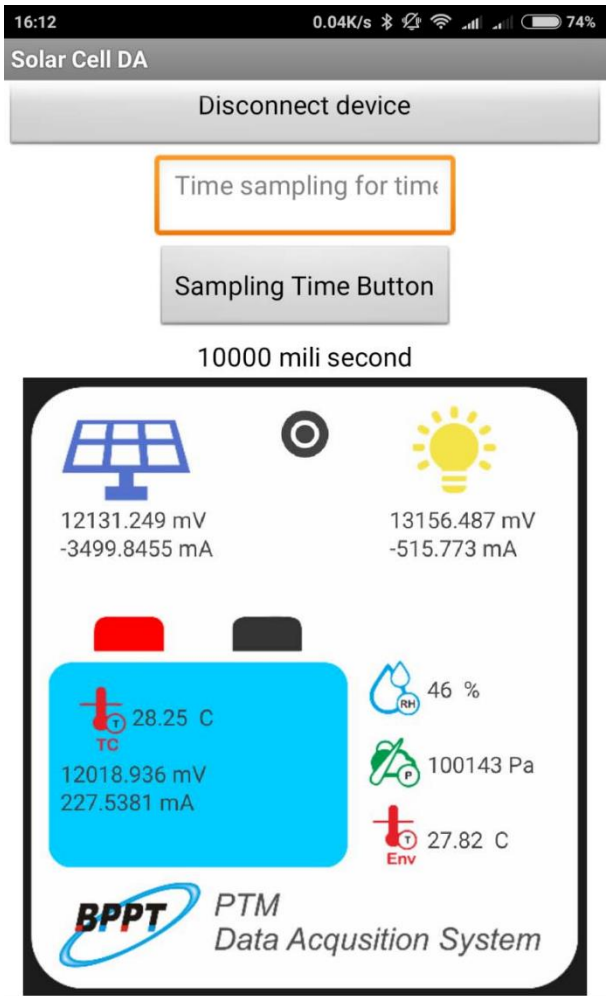
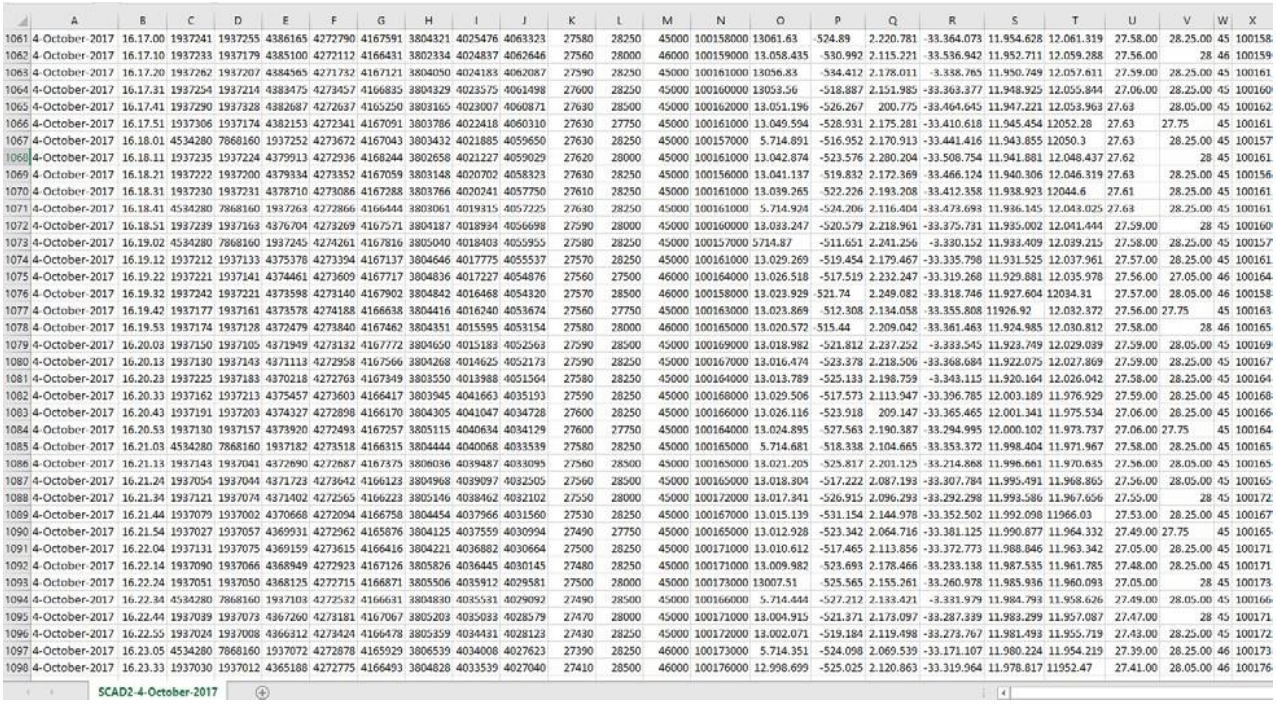


Figure 8.Screenshot of display screen.



	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S	T	U	V	W	X
1061	4-October-2017	16.17.00	1937241	1937255	4386165	4272790	4167591	3804321	4025476	4063323	27580	28250	45000	100158000	13061.63	524.89	2.220.781	-33.364.073	11.954.628	12.061.319	27.58.00	28.25.00	45	100158
1062	4-October-2017	16.17.10	1937233	1937179	4385100	4272112	4166431	3802334	4024837	4062646	27560	28000	46000	100159000	13.058.435	-530.992	2.115.221	-33.536.942	11.952.711	12.059.288	27.56.00	28	46	100159
1063	4-October-2017	16.17.20	1937262	1937207	4384565	4271732	4167121	3804050	4024183	4062087	27590	28250	45000	100161000	13056.83	-534.412	2.178.011	-3.338.765	11.950.749	12.057.611	27.59.00	28.25.00	45	100161
1064	4-October-2017	16.17.31	1937254	1937214	4383475	4273457	4166835	3804329	4023575	4061498	27600	28250	45000	100160000	13058.56	-518.887	2.151.985	-33.363.377	11.948.925	12.055.844	27.06.00	28.25.00	45	100160
1065	4-October-2017	16.17.41	1937290	1937328	4382687	4272637	4165250	3803165	4023007	4060871	27630	28500	45000	100162000	13.051.196	-526.267	200.775	-33.464.645	11.947.221	12.053.963	27.63	28.05.00	45	100162
1066	4-October-2017	16.17.51	1937306	1937174	4382153	4272341	4167091	3803786	4022418	4060310	27630	27750	45000	100161000	13.049.594	-528.931	2.175.281	-33.410.618	11.945.454	12052.28	27.63	27.75	45	100161
1067	4-October-2017	16.18.01	4534280	7868160	1937252	4273672	4167043	3803432	4021885	4059650	27630	28250	45000	100157000	5.714.891	-516.952	2.170.913	-33.441.416	11.943.855	12050.3	27.63	28.25.00	45	100157
1068	4-October-2017	16.18.11	1937235	1937224	4379913	4272936	4168244	3802658	4021227	4059029	27620	28000	45000	100161000	13.042.874	-523.576	2.280.204	-33.508.754	11.941.881	12.048.437	27.62	28	45	100161
1069	4-October-2017	16.18.21	1937222	1937200	4379334	4273352	4167059	3803148	4020702	4058323	27630	28250	45000	100156000	13.041.137	-519.832	2.172.369	-33.466.124	11.940.306	12.046.319	27.63	28.25.00	45	100156
1070	4-October-2017	16.18.31	1937230	1937231	4378710	4273086	4167288	3803766	4020241	4057750	27610	28250	45000	100161000	13.039.265	-522.226	2.193.208	-33.412.358	11.938.923	12044.6	27.61	28.25.00	45	100161
1071	4-October-2017	16.18.41	4534280	7868160	1937263	4272866	4166444	3803061	4019315	4057225	27630	28250	45000	100161000	5.714.924	-524.206	2.116.404	-33.473.693	11.936.145	12.043.025	27.63	28.25.00	45	100161
1072	4-October-2017	16.18.51	1937239	1937163	4376704	4273269	4167571	3804187	4018934	4056698	27590	28000	45000	100160000	13.033.247	-520.579	2.218.961	-33.375.731	11.935.002	12.041.444	27.59.00	28	45	100160
1073	4-October-2017	16.19.02	4534280	7868160	1937245	4274261	4167816	3805040	4018403	4055955	27580	28250	45000	100157000	5714.87	-511.651	2.241.256	-3.330.152	11.933.409	12.039.215	27.58.00	28.25.00	45	100157
1074	4-October-2017	16.19.12	1937212	1937133	4375378	4273394	4167137	3804646	4017775	4055537	27570	28250	45000	100161000	13.029.269	-519.454	2.179.467	-33.335.798	11.931.525	12.037.961	27.57.00	28.25.00	45	100161
1075	4-October-2017	16.19.22	1937221	1937141	4374461	4273609	4167717	3804836	4017227	4054876	27560	27500	46000	100164000	13.026.518	-517.519	2.232.247	-33.319.268	11.929.881	12.035.978	27.56.00	27.05.00	46	100164
1076	4-October-2017	16.19.32	1937242	1937221	4373598	4273140	4167902	3804842	4016468	4054320	27570	28500	46000	100158000	13.023.929	521.74	2.249.082	-33.318.746	11.927.604	12034.31	27.57.00	28.05.00	46	100158
1077	4-October-2017	16.19.42	1937177	1937161	4373578	4274188	4166638	3804416	4016240	4053674	27560	27750	45000	100163000	13.023.869	-512.308	2.134.058	-33.355.808	11926.92	12.032.372	27.56.00	27.75	45	100163
1078	4-October-2017	16.19.53	1937174	1937128	4372479	4273840	4167462	3804351	4015595	4053154	27580	28000	46000	100165000	13.020.572	515.44	2.209.042	-33.361.463	11.924.985	12.030.812	27.58.00	28	46	100165
1079	4-October-2017	16.20.03	1937150	1937105	4371949	4273132	4167772	3804650	4015183	4052563	27590	28500	45000	100169000	13.018.982	-521.812	2.237.252	-3.333.545	11.923.749	12.029.039	27.59.00	28.05.00	45	100169
1080	4-October-2017	16.20.13	1937130	1937143	4371113	4272958	4167566	3804268	4014625	4052173	27590	28250	45000	100167000	13.016.474	-523.378	2.218.506	-33.368.684	11.922.075	12.027.869	27.59.00	28.25.00	45	100167
1081	4-October-2017	16.20.23	1937225	1937183	4370218	4272763	4167349	3803550	4013988	4051564	27580	28250	45000	100164000	13.013.789	-525.133	2.198.759	-3.343.115	11.920.164	12.026.042	27.58.00	28.25.00	45	100164
1082	4-October-2017	16.20.33	1937162	1937213	4375457	4273603	4166417	3803945	4041663	4035193	27590	28250	45000	100168000	13.029.506	-517.573	2.113.947	-33.396.785	12.003.189	11.976.929	27.59.00	28.25.00	45	100168
1083	4-October-2017	16.20.43	1937191	1937203	4374327	4272898	4166170	3804305	4041047	4034728	27600	28250	45000	100166000	13.026.116	-523.918	209.147	-33.365.465	12.001.341	11.975.534	27.06.00	28.25.00	45	100166
1084	4-October-2017	16.20.53	1937130	1937157	4373920	4272493	4167257	3805115	4040634	4034129	27600	27750	45000	100164000	13.024.895	-527.563	2.190.387	-33.294.995	12.000.102	11.973.737	27.06.00	27.75	45	100164
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1086	4-October-2017	16.21.13	1937143	1937041	4372690	4272687	4167375	3808036	4039487	4033095	27560	28500	45000	100165000	13.021.205	-525.817	2.201.125	-33.214.868	11.996.661	11.970.635	27.56.00	28.05.00	45	100165
1087	4-October-2017	16.21.24	1937054	1937044	4371723	4273642	4166123	3804968	4039097	4032505	27560	28500	45000	100165000	13.018.304	-517.222	2.087.193	-33.307.784	11.995.491	11.968.865	27.56.00	28.05.00	45	100165
1088	4-October-2017	16.21.34	1937121	1937074	4371402	4272565	4166223	3805146	4038462	4032102	27550	28000	45000	100172000	13.017.341	-526.915	2.096.293	-33.292.298	11.993.586	11.967.656	27.55.00	28	45	100172
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1090	4-October-2017	16.21.54	1937027	1937057	4369931	4272962	4165876	3804125	4037559	4030994	27490	27750	45000	100165000	13.012.928	-523.342	2.064.716	-33.381.125	11.990.877	11.964.332	27.49.00	27.75	45	100165
1091	4-October-2017	16.22.04	1937131	1937075	4369159	4273615	4166416	3804221	4036882	4030664	27500	28250	45000	100171000	13.010.612	-517.465	2.113.856	-33.372.773	11.988.846	11.963.342	27.05.00	28.25.00	45	100171
1092	4-October-2017	16.22.14	1937090	1937066	4368949	4272923	4167126	3805826	4036445	4030145	27480	28250	45000	100171000	13.009.982	-523.693	2.178.466	-33.233.138	11.987.535	11.961.785	27.48.00	28.25.00	45	100171
1093	4-October-2017	16.22.24	1937051	1937050	4368125	4272715	4166871	3805506	4035912	4029581	27500	28000	45000	100173000	13007.51	-525.565	2.155.261	-33.260.978	11.985.936	11.960.093	27.05.00	28	45	100173
1094	4-October-2017	16.22.34	4534280	7868160	1937103	4272532	4166631	3804830	4035531	4029092	27490	28500	45000	100166000	5.714.444	-527.212	2.133.421	-3.331.979	11.984.793	11.958.626	27.49.00	28.05.00	45	100166
1095	4-October-2017	16.22.44	1937039	1937073	4367260	4273181	4167067	3805203	4035033	4028579	27470	28000	45000	100171000	13.004.915	-521.371	2.173.097	-33.287.339	11.983.299	11.957.087	27.47.00	28	45	100171
1096	4-October-2017	16.22.55	1937024	1937008	4366312	4273424	4166478	3805359	4034431	4028123	27430	28250	45000	100172000	13.002.071	-519.184	2.119.498	-33.273.767	11.981.493	11.955.719	27.43.00	28.25.00	45	100172
1097	4-October-2017	16.23.05	4534280	7868160	1937072	4272878	4165929	3806539	4034008	4027623	27390	28250	46000	100173000	5.714.351	-524.098	2.069.539	-33.171.107	11.980.224	11.954.219	27.39.00	28.25.00	46	100173
1098	4-October-2017	16.23.33	1937030	1937012	4365188	4272775	4166493	3804828	4033539	4027040	27410	28500	46000	100176000	12.998.699	-525.025	2.120.863	-33.319.964	11.978.817	11952.47	27.41.00	28.05.00	46	100176

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Figure 9.Screenshot of data logging results.

Figure 10. Documentation of Display 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

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