Low-Power WSN-Based Solar-Cell Monitoring System

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Abstract

Solar-cell systems have found a wide-range implementation area. However, a monitoring system becomes a must requirement to add to maintain the optimum performance of the system. Much research so far focuses only on the functionality of the monitoring system. This paper presents the design and implementation of a low-cost, low-power monitoring system based on a wireless sensor network (WSN) schema. A low-power monitoring system offers an additional advantage because it uses the battery power produced by the photovoltaic (PV) system itself. Being implemented on a streetlight solar-powered system, the results indicated that the designed monitoring system could perform efficiently. It helps the utility authorities to maintain and to manage the streetlights. Moreover, the proposed system only requires a small amount of power from the PV-cells battery.

1. Introduction

Solar energy is one of the most promising energy alternative sources. It offers more advantages with zero pollution rate than the other energy sources do. Photovoltaice (PV) or solar cell is the main component which converts the solar energy into electricity using the photovoltaic concept. The implementation of solar-cell systems have been widely adopted especially in the area being far and without direct connectivity to a power plant. One the most popular implementation of such this system is the solar-cell based streetlight system. It is very often found that after a couple of months following its installation the streetlight system is not working properly anymore. It is mainly caused by the lack of information about the performance of each component in the system.

A monitoring system is very important to guarantee that the solar-cell system works on its optimum and maximum efficiency. The monitoring system provides the data of all solar-cell system components. An optimum electricity production can be ensured ensured with a good monitoring system.

In most implementations, the solar-cell systems are working independently with no direct connectivity to electricity or communication facilities. It is the reason why any solar-cell monitoring system must be adjusted to the solar-cell condition. The output of the PV system is normally stored in a battery. The PV cells produce electricity only when the sun is shining. In the night, there is no sunlight energy to produce enough current to supply the battery. In this condition, an excessive use of the stored power by the monitoring system must be avoided.

In a research [1] [2], the researcher implemented a communication system between sensor and server using an SMS (short messaging system). This system works well since the most area of the city already covered by Cellular Networks. But GSM required high power to transmit data. The use of GPRS for the communication between sensor and server has been applied to implement the Internet of Things (IOT) system on a solar power plant [3]. Another solution to overcome the problems in a PV system was proposed by combining zigbee network and GPRS network. [4] [5] [6]. Those research only focussing on the functionality of the sensor, but the effectiveness of each monitoring system not yet explained, even though most of the system using the same battery power, produced by PV system.

This research work presents the design and implementation of a solar-cell monitoring system which consumes low power and only requires low cost investment using the wireless sensor network scheme. The choice of wireless system to be used depends on the location of installation. It can be used with Wi-Fi network, GPRS/SMS, Lora or NRF module, etc.

2. System Design

The monitoring system to be designed comprises the following subsystems:

1. Voltage, Current, Temperature and Humidity Sensor
2. Sensor Node
3. Communication System
4. Dashboard system monitoring system.

2.1. Voltage, Current, Temperature and Humidity Sensor

Sensor is the key point of this monitoring system. To ensure the correct values of the measured data of the system, a sensor must be chosen selectivelty. For each parameter to be measured, some concerns to consider include the required resolution, linearity, sensitivity and price.

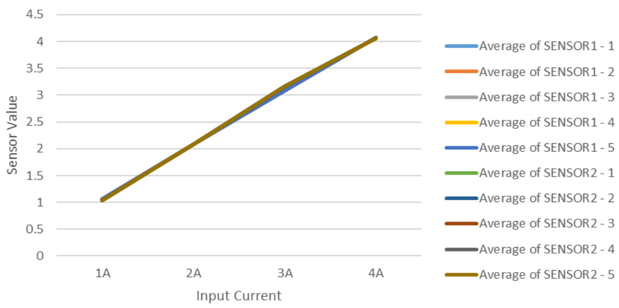

Fig. 1. Characteristic of the ACS172 sensor

A current sensor ACS712 is used in this system. To ensure that this type of sensor will function well in the system and is adequate based on the system requirements, we compared the performance of three sensors to that of a reference meter, i.e. a voltmeter. The results of the test is displayed in Fig. 1. As seen, the reading results of the three sensors indicate the errors of not more than of

2%. The linearity and the resolution of the sensor are acceptable for the system's work [7], as in general 1V of resolution is enough.

For the voltage sensor, a simple voltage divider has been used to sense the voltage. The output is connected to the ADC inside a microcontroller to result in a sensing range from 0 to 100V. The Humidity and Temperature values are provided using the DHT11 sensor [8]. This Sensor can read temperature within the range of 0-50 °C with ± 2 °C, and the humidity range from 20-90% RH with ± 5% RH error. One of the advantages of this sensor is that it is provided with a digital interface to ensure the accuracy the reading process.

2.2. Sensor Node

Sensor node is a devices located on the PV system. Fig. 2 shows the diagram of a sensor module. The voltage and current sensors measure the output voltage of the PV cell, the battery and its load. This module consists of three sets of voltage and current sensors.

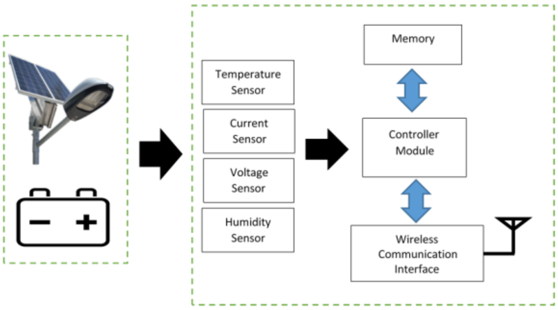

Fig. 2. Sensor Node

The controller module is the brain of this monitoring system. The measured data are stored temporarily on the local memory. In a scheduled time, the data will be sent to the cloud database using the wireless communication interface over the internet. The internet access of its system possesses multiple wireless interface. Using the GPRS of cellular data, using Wi-Fi if the location of solar-cell streetlight is near the Wi-Fi access point, or using the point-to-point wireless communication if no direct access to internet exists. Since the wireless communication interface uses more power to send the data, the data transmission scheduling is very important to save the power of the battery.

To make sure that all components work efficiently, each component of the monitoring system must be tested. Table 1 show the required power for each component.

Table 1. Current requirement for sensor module

No.	Component	Min Current	Max Current
1	Controller Module (Typical)	80mA	200mA
2	Controller Module (sleep)	200uA	400uA
3	Memory Module Write	40mA	100mA
4	Wifi Module (Transmit)	80mA	300mA
5	GPRS Module (Transmit)	180mA	1000mA

As can be observed on Table 1, a careful procedure is very important to save the stored energy. Hence, the whole system will live much longer. Since the transmission of the collected data over the Wi-Fi or GPRs requires high current, the procedure will be executed when the PV cells produce electric power. The collected data will remain on its local memory if the solar-cell system works on the battery power. The sequence of this procedure is presented on the algorithm displayed in Fig. 3. When the output voltage of the PV cell is much higher than the threshold and the unflagged data is more than 100, the sensor node will send the all unflagged data to the sensor gate. This checking process works every 15 minutes. System nodes will stay on the sleep mode between the checking processes.

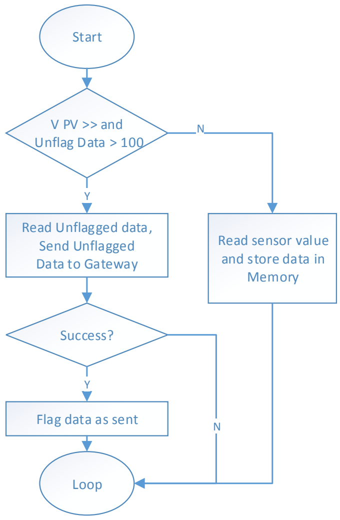

Fig. 3. Sensor Node Algorithm

2.3. Communication System

To ensure that all data from the sensor node are transmitted, the communication mechanism of the data is presented in Fig. 4.

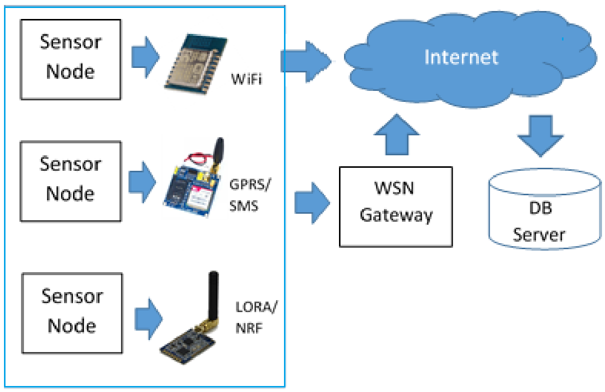

Fig. 4. Communication Mechanism

As shown in Fig. 4, the mechanism of the data transmission is started with the data collected by the sensor node. All the collected data will be transmitted to the Database Server. But, since each sensor node has different type of communication interface, and not every interface has direct access to the internet, the gathered data must be sent to the gateway first. Next, the gateway will send all the received data to the database server over internet. If the Sensor node using Wifi to send the data over the near public access point, than it can directly send the data to DB

Server over internet connection. Without sending trough the Gateway.

The WSN Gateway is a device with all possible communication interface and direct access to internet. This device is designed with more computing power than the sensor nodes since it must handle all the data from sensor nodes. This device utilize Raspberry Pi3 as core processing module. The schema of WSN Gateway displayed in Fig. 5.

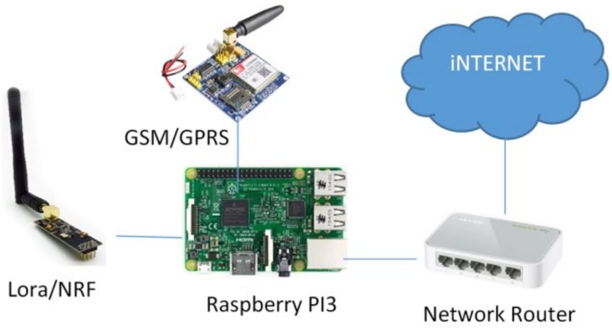

Fig. 5. Gateway

This Gateway received data from the sensor node from variety communication method, using SMS or GPRS throug GSM/GPRS module, or direct point to point communication over Lora or NRF radio module.

This data can be accessed using a web-based application to show each parameter generated by the sensor. Each sensor module will send data to the internet server based on the communication module provided.

2.4. Dashboard Monitoring System

For the monitoring purpose, a web-based monitoring dashboard is provided. Fig. 6 displays the dashboard system.

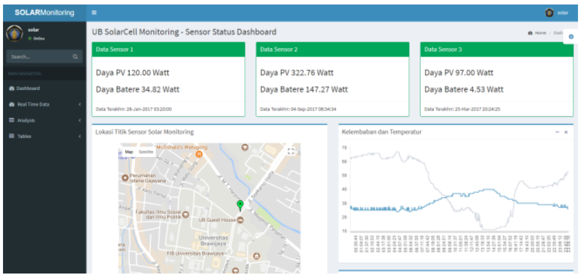

Fig. 6. Dashboard Monitoring System

Fig. 7. Sensor Data Detail

This dashboard displays the actual voltage, current, temperature and humidity of each sensor node graphically. The location of the sensor node is also displayed on a map with the green or red marks, to show which sensor is active or not. Since the data will be sent only when the PV cells receive enough light, this display indicates the status of the latest data. The interval of this status is 12 hours. If the database is not receiving any updates from the sensor nodes, the red marks will be displayed and notify that the sensor nodes experience a problem.Fig. 7 shows the detail dashboard from each sensor node. All the last parameter shows to give information of the PV system condition

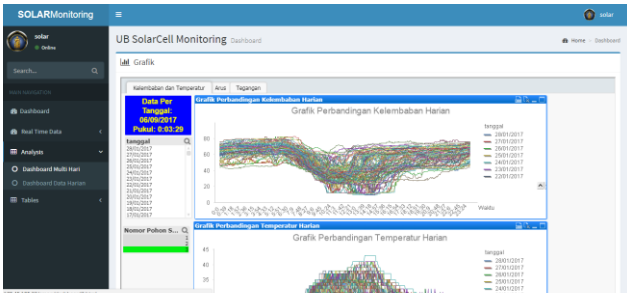

Fig. 8. Data Analysis from Sensor

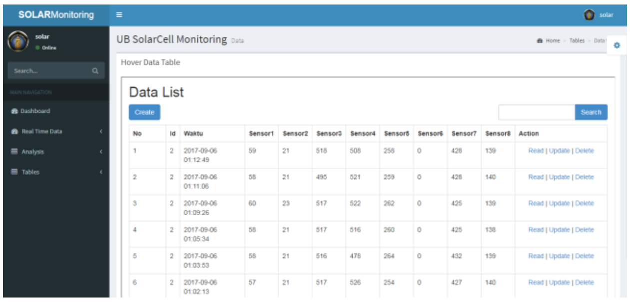

Fig. 9. Data Analysis from Sensor

Fig 8 and Fig 9 Show the analysis menu of this monitoring system. This menu provide resume of all gathered data on the database. This data is needed for analysis of PV system performance. During the implementation of the designed system, we used three sensor nodes, being installed on different locations.

3. Results and Discussion

During the implementation of the designed system, we used three sensor nodes, being installed on different locations. Fig. 10 indicates the location map of each sensor module. All sensors were placed around the Brawijaya University campus area and have been working for a year. Fig. 11 show the Street light Solar Powered monitored in this work. The sensor installed inside panel box of the system. The gateway was located in the highest building in the middle of the campus area, to handle the radio communication between the sensor node and the gateway node

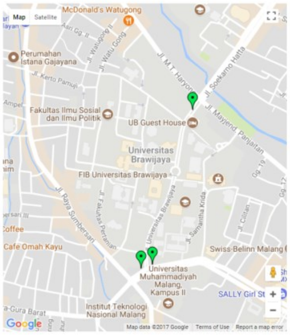

Fig. 10. Sensor Location Map

Fig. 11. Street Light PV Cell

Fig. 12 shows the sample results comparison of the PV ouput voltage of three consecutive days between 12 to 14 August 2017. The chart shows that the PV started to produce electric power since 05.24 in the morning until 17.30 in the afternoon. The peak voltage of the data indicates a value of 60V.

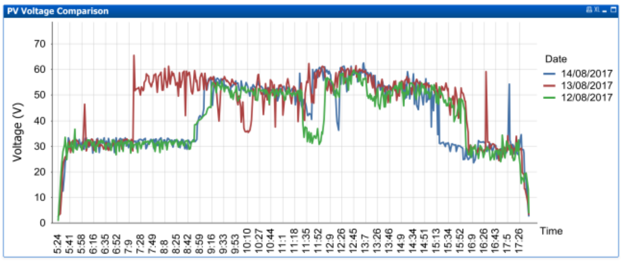

Fig. 12. PV Voltage Comparison of 3 Days

Fig. 13 indicates the results of monitoring values of the PV current, battery current and the lamp current on 12 August 2017, whereas the respective values of the voltage are given in Fig. 14. Based on the evaluation both the current and voltage of the PV sysem, it can be known that the maximum resulted power of the PV cells on that day was 80 watt, as confirmed by the graphic in Fig. 15.

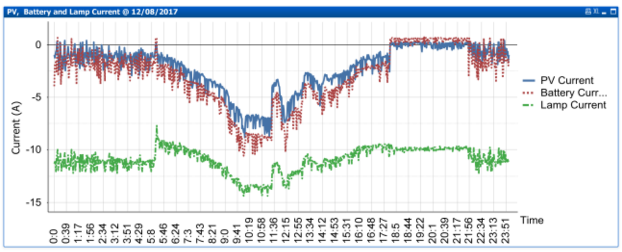

Fig. 13. Current ouput of the solar-cell system

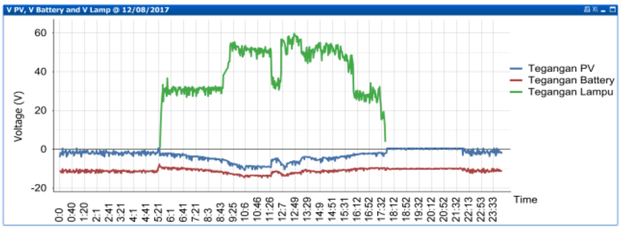

Fig. 14. Voltage ouput of the solar-cell system

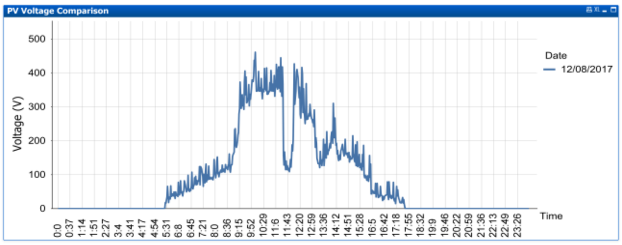

Fig. 15. Ouput Power of the PV system on 12/08/2017

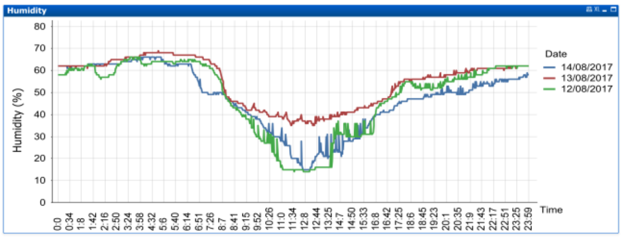

Fig. 16. Daily Humidity comparison

Beside the voltage and current data, this sensor node also provides the temperature and humidity of the environment as presented in Fig. 16 - Fig. 18. Fig. 16 and Fig. 17 present the daily humidity comparison and the daily temperature comparison respectively, whereas Fig. 18 indicates the hourly comparison of the temperature and humidity values.

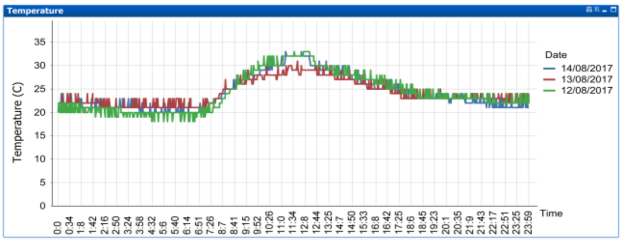

Fig. 17. Daily Temperature comparison

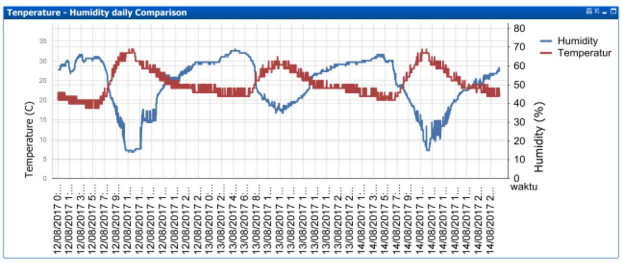

Fig. 18. Hourly Humidity and Temperature comparison

6. Conclusions

The streetlight PV system monitoring has been implemented on a streetlight solar-powered system, the results indicated that the designed monitoring system could perform efficiently. It helps the utility authorities to maintain and to manage the streetlights. Moreover, the proposed system only requires a small amount of power from the PV-cells battery.

7. References

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