Designing Energy and Power Monitoring System on Solar Power Plant Using Raspberry Pi

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Abstract. The application of Information Technology (IT) has been growing rapidly recently. IT utilized to monitor flowing power and stored electrical energy which is produced by solar cell. This project explains how to build and design interface system. Electrical energy need to be monitored in order to keep energy stored. Single Board Computer (SBC), microcontroller, sensors, and transceivers are used in logging electrical power for this project. These nodes are connected wirelessly. Raspberry Pi 2 B, Arduino Nano, NRF24L01, Voltage sensor and ACS712 sensor are required to run this project. IDLE, Apache, BIND, hostapd, udhcpd, and highcharts are programs used in Raspberry Pi 2 B. The values of power are displayed into graphical chart and log energy table are able to be accessed by using computer or smartphone. By connecting to local network via Wi-Fi and go to http://solmon.home to see measurement results.

1. Introduction
The current development of technology produce a tremendous number of electronic devices with its functionality. Electronic device for controlling and automating is one of the most developed technology. Electronic device is being utilized in every aspect, such as in house as smart home [1]. Raspberry Pi has been used for multipurpose monitoring such for surveillance [2]. By using Raspberry Pi as a server solar power plant can be monitored both power and stored energy.

An independent home of producing electrical energy by installing solar panel. Using a solar panel, there is no any sound noise as mechanical electrical energy generator [3]. This energy production could be used for lighting or home appliance. Before energy are being used, it should flow first into battery. Monitoring of flowing energy is needed in order to check whether the energy is available or not.

Microcontroller and single board computer (SBC) are already used for load monitoring on previous works [4-7]. However there is some lacks, as the system is unable to be accessed in flexible range in the reason of limitation by using wire for the media connection. The others consideration, cost to build the systems are pricey, rare or unavailability components to find, and complexity for user to use the system.

Our goal is to design a system for monitoring power and flowing energy from the solar panel through battery and monitoring a simulated load by using a Raspberry Pi 2 B as main component or server to display data and two Arduino Nano as data fetcher for power and energy [8]. The communication among server, data fetcher and user are wirelessly.
2. Methods

There are bunch of module communication to build, the communication established from Arduino Nano to Raspberry is using NRF24L01, a RF module that only communicate between those two devices. NRF24L01 is used since its effective and efficient for this proposed system. While for connection between Raspberry Pi to user’s device is using Wi-Fi connection. TP-Link TL725WN is attached to Raspberry Pi since Raspberry Pi 2 B does not have built-in Wi-Fi. Thus this module is chosen for its compatible with Raspberry Pi 2 B to work as hotspot and it is more familiar in several online forums.

The objects is to monitor solar cell and a simulated load. We used solar cell system at High Voltage Laboratory Universitas Pendidikan Indonesia. The simulated load is a single resistor with a DC supplied.

For the designing software, we split into two parts that is server side and node side. This begins from designing Arduino Nano script as node side to make sensors are working well. Compiled the script using Arduino IDE from PC. The calibration occurs in this progress. Voltage sensor should read voltage in parallel circuit and current sensor read current as in series circuit. Calibrating current sensor need a special sampling. Current sensor we are using is ACS712 which manufactured by Allegro MicroSystems. It performs based on Hall effect means converting DC or AC current into proportional voltage output within 0-5 volt range. Magnetic field is applied for this reading current sensor. This sensor should be programmed by using sampling data to get smooth value of reading current. Since Arduino Nano has an analogue pin input, it is just a common reading analogue pin. Then, configure networking of NRF24L01. Arduino IDE using C as a programming language. ACS712 and voltage sensor need to be calibrated in order to get good measurement.

Once sensor management is done, we move on into server side it is Raspberry Pi. The server using Python programming language to run the script. This device works as an intermediate to user’s device. User device can be personal computer or smartphone as long it has web browser to access and connected to Wi-Fi from Raspberry Pi. The whole activities occur as shown in Figure 1.

![Figure 1. Block diagram of system.](image-url)
Programs is not packed so need to be configured themselves independently. One program could impact to other programs. For example if hotspot program is not working, user could not access data. The programs become a whole system to perform at the same time. The programs are installed on the server are driver on Raspberry Pi to communicate between Raspberry Pi and TL-725N, Raspberry Pi and NRF24L01; Apache2 for web server, MySQL and PHPmyAdmin for logging and configuring database, hotspot program which consist of udhcpd for giving IP address automatically to user’s device, hostapd for making wireless access point from server; and the last is DNS server for converting IP address into name domain.

To identify energy flow from solar panel, we log to database of the value which is sent by node side into server. After logging, the web server program performs a reading database and convert the value into a graphical display. In order to make easier to troubleshoot, figure 2 shows the flowchart of this designed system.

![Figure 2. Node on solar cell circuit.](image)

Figure 2 shows that Node is placed between solar cell and charge controller. The placement of node for real is shown in figure 4.

3. Results and discussion

According to experiment from designing this system at High Voltage Laboratory FPTK UPI, we obtained the results:

- A prototype of system logging power solar panel.
- Designs and configuration programs to make this system.
- The output which can be accessed by user in a local network.
- The devices are connected each other can communicate as well as designed.
Figure 3. Raspberry Pi as a server is packaged in an acrylic with Raspberry Pi logo.

Raspberry Pi is bundled into a single acrylic box and only has one input power source from USB cable. Since Raspberry uses wireless communication both to nodes and user, thus transceiver is inside the box. This device is the central unit of the system [9].

Figure 4. Arduino Nano as a node in an acrylic box with Arduino Logo.

Two Arduinos as nodes are shown in Figure 4. Each has the same two power inputs by using USB source cable. For reading media, using four cables connector. Two cables for reading voltage positive side and negative side; two others cables are used for reading current.
Figure 5. Integrated node in solar cell system in High Voltage Laboratory.

This calibrating sensor is needed to make sure the sensors are in standard condition. By comparing the value result from 10 multi meters to a sensor voltage. This calibrating using an object which is rheostat as load and DC power supply. Set to 100Ω and 12V as the object. Calibrating current sensor apply the same object as calibrating voltage sensor. Table 1 shows the measurement.

| Table 1. Voltage measurements.            |
|------------------------------------------|
| Voltmeter | Value (V) |
|-----------|-----------|
| 1         | 10.22     |
| 2         | 10.17     |
| 3         | 10.21     |
| 4         | 10.22     |
| 5         | 10.24     |
| 6         | 10.25     |
| 7         | 10.26     |
| Sensor    | 10.14     |

| Table 2. Current measurements.           |
|------------------------------------------|
| Ampere meter | Value (A) |
|--------------|-----------|
| 1            | 2.64      |
| 2            | 2.60      |
| Sensor       | 2.68      |

These calibrating result obtain a low error. By using descriptive statistic, we obtain error on Voltage is 0.005% and current is 0.02%. This has fulfilled for some applications which requires error 0.1%-1% [10].
Once user access to network, the user’s device will obtain automatic IP address and just typing on address bar the IP address 10.1.30.1 or domain name http://solmon.home the server will redirect user into a web page which contains graphical information. Also there is an option to access log which allow user to view the last value. It could be chosen per date. Figure 4 shows the result of web page accessed by personal computer. Figure 5 shows the result of web page accessed by mobile phone. Figure 6 shows the option to view the log.

![Figure 6. Main web page on phone.](image)

![Figure 7. The result of log on web browser.](image)
Raspberry Pi 2 B is chosen as a server in this system hence it has a parts to support this system works such a GPIO ports to connect NRF24L01. This server performs like a PC yet only using low voltage than a PC [11, 12]. This device has a wide community and support. There are other sort of this device like Banana Pi, Intel Galileo, BeagleBone, Orange Pi, C.H.I.P, etc. [13]. The Raspberry Pi is a device which can purchased and available in many robotic store.

The Arduino Nano is node side which is the compact, effective and efficient circuit to support this system. There are many sort of this circuit board such as Arduino UNO, MKR1000, etc. This circuit can be replaced by these circuit board for later works and development.

This system can monitor how much energy stored from solar cell. At the database server, energy values shows in a table as shown on figure 7. User could monitor by choosing date to show energy values.

4. Conclusions
This system logging for power and energy from solar panel and simulated load are built by node. Both are connected to server to show values from sensors in graphical and stored to database in server. The sensors must be calibrating first, especially for current sensor. Hence, sensors are affected by noise and sensitivity, also this sensor using hall effect which convert current into magnetic field and the output become a proportional 0-5 volt. The server installed some programs which is not much configuration. The user could use a PC or mobile phone to access server via Wi-Fi networks.

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References
[1] Augusto J C and Nugent C D 2006 Designing Smart Homes The Role of Artificial Intelligence (New York: Springer-Verlag Berlin Heidelberg).
[2] Jain A, Basantwani S, Kazi O and Bang Y 2017 “Smart Surveilliance Monitoring System” pp. 269–273.
[3] Palz W 2011 The Emergence of Electricity from the Sun Power for the World (Singapore: Pan Stanford Publishing Pte, Ltd.).
[4] Firnandi I, Kustija J and Trisno B 2016 “Rancang Bangun Sistem Kontrol Beban dan Akuisisi Data Berbasis Web dengan menggunakan Single Board Computer” 14(1).
[5] Sulistyowati R, Febrianto D D, Elektro J T, and Industri F T 2012 “Perancangan Prototype Sistem Kontrol dan Monitoring Pembatas Daya Listrik Berbasis”.
[6] Setiono A and Suharto 2009 “Prototipe Aplikasi KWh Meter Digital Menggunakan Mikrokontroler ATMEGA8535 untuk Ruang Lingkup Kamar” 26 pp. 32–39.
[7] van Staden P and Kotze B 2017 “Wireless Node Energy Monitor using common Development Platforms” pp. 1514–1519.
[8] Melgar E R, Diez C C and Jaworski P 2012 “Arduino and Kinect Projects Design, Build, Blow Their Minds”.
[9] Guleci M and Orhun M 2017 “Android Based Wi-Fi Controlled Robot using Raspberry Pi” pp. 5–9.
[10] Moghe R, Iyer A R, Member S, Lambert F C, Member S and Divan D M 2014 “A Low-Cost Wireless Voltage Sensor for Monitoring MV / HV Utility Assets” 5(4) pp. 2002–2009.
[11] Pardeshi V, Sagar S, Murmuruwar S and Hage P 2017 “Health Monitoring Systems using IoT and Raspberry Pi - A Review” pp. 134–137.
[12] Sunehra D and Ramakrishna P 2016 “Web Based Patient Health Monitoring System using Raspberry Pi” pp. 568–574.
[13] Saari M, Hyrynsalmi S and bin Baharudin A M “Survey of Prototyping Solutions Utilizing Raspberry Pi” pp. 991–994.