Design and analysis of a portable web-based monitoring system for electrical parameters measurement

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Abstract. Currently, to monitor the parameters of an electrical system, including current, voltage, power, and frequency can be done remotely by using either computers, laptops, or android mobile phones, as long as those gadgets are connected to the internet. Generally, the equipment of this monitoring system is installed in a module at a fixed position. As a measurement tool, it is required that the measurement values are valid. For this reason, to ensure that the measurements shown by the remote monitoring system that has been installed are valid, another monitoring system is needed as a comparison. Based on the problems mentioned above, this research aims to design and analyse a portable web-based monitoring system for electrical parameters measurement. This equipment has a web-based monitoring system, which can remotely monitor the measurement of electrical parameters through the web. In addition, the equipment is light and portable, which can be easily moved from one place to another. Due to its advantages, this equipment can be used as a comparative tool to get valid values for electrical parameters measurement.

1. Introduction
The need for electrical energy is increasing from time to time in line with the increase in population and demand for the availability of electrical energy itself. At the same time, fossil energy sources, as the main source in generating electrical energy, are decreasing and becoming increasingly rare in the future. To deal with these problems, the use of renewable energy sources is needed, including wind energy and solar energy.

The obstacles faced in developing renewable energy sources, especially large-scale power plants, are location and cost. So, one way to deal with this problem is to develop small-scale generators, which are relatively easy and cheaper to install. Malang State Polytechnic has a prototype of a Wind Power Plant and a Solar Power Plant, which are located near the Renewable Energy laboratory.

Monitoring of electrical parameters on the prototype generation system can be done remotely because it is equipped with a remote monitoring system using a web-based Arduino. Monitoring can be done using a computer or a mobile phone, as long as it is connected to the internet by accessing the monitoring page.

To ensure that the measurements shown by the remote monitoring system are valid, another monitoring system is needed as a comparison. So, the idea emerged to create a web-based Portable Remote Monitoring System, where monitoring of the Wind Power Plant (WPP) prototype above can be done remotely, either via the web or via an Android phone. With this system, the supervision and system regulation will be more efficient and optimal. In addition, this system is also portable, where monitoring
equipment can be brought and moved at any time. So that this tool can also function as a comparison of the measurement results of the monitoring tools installed on the WPP panel.

2. Wind power plant

2.1. Work principle of a wind power plant

The Wind Power Plant converts wind energy into electrical energy by using a wind turbine or windmill. The way it works is quite simple, the wind energy that rotates the wind turbine is continued to rotate the rotor on the generator, so that it will produce electrical energy [1-3]. Electrical energy is usually stored in batteries before it can be utilized. According to the arrangement and function of several important components in the power generator turbine, their respective duties and functions can be described.

![Wind power plant scheme](image)

Figure 1. Wind power plant scheme.

Figure 1 shows the wind power generation scheme. The main components in this generation system can be described as follows [3]:

2.1.1. Wind turbine. Wind turbine takes wind energy through two or three propellers which are designed like airplane wings. To get a wind speed that is high enough, constant, and not too much turbulence, a wind turbine is installed on top of a tower. When the wind blows through the blades, there is low pressure air at the bottom of the blades. Low air pressure will pull the propeller into the area. The force that is generated is called the lift. The amount of lift is usually stronger than the pull force. The combination of lift and pull causes the rotor to rotate like a propeller and turn the generator. The components of a wind turbine can consist of:

- Blades, most wind turbines have 2 or 3 fan blades. The wind that blows causes the turbine to spin.
- The rotor, the shaft of the fan blade rotates according to the rotation of the fan blade.
- Pitch, the angle of the fan blade can be adjusted according to the desired rotor speed, depending on wind conditions: low or high.

2.1.2. Controller / charge controller. This section functions to regulate the charging of electric current into the battery so as not to damage the battery due to excessive charging (over charging).

2.1.3. Battery. This section will store the electric current generated by the electric generator so that it can be used at any time. The charge controller controls the storage of electric power in the battery.

2.1.4. Inverters. This section functions to convert the DC voltage from the battery to AC mains voltage (110V or 220V) for equipment with the appropriate voltage rating.
2.1.5. Load. The load is an electric load with a voltage rating that matches the inverter output (110V or 220V)

2.2. Internet of things
In 1999, Kevin Aston has introduced The Internet of Things and it has continued to develop. This term has an aim to expand the benefit of internet which is connected continuously. For example, it can be utilized for data sharing, remote control, etc., including objects in the real world. Almost all human needs, nowadays require the existence of internet connection, such as food, electronic equipment’s, collections, including living things that are all connected to local and global networks.

The Internet of Things is also related to the terms monitoring and controlling processes. For example, the application of monitoring and controlling system in the area of electricity utilization. This system can help us to monitor and analyse the waste of electricity. So that we can take some wise actions to rectify the condition.

![Figure 2. Internet of things](image)

2.3. Components of a portable remote monitoring system
In this WPP control system, there are several components that are designed to be one so that it forms a control system and can monitor according to its function [4-6]. These components include:

2.3.1. Smart kWh Meter. The use of Smart kWh Meter functions to measure several electrical parameters such as voltage, current, power etc. The measurement result data will be displayed on the website and android application which contains several electrical parameters for a certain period of time. The specification of the smart kWh meter used in this research is as follows:
- Measured parameters: kWh, W, V, A, PF & Hz, Accuracy Class: Class 1.0
- Reference Voltage (Un): 230V AC, operating Voltage: 176 ~ 276VAC
- Rate Current (Ib) / (Imax): 5(45) A, Operating Frequency Range: 50/60 Hz + 10%
- Communication port protocol: Modbus RTU 2 wires, 4800 bps, 9600 bps, 19200 bps, 2400 bps, 1200 bps, Communication port support: Screw terminal block Max485

2.3.2. Arduino. The Arduino is an open-source single-board micro controller, derived from the Wiring platform, designed to facilitate electronic use in a variety of fields. The hardware has an Atmel AVR processor and the software has its own programming language [7].

The use of the Arduino Mega 2560 in the Monitoring and Controlling system is a data processing center for the measurement results of the smart kWh meter which will be displayed on the website and as a process for processing commands for controlling relays from the on / off command on the website.

2.3.3. Relay. The relay in the Monitoring and Controlling system functions as controlling the load by activating the contactor as a breaker or load connector. The specification of the relay used in this research is as follows [8]:
- 2-Channel relay module, Power Supply: 5 VDC
- Equipped with a high current relay, 250 VAC 10A
- Equipped with LED Relay Output Indicator for each Channel

2.3.4. **MAX485 Module.** The use of the MAX485 Module functions for data communication such as RS485 between the Smart kWh meter and Arduino, which converts data such as readings on the Smart kWh Meter before it is processed by Arduino. This module has a working voltage of 5 VDC.

2.3.5. **Modul Wi-Fi ESP8266.** The function of the ESP8266 is as an intermediary between Arduino and the website where the ESP8266 will send a signal connected to the internet from data processing or Arduino commands to the website.

2.3.6. **CT-Clamp.** This component serves to make accurate measurements of alternating current flowing in a conductor without the need for contact with the conductor so it is suitable for the use of portable sensors. The specification of the CT-Clamp used in this research is as follows:

- Input current: 0-20A, turn ratio: 20A:1V
- Output voltage: 0-1V, work temperature: -25°C~+70°C
- Non-linearity: ±3%, dielectric strength (between shell and output): 1000V AC/1min 5mA

3. **Workflow and system design**

3.1. **Problem solving workflow**

The work flow of the research stages are described as follows:

- The preparations stage, include literature studies on hybrid power plants, controllers, remote sensing components, and remote monitoring and controlling systems.
- Planning a web-based portable monitoring system and an android application on a wind power generator prototype.
- Selection of components for system development, including the selection of system support components, including the Arduino Mega microcontroller, power meter, smart kWh meter, contactor relay, LVDP panel
- Analysis of System Effectiveness and Accuracy, including effectiveness in monitoring, data collection and operation of safety equipment.
- Conclusion: The conclusion is the result of analysis by comparing with existing standards or installation regulations.
3.2. System design

Figure 3. Block diagram of a portable remote monitoring system.

Figure 4. Schematic diagram of a portable remote monitoring system.

Figure 3 and 4 show a block diagram and a schematic diagram of a portable remote monitoring and controlling system. The measurement data is taken from the kWh meter and CT clamp, in the form of data on voltage, current, power, power factor, and frequency. Max485 functions as a data communication tool between the smart kWh meter or CT clamp and Arduino. This data will be forwarded by ESP 8266 to the internet network so that the data can be accessed via the web and the application.
will display the measurement data from the smart kWh meter and CT-Clamp. This system can operate the system remotely, including load on / off via the web and applications with the help of relays.

4. Results and analysis

4.1. Voltage measurement

Figure 5 shows the circuit of measuring voltage on an electrical panel using a portable remote monitoring system. The results of voltage measurements and the comparison of measurement results with fixed remote monitoring equipment can be seen in the table 1.

![Circuit for voltage measurement](image)

**Figure 5.** Circuit for voltage measurement.

**Table 1.** Results of voltage measurement.

| No | Date          | Measurement Value | Error % |
|----|---------------|-------------------|---------|
|    |               | Portable Module   | Fixed Module |       |
| 1  | 24/06/2019 09:10 | 224.2             | 226.3    | 0.94%  |
| 2  | 24/06/2019 09:15 | 224.1             | 225.3    | 0.54%  |
| 3  | 24/06/2019 09:20 | 224.8             | 226.0    | 0.53%  |
| 4  | 24/06/2019 09:25 | 224.5             | 226.1    | 0.71%  |
| 5  | 24/06/2019 09:30 | 224.1             | 226.0    | 0.85%  |
| 6  | 24/06/2019 09:35 | 224.3             | 225.4    | 0.49%  |
| 7  | 24/06/2019 09:40 | 224.5             | 225.6    | 0.49%  |
| 8  | 24/06/2019 09:45 | 224.3             | 225.4    | 0.49%  |
| 9  | 24/06/2019 09:50 | 224.1             | 225.0    | 0.40%  |
| 10 | 24/06/2019 09:55 | 223.4             | 224.6    | 0.54%  |
| 11 | 24/06/2019 10:00 | 223.3             | 224.9    | 0.72%  |
| 12 | 24/06/2019 10:05 | 224.0             | 224.7    | 0.54%  |

From the table 1, it can be seen that the error percentage of voltage measurements using the portable monitoring system when compared to a fixed monitoring system has a small value, around 0.6%.
4.2. Electrical current measurement

![Image of Circuit for current measurement]

Figure 6 shows the circuit of measuring the electrical current on an electric panel using a portable remote monitoring system. The results of electric current measurements and the comparison of measurement results with fixed remote monitoring equipment can be seen in the table 2.

Table 2. Results of electrical current measurement.

| No | Date       | Measurement Value | Error % |
|----|------------|-------------------|---------|
|    |            | Portable Module   | Fixed Module |     |
| 1  | 24/06/2019 09:10 | 6.8               | 6.82         | 0.29% |
| 2  | 24/06/2019 09:15 | 5.9               | 5.9         | 0.00% |
| 3  | 24/06/2019 09:20 | 5.8               | 5.88         | 1.38% |
| 4  | 24/06/2019 09:25 | 5.9               | 5.95         | 0.85% |
| 5  | 24/06/2019 09:30 | 5.8               | 5.8          | 0.17% |
| 6  | 24/06/2019 09:35 | 5.8               | 5.89         | 1.55% |
| 7  | 24/06/2019 09:40 | 5.8               | 5.88         | 1.38% |
| 8  | 24/06/2019 09:45 | 5.8               | 5.87         | 1.21% |
| 9  | 24/06/2019 09:50 | 5.8               | 5.86         | 1.03% |
| 10 | 24/06/2019 09:55 | 5.8               | 5.81         | 0.17% |
| 11 | 24/06/2019 10:00 | 5.7               | 5.76         | 1.05% |
| 12 | 24/06/2019 10:05 | 5.8               | 5.83         | 0.52% |
|    |            |                   |             | 0.80% |

From the table 2, it can be seen that the error percentage of electrical current measurement using a portable monitoring system when compared to the fixed monitoring system has a small percentage of errors, around 0.8%.

5. Conclusion

Based on the testing and analysis that has been done, it can be concluded that:

- The main components used in the Portable Remote Monitoring System for Electrical Parameters Measurement are: A Smart kWh meter module THERA TEM015XP-D, a Max485 Module, an Arduino Mega 2560, a 2-Channel Relay Module, a Node MCU, and a CT-Clamp YHDC SCT-013-000. This equipment can facilitate monitoring of electrical parameters on the electrical
panel, in addition to the relay control feature, the load can be ON / OFF when not needed. This Monitoring and Controlling System Module can be accessed via the web or android application.

- The THERA TEM015XP-D Smart kWh meter module is able to read parameters of voltage, current, active power, power factor, frequency.
- This module makes it easy to monitor electrical parameters on the electrical panel; it can be accessed via the web or android applications, and it is portable (easy to move and carry) with the error percentage less than 1%

6. Future work
After implementing a remote monitoring system for electrical parameter measurement, which is based on websites and android applications, there are some points that can be developed in the future in order to improve the quality of it. Here are some suggestions:

- Selection of the CT Clamp circuit using the OP-M amplifier so that the monitoring readings are more accurate.
- To increase the reliability of the equipment, it is better to add a safety device such as Fuse.
- Adding relays in order to control even more loads.

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