Testing of R-EMS 1.1 Modular Renewable Energy Management System with the Mini SCADA Concept Using IoT

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Abstract. The 4.0 industrial revolution marked by the existence of the Internet of Things caused the development of technology increasingly rapidly. That makes the need for the use of electrical energy also increases rapidly. Cooperation between the government and the community is needed to increase the role of renewable energy. Thus minimizing the use of electricity from PLN and optimizing electricity from renewable energy. Modular R-EMS is a technological innovation that enables the use of more than one renewable energy that can monitor and control wirelessly using the Internet of Things. Modular R-EMS has an interface to make the user easy to see the system. That Interface displays data in the form of voltage, current, power, percent of battery, monthly usage charge, and load back up system when PLN is not operating. Error generated at AC voltage 0.9% DC voltage 1.89% AC current 0.7% DC current 3%. In the process of sending data in the form of current and voltage from the module to the smartphone has a time lag of 3 seconds. The use of PLN energy at a load of up to 100% at night. The use of renewable energy in the morning 76.58% to 100% in the afternoon 78.95% - 100% in the afternoon 19.64% to 62.85%. The excess power from renewable energy automatically flows to PLN.

Keywords: Internet of Things, Modular R-EMS, Management Energy

1. Introduction
The use of EBT (renewable energy) is being increased to reduce the use of non-renewable energy. The use of solar cells as electricity generation is still in the small and medium scale because solar cells utilize sunlight to produce electricity, this is a weakness of solar cells because when the daylight dims, solar panels will not produce electricity. So that PLN still has an important role in the supply of national electricity. In an effort to increase the national electrification ratio, it is necessary to collaborate between the community and the government that functions in enhancing the role of EBT, namely solar panels and wind turbines as
environmentally friendly power plants. So that the government represented by PLN can increase the national electrification ratio to 100%. Studies show that around 9-18% of electricity savings can be achieved if users can obtain energy information directly [9].

Internet of Things or IoT is a communication technology innovation in the use of an expanded internet network that can be connected to other components and able to do monitoring and automatic control in real-time. With the availability of the internet network, the Internet of Things technology can be applied by identifying specifically the components of the objectives so that they can communicate online through the internet.

The Internet of Things technology that is developing at this time is an alternative in managing energy on electrical quantities such as current and voltage and performing automatic control of online relays.

2. Literature Review

2.1 Internet of Things

Kevin Ashton first conceived the Internet of Things in 1999, which allowed objects around to communicate through a network such as an internet. Starting from the Auto-ID center, technology based on radio frequency identification (RFID) which is the identification of electronic products that are unique and then developed into technology that every object can have an internet protocol (IP) address [5]. So IoT is a concept that forms a giant network that connects all devices to collect and share data about how a device is operated.

Developments in the digital age have enabled technology to connect people with objects and also objects with objects. These supporting IoT technologies serve to illustrate how the various technologies relate to each other and communicate with each other with scalability, modularity, and configuration of IoT deployments in different scenarios.

2.2 SCADA

SCADA is an abbreviation of Supervisory Control and Data Acquisition, which serves to supervise, control, and process data in real-time in each process [7]. Real-time in a source stated, "real-time in a simple phrase is said that the user asks the computer system and then the computer system processes and answers it [4]. SCADA has four main parts, namely the Master terminal unit (MTU), Data communication, Remote terminal Unit (RTU), Field and Device.

MTU or master terminal unit is a system that functions as a server that receives data from RTU. Data from RTU is processed by MTU and displayed in the form of numbers and graphs according to the data that has been collected. MTU allows integration with HMI to make it easier to analyze data.
RTU or remote terminal unit is a system that is close to the object being observed. RTU is integrated with the sensor that is attached to the object being observed and functions as a receiver of data from the sensor and sends data from the sensor to the MTU for data processing and analysis.

Communication is a system that connects RTU and MTU so that it can transmit data originating from sensors. SCADA performs data communication via radio, modem, optical fiber, and serial communication.

Field and Device are sensors and actuators that are attached to the observed object. The sensor functions to measure digitally and are received by RTU and sent to MTU for data analysis.

### 2.3 ON GRID PV SYSTEM

The grid-connected system is a system that is connected to a PLN cable so that it can sell the excess electricity available. This system uses solar panels (photovoltaic panels) to produce electricity that is environmentally friendly and emission-free. With this system will reduce household electricity bills, and provide added value to the owner. This series of systems will remain connected with the PLN network by optimizing the use of energy from solar panels to produce electrical energy as much as possible.

There are several studies that support this research. In that study, it is used as the basis for this research. Journal "Designing PLTS Hybrid Systems with PLN Electric Nets for Urban Homes." In the journal discusses the hybrid PLTS system with PLN, which uses batteries as a storage of electrical energy (storage system). The hybrid PLTS system with PLN electricity can be applied to urban homes, as well as analyzing factors that influence the amount of electrical energy produced by solar cells related to the working time of the PLTS system. PLTS will supply about 30% of electricity from the overall burden of household electrical equipment, while the remaining 70% of power is from PLN. (Bien, L E. 2008).

![Figure 2: On Grid PV System](image-url)

Comparative Study 2 Model of Power Plants Hybrid PLTS and PLN / Genset systems. In this journal discusses the comparison between PLTS model 1, which is hybrid
with PLN and PLTS model 2, which is made in series which is analyzed to get the best PLTS model. There are differences between the two models, namely the switch controller (PLTS regulator unit). Model 2 energy generated from PLTS, Genset, and windmills will be distributed directly to the battery and the load without any supply from PLN. From the configuration of the hybrid system model 1 and model 2 (both series and parallel), it can be concluded that the performance of the two models in principle has the same reliability in maintaining the continuity of power supply to the load, but from the simplicity of the equipment system, the PLTS 1 model is simpler than PLTS 2 model, and when viewed from the readiness of PLTS in supplying power to the load, the PLTS 2 model is far better than the PLTS 1 model, whereas from the investment side the model 2 is far more expensive than Model 1. (Indrajaya, 2012).

Study of PLTS Utilization as an Additional Power Supply in the Hospitality Industry in Nusa Lembongan, Bali. This study discusses the planning of a hybrid solar power plant with PLN, where the solar power system that will be developed to supply electricity is planned at 30%. The PLTS power that will be generated to supply the planned hotel energy is 21.6 kWp, which will be produced from 144 panels with a capacity of 150 Wp. The cost of PLTS energy at the current price of solar panels is Rp.8500 / Kwh. Taking into account the decline in the price of solar panels by an average of 9% per year and the tendency of an increase in world oil prices, it was found that in the next five years the PLTS energy costs would decrease to Rp.6100 / Kwh, close to the energy costs of a PLTD. The feasibility analysis of PLTS investment conducted using NPV, PI, and DPP shows the results that the PLTS investment is feasible to be carried out. Alternative strategies to determine the feasibility of PV-VP as an additional power supply are obtained by analyzing technical aspects, cost aspects, and regulatory aspects using a SWOT analysis. An alternative strategy from the SWOT analysis shows that the stipulation of regulations from the government is very instrumental in making the use of PLTS as an additional power supply, feasible to be developed in the hospitality industry in Nusa Lembongan, especially at the Bali Hai Tide Huts hotel. (Santiari, Dewa Ayu Sri 2011)

3. Modular Renewable Energy Management System
Modular Renewable Energy Management System (Modular R-EMS) adalah alat yang bisa melakukan monitoring, kontrol, serta proses management dari sumber renewable energi. Modular R-EMS terhubung secara wireless antar modulnya melalui internet yang kemudian terhubung pada cloud sehingga dapat dikontrol dan setiap datanya dapat diakses dimanapun melalui smartphone.

3.1 Modular R-EMS
Modular R-EMS has two main parts, namely hardware integrated with the concept of mini-SCADA and internet of things.
Integrated hardware with the Miniscada concept in this study consists of five R-EMS modules, each of which is mounted on a solar panel, wind turbine, PLN, Battery, and house load. In one of the R-EMS modules, there is a relay to control the source that we want to use. Internet of things consists of cloud and software embedded on smartphones.

### 3.2 Hardware Modular R-EMS

The R-EMS modular hardware is equipped with a voltage and current sensor to read the required quantities, and fitted with a relay to make the selection of the desired source. Sensors and relays are connected to Arduino and MCU nodes and then sent to the cloud via the internet.

### 3.3 Software Modular R-EMS

Software that is programmed on the Modular R-EMS is found on smartphones, either based on Android or IOS. From the application, the user can monitor the voltage, current, and power from the PLN, the load, the installed Renewable Energy, or the battery. And it is possible to see the costs that must be paid to PLN.
4. Result and Analysis

After the modular R-EMS tool is finished, testing is needed to see its performance. Initially calibrated from each sensor installed. After the sensor calibration is complete the system testing of each R-EMS module is done to coordinate and carry out the process following what has been programmed.

4.1 Testing of data transmission

In conducting microcontroller, communication requires the media to transmit analog and digital data. When communicating between two or more microcontrollers, serial
communication and wireless communication are used. Serial communication is used to send data in the form of numerical data in bytes to do data parsing on the destination microcontroller so that the data obtained by the data obtained can be executed with mathematical operations. In the process of sending data wirelessly, it takes communication media in the form of an internet network.

In the process of data communication from current sensors and voltage sensors needed in the process of sending data from the microcontroller, the transmitter needs the media to communicate. The media used in conducting wireless communication is by utilizing internet facilities obtained from smartphones connected to Wifi and data packages. When the smartphone is connected, the smartphone is ready to receive data from the client. The microcontroller that has been connected to the internet will upload data obtained from the conversion of the output signal from the current and voltage sensors. In the process of monitoring and control, the battery indicator needs to be considered to facilitate the selection of sources.

![Figure 7: Battery Interface on Smartphones](image)

### 4.2 R-EMS Modular Testing

System testing is done by taking data with variations in the load carried out at different times in the same place.

The first test was conducted on July 4, 2019, at 19:00 WIB.

| Voltage (V) | Current (A) | Voltage (V) | Current (A) | Voltage (V) | Current (A) |
|------------|-------------|-------------|-------------|-------------|-------------|
| 223        | 0           | 223         | 0           | 223         | 0           |
| 223        | 0.42        | 223         | 0           | 223         | 0.41        |
| 223        | 0.75        | 223         | 0           | 223         | 0.73        |
| 223        | 0.99        | 223         | 0           | 223         | 0.96        |
| 223        | 1.14        | 223         | 0           | 223         | 1.08        |

In the first test, it was found that all the burden was borne by PLN; this is because, at night, the EBT / Solar panel could not produce electricity. It can be seen that the current generated by EBT is always 0 Amperes despite the change in load.
The second test was conducted on July 5, 2019, at 15:30 WIB.

Table 2: Hasil pengujian EBT On Grid pukul 15.30WIB

| PLN | EBT | Beban |
|-----|-----|-------|
| Voltage (V) | Current (A) | Voltage (V) | Current (A) | Voltage (V) | Current (A) |
| 219 | 0.22 | 219 | 0.22 | 219 | 0 |
| 219 | 0.24 | 219 | 0.22 | 219 | 0.35 |
| 219 | 0.39 | 219 | 0.22 | 219 | 0.73 |
| 219 | 0.72 | 219 | 0.22 | 219 | 0.93 |
| 219 | 1.08 | 219 | 0.22 | 219 | 1.12 |

In the second test, the EBT power is 48.18 Watt, or in other words, the current generated is 0.22 Ampere. When testing with five different loads from 0.35 to 1.12 Amperes, data obtained that the R-EMS was successful in reading and displaying the configuration of the generated power. If EBT is higher, then EBT will send the remaining energy to PLN. And if the burden is higher than EBT, then the lack of power is obtained from PLN.

The third test was conducted on July 6, 2019, at 11:30 WIB.

Table 3: Hasil pengujian EBT On Grid pukul 11.30 WIB

| PLN | EBT | Beban |
|-----|-----|-------|
| Voltage (V) | Current (A) | Voltage (V) | Current (A) | Voltage (V) | Current (A) |
| 222 | 0.9 | 222 | 0.9 | 222 | 0 |
| 222 | 0.55 | 222 | 0.9 | 222 | 0.37 |
| 222 | 0.4 | 222 | 0.9 | 222 | 0.75 |
| 222 | 0.4 | 222 | 0.9 | 222 | 0.97 |
| 222 | 0.4 | 222 | 0.9 | 222 | 1.14 |

In the first variation which is conditioned to have no load, the on-grid inverter current is the same as the PLN current, and this is possible because the power generated by the On-grid inverter is excessive so that it is given to PLN for the amount of power generated. In the second and third variations, a load of 0.37 A and 0.75 A is needed because this is to know the power conditions of the EBT, PLN, and load. The results obtained in the second and third variations are that the load is still supplied by EBT because the power generated by EBT is greater than the load and the remainder of the power used for the load is given to PLN. In the fourth and fifth variations, it is known that EBT is not able to supply the power needed by the load so that power is needed from PLN.

Tests carried out using EBT load and power variations. Load variations are given to determine the magnitude of the comparison that occurs between the use of PLN and EBT. In tests conducted on July 4, 2019, at 19:00 IWST it is known that EBT does not produce
current because the voltage needed to operate the On Grid inverter is not met. So that 100% power usage is supplied from PLN to the load.

Tests carried out on July 5, 2019 at 15:30 WIB it is known that the use of EBT at a load of 76.65 Watt at 62.85% and the use of PLN at 31.15% this is because the power supply from EBT has not been sufficient to meet the load requirements. Furthermore, an additional load of 159.87 Watt is carried out, with the power produced by EBT, which is relatively the same, the use of EBT is 30.13%, and PLN is 69.87%. At 203.67 Watt load usage, use EBT 23.66% and PLN 76.34% and 245.28 Watt load use EBT 19.64% and PLN 80.36%. The use of EBT continues to decrease while the use of load continues to increase. This is because the power generated by EBT is not able to supply all the power needed by the load. So that PLN automatically adds less power than EBT to operate the load.

Tests conducted on July 6, 2019, at 11:30 IWST are known to produce the greatest power compared to previous tests so that the use of PLN is only 7-11%.

5. Conclusion

From the results and analysis of the research that has been done so that it can be concluded as follows:

1. The error obtained from testing the AC / DC voltage and current sensor compared to the measurement on the multimeter is less than 5%.
2. NodeMCU can be used as a microcontroller that can process data and upload data obtained from AC / DC voltage and current sensors in realtime and online.
3. In testing 1, the load consumption of PLN was 100%. Testing 2 load consumption of PLN worth 31% - 80%. Testing 3 load consumption of PLN is worth 12% - 23%. Testing 4 load consumption of PLN is worth 7% - 11%.

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