Experimental study of mini SCADA renewable energy management system on microgrid using Raspberry Pi

E Tridianto¹,², P D Permatasari¹ and I R Ali¹

¹ Electronic Engineering Polytechnic Institute of Surabaya, Kampus PENS Jalan Raya ITS Keputih Sukolilo Surabaya 60111

* Corresponding author: erik@pens.ac.id

Abstract. Renewable Energy Management System (REMS) is a device that can be able to monitor power through a microgrid. The purpose of this system is to optimize power usage that produced from renewable energy with the result that reduces power demand from the grid. To reach the goal this device manage the load power needs fully supplied by renewable energy when the power produced from renewable energy is higher than load demand, besides power surplus will be stored in battery in this way energy stored in battery can be used when it needed. When the power produced from renewable energy can not satisfy the power demand, power will supply by renewable energy and grid. This device uses power meters for record any power flow through microgrid. In order to manage power flow in microgrid this system use relay module. The user can find out energy consumption (consumed by the load) and production (produced by renewable energy) in a period of time so that the user can switch on the load in right time.

1. Introduction

Electrical energy has become one of the main resources that human needed. In 2013 Indonesian people need 764 kWh per capita and has predicted will increase continuously. The main fuel used by the power plant is coal. If we assume that there is no discovery of new coal source coal will run out in 72 years. In this rate, people must discover a way to optimize renewable energy use. As a region located in ecuator line, Indonesia has huge amount of renewable energy potential especialy solar energy and wind energy. Unfortunately there are just 1.96MW wind farm and 19.2 solar farm installed although wind energy have potential up to 970MW and solar energy have 4,80kWh/m²/day [1]. This condition is caused by Availability of renewable energy is not sustainable. It mean that renewable energy resource can not supply the load demand well.

2. Methods

Renewable energy management system manages the load demand will be fully supplied by renewable energy when renewable energy resource produces energy more than load demand and store the surplus of it. If renewable energy resource cant fully supplies load demand it will be backed up by the grid [2]. This system algorithm shown in Figure 1. This device use power meters that consist of voltage sensors module and current sensors module. To manage power flow this device use relay module. Because
renewable energy produces power in DC and load demands are AC some power converter must be installed in this system like Figure 2.

Figure 1. System algorithm

**Figure 2. System design**

2.1 **Power meter**

To run the algorithm this system need to know the value of power in each point (renewable energy produced and load consumed). To determine it this device senses voltage and current in each point then the controller use equation 1 to determine power’s value

\[ P = V \cdot I \] (1)

ACS 712 module is used for sense current’s value. For sense AC voltage value this device uses ZMPT101b module and voltage divider for DC. ACS712 current sensor is connected between supply and load to measure the current flowing through load. This current sensor is based on the principle of hall-effect. The principle states that whenever current carrying conductor placed in magnetic field, the voltage is created across its edges perpendicular to the direction of both current and magnetic field (Figure 3, Figure 4, and Figure 5). The voltage generated is called as Hall voltage which is in microvolts [3]. The ZMPT101B is a voltage sensor, that the setting has to be provided by the user through the trim potentiometer [4].

Figure 3. ACS712 module  Figure 4. ZMPT101b module  Figure 5. Voltage divider
2.2 Raspberry Pi for main controller
Raspberry Pi is a single-board computer developed by the Raspberry Pi Foundation. Like other computers, Raspberry Pi runs various tasks (such as making documents, playing media, browsing, etc.). One of its powerful features is GPIO pins that allow Raspberry Pi to perform physical computing. GPIO pins can be connected to sensors (e.g., ACS modules) or actuators (e.g., relay modules) [5]. The Raspberry Pi language used for communication of the kit is Python. These platforms are Free Open Source Software. So, the overall implementation cost is low and can be easily configured [6]. But Raspberry Pi just can read digital input because in this project, an analogue sensor Analog Digital Converter must be added. The connection between GPIO's Raspberry Pi and other components in this device is shown in Figure 6.

![Figure 6. GPIO pin connection](image)

2.3 Power converter
This device uses a grid-tie inverter that can automatically synchronize with the grid so renewable energy resources can work well with the grid. It means energy produced by renewable energy resources will be transferred to the grid, and the grid will supply load demand. This system will optimize the usage of renewable energy and prevent under-voltage to the load. This device is also completed by a pure sine wave inverter that can convert DC source from storage systems into AC sources that can be used by the load if necessary (backup system when the grid is down). Pure Sine Wave Inverter is one of the most recognizable technologies that has been utilized by both industrial and private sectors in Distributed Power Generation (DG) Systems [7].

The output voltage of a grid-tie inverter should maintain some fixed requirements so that it can provide power to the utility grid [8]. The requirements are given below (Figure 7 and Figure 8):

i. The output voltage amplitude of the grid-tie inverter should be the same as the grid amplitude.
ii. The frequency of inverter should be the same as the grid frequency (50 Hz in Bangladesh).
iii. The phase of inverter should match with the grid.
3. Results and discussion
After being assembled the renewable energy management system is shown in Figure 9.

This device sensor tested to get this performance. The result of voltage and current sensor is in figure 10, 11, and 12. To test voltage divider sensor DC power supply has been used. Voltage divider tested in 10VDC to 14VDC. To test ZMPT101b variac (variable AC source) has been used. This module tasted in 180VAC to 240VAC. To test ACS712 module some load parallely connected and supplied by grid and turned on one by one (Figure 10).
In range from 10VDC until 14VDC the voltage divider highest error at point 10VDC but this error is under 5% so it can be neglected. ZMPT101b module with tested at 180VAC until 240 VAC provide error under 2% at all point. Unfortunatly ACS712 module have more than 5% error when current rated under 1.5A (Figure 11 and Figure 12). This error can reduced by recalculated reading formula in the program. But because some sensor have no linear output it imposible to determine the formula witch can suitable in long range [9,10].

4. Conclusion
The performance of renewable energy management system is good at certain point and going worst at other point of physical parameter. So it is necesary to estimate in witch point this device will work. After the point estimate formula that program sensor to read the value of physical properties must be built according to it.

References
[1] Conti J, Holtberg P, Diefenderfer J, LaRose A, Turnure J T and Westfall L 2016 International Energy Outlook 2016 With Projections to 2040 (Washington, DC: USDOE Energy Information Administration (EIA))
[2] Manas M 2015 Energy Rep. 1 156
[3] Bekara C 2014 Procedia Comput. Sci. 34 532
[4] Karoly R and Dumitru C D 2015 Procedia Technol. 19 689
[5] Oliver K M 2016 Tech Trends. 60 160
[6] Abubakar I, Khalid S N, Mustafa M W, Shareef H and Mustapha M 2017 ARPN J. Eng. Appl. Sci. 12 1076
[7] Kumar Y P and Bhimasingu R 2015 J. Mod. Power Syst. Clean Energy 3 1
[8] Patel J A, Shubhangi A, Joshi S, Pawar A and Bari N 2016 Int. J. Eng. Sci. 2800
[9] Hasan M, Maqsood J, Baig M Q, Bukhari S M and Ahmed S 2015 Design and Implementation of Single Phase Pure Sine Wave Inverter Using Multivibrator IC. In Modelling and Simulation (UKSim), 2015 17th UKSim-AMSS International Conference on 2015 Mar 25 (pp. 451-455). IEEE.
[10] Chakraborty S and Razzak M A 2014 Int. J. Renew. Energy Res. 4 91