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BIOGAS CONTROL AS A BACKUP SYSTEM ON A PV/WIND HYBRID MICROGRID WITH A BATTERY SYSTEM

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Abstract. *This research designs a biogas generator as a backup system for a micro-grid hybrid Photovoltaic (PV)/Wind Turbine (WT) with a battery and load. The system design is divided into two parts: the main system and the backup system. The main system consists of a PV generator of 30 kWp, and WT of 1250 kW which are connected in parallel with the main battery with a capacity of 4400 kWh. The backup system consists of a biogas generator of 1.175 kW and a backup battery capacity of 700 kWh, serving the 156 kW of total base load in Rongi with 312 kW of peak load. The control is conducted for the system coordination between the battery in the main system and the battery in the backup system. The system simulation results display the monitoring of input conditions, PV and WT power outputs, main system battery conditions, and the backup system. By controlling the coordination between the main system battery and the battery backup system, the continuity of energy distribution to the load will be better maintained and it also acts as system safety when the main generators (PV and WT) are not operating optimally.*
Keywords: Microgrid hybrid PV/WT, Biogas backup system, Battery system, Energy Management System (EMS), Lithium-ion

1. **Introduction.** As one of the impacts of pollution and greenhouse gas emissions, there is a shift in the use and dependence on non-renewable energy sources to renewable energy in building new power generators or expanding the existing electricity networks [1]. Several countries have made priority policies and taken effective steps to increase the installed capacity of renewable energy systems [2,3]. The microgrid system can be used as a solution to create energy-independent areas for areas that have not yet been reached by PLN's electricity services. A microgrid is a distributed generation system that includes various energy sources, such as fossil sources and renewable energy sources (e.g., wind, solar, and biogas).

Hybrid renewable energy sources are a promising technology for future energy sources. [4] conducted a model design and analyzed the optimization of the Photovoltaic (PV)/ Wind Turbine (WT) hybrid system for use in healthcare building loads. Several techniques were carried out to optimize the power generated by PV using a Maximum Power Point Tracker (MPPT) with a battery system. [5] performed control by adding a DC-DC boost converter to control the output power of a PV panel array using the Takagi-Sugeno

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(T-S) fuzzy model-based approach. [6] performed MPPT control using different control techniques such as fuzzy logic controller, neural networks, and particle swarm optimization to evaluate PV and Fuel Cell (FC) through DC-DC boost converters for enhanced settlement point. [7] presented a method for integrating solar trackers and MPPT to improve PV system efficiency. The integrated system provides a closed-loop solar tracker without sensors. The output power of the MPPT is employed as a feedback signal to the solar tracker.

As renewable energy power plants are intermittent, Battery Energy Storage Systems (BESS) and other reservoirs, such as biogas energy sources, have the potential to be integrated with renewable energy sources to ensure sustainable access to electricity and energy security [8]. Energy storage allows the energy produced to be stored when demand is low and supplied when the demand is high. It can stabilize the power grid with a high penetration rate of renewable energy [9]. Electricity from biomass, especially from biogas, can be independently produced during the day or night under different weather conditions, making it possible to adjust the energy supply to meet the load requirements [10,11].

Several previous researches related to microgrid hybrid biogas with other renewable energy sources [12,13] discussed Hybrid Renewable Energy System (HRES) solar-biogas which is safe and efficient in providing energy for on-grid or off-grid systems. [14,15] discussed modeling, simulation, and optimization for the hybrid diesel-biogas-PV microgrid combination by designing the model in Simulink and performing optimization using Homer related to the techno-economic analysis of the diesel-biogas hybrid microgrid system. The biogas-solar-wind hybrid microgrid combination can be utilized to facilitate renewable intermittency mitigation and efficient battery utilization, multicarrier generation scheduling schemes for energy efficiency, and an approach to managing energy efficiency [16].

Researchers in [17-20] conducted studies related to the technical feasibility and economic analysis of the hybrid system where the results of the analysis showed that the biogas hybrid system is more economically profitable than other solutions. Based on a review of previous research, it is interesting to design a biogas generator as a backup system on a hybrid microgrid due to the fact that biogas can be produced at any time by adjusting to the energy supply so that it can meet the load requirements. This research is a continuation of our previous research entitled improved battery efficiency with blade pitch control of wind turbine [21]. This research utilizes biogas as a renewable energy source because its production is controlled, so it is very appropriate to use biogas as a backup system in a PV/ WT hybrid microgrid with a battery system to improve microgrid system performance.

Based on a review of previous research related to the combination of microgrid hybrid PV, WT, and biogas, there has been no research that has coordinated control systems and optimized the three renewable energy sources using two battery systems as an energy storage system; the battery in the main system and the battery in the backup system. The advantage of this system is the coordination control between the main system and the backup system, which is controlled by the battery control used to maintain the continuity of the distribution of electrical energy to the load.

This paper is organized into several sections. Section 1 consists of introduction and research studies related to the energy storage system, hybrid microgrid control systems, and microgrid hybrid biogas; Section 2 shows the design of biogas backup system configuration on hybrid PV/WT microgrid and battery system; Section 3 consists of the results that present a graph showing monitoring input from scenario data, power output generated by PV and WT generators, battery current in the main system, main system battery condition, backup battery condition, and load monitoring; and Section 4 is a conclusion consisting of several important conclusion points.

2. Biogas Backup System Configuration on Hybrid PV/WT Microgrid and Battery System. This section briefly presents the biogas backup system configuration on a hybrid PV/WT microgrid and battery system, input data scenario, main system model, and backup system model. The configuration of the designed model consists of the main system and a backup system as shown in Figure 1. The main system consists of PV and WT generators which are connected to the main battery system. The PV output is direct current so that it can be directly stored in the battery system. The WT output is alternating current so it must be rectified first before being stored in the battery system. The connection form is the DC which is used to charge the battery from each PV/WT generator and then channeled to the load by converting DC to AC. While the backup system consists of a biogas generator that is connected to a backup battery system that will be connected to the load when the main system battery is low or disconnected from the load. The control is conducted for the coordination between the main battery and the backup battery to supply power to the load.

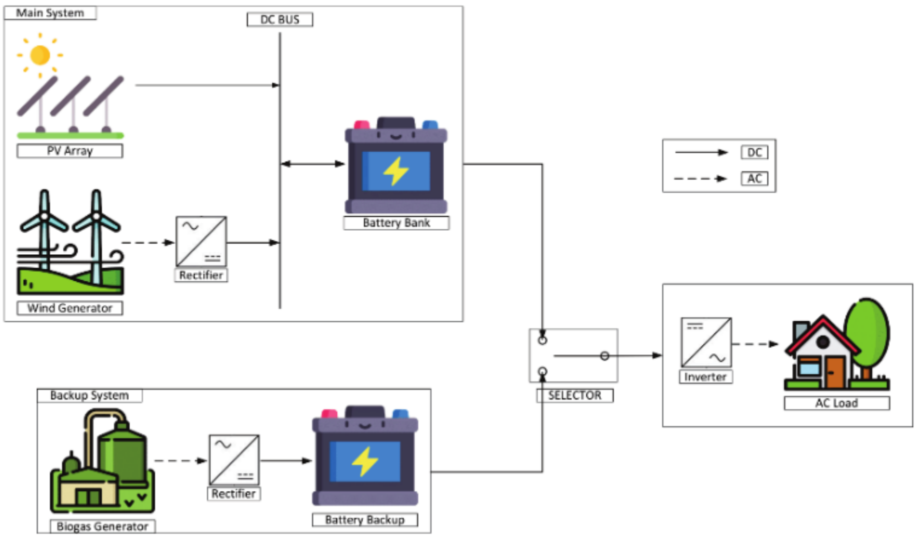

FIGURE 1. Biogas backup system configuration on hybrid PV/WT microgrid and battery system

The input data used in this system is the real data which was taken in Rongi, South Buton, Southeast Sulawesi as shown in Table 1. Irradiance data shows that the irradiance peak of 1000 W/m^2 occurs at 12.00, while the wind speed reaches a peak of 14 m/s at 14.00. The base load is 156 kW and the peak load is 312 kW occurring from 17.00 to 22.00. In the system, the main system modeling and backup system input data modeling are conducted according to the real data in Rongi, South Buton.

2.1. **Main system model.** The main system consists of PV and WT generators which are connected to the battery system to serve the load. The power output produced by PV and WT is stored in the Li-ion battery with a capacity of 4400 kWh, a minimum voltage of 200 Volts, a rated capacity of 2200 Ah, and a 30% State of Charge (SoC). In the discharge condition, the maximum capacity is 2200 Ah, the cut-off voltage is 150 Volts, the fully charged voltage is 232.7974 Volts and the nominal current discharged is 8782.6087 A.

2.2. **Backup system model.** The backup system consists of a biogas generator with a capacity of 1.175 kW connected to a battery storage system. The battery used is a Li-ion

TABLE 1. Data scenario PV, wind, load

Time	Irradiance (W/m^2)	Temperature (°C)	Wind speed (m/s)	Load (kW)
0	0	21	7	156
1	0	21	6	156
2	0	21	7	156
3	0	21	4	156
4	0	21	6	156
5	0	30	6	156
6	130	51	6	156
7	350	52	7	156
8	700	54	6	156
9	800	56	8	156
10	650	58	5	156
11	850	60	8	156
12	1000	61	9	156
13	875	61	9	156
14	650	60	14	156
15	780	59	11	156
16	350	58	6	156
17	175	57	6	312
18	120	55	5	312
19	0	25	9	312
20	0	24	4	312
21	0	23	8	312
22	0	22	9	312
23	0	21	5	156

type with a capacity of 700 kWh, a nominal voltage of 200 Volts, a rated capacity of 3500 Ah, and an initial SoC of 50%. In the discharge condition, the maximum capacity is 3500 Ah, the cut-off voltage is 150 Volts, the fully charged voltage is 232.7974 Volts and the nominal current discharged is 1521.7391 A. In the backup system, monitoring the condition of the main system battery is carried out to regulate the SoC control of the battery backup system and the main system battery. The control is carried out on the backup battery to regulate the connection and disconnection conditions of the backup battery system to the load. The backup system control will work when the battery condition in the main system is at a level of less than 25% level and will stop working when the battery in the backup system is at 0% level or when the main system battery is at a level above 25%.

2.3. **Biogas backup system model on microgrid hybrid PV/WT.** The overall system design is shown in Figure 2. The system consists of the main system and the backup system connected to the load. In the main system, the PV and wind hybrid microgrids are connected in parallel with the battery and load systems. PV is designed with a capacity of 30 kWp with input irradiance and temperature. While the WT with a capacity of 1250 kW with input wind speed. In WT, blade pitch control is carried out to adjust the speed of the WT generator so that the power produced is flat or according to the provisions. With blade pitch control on WT, the effectiveness of the main system battery used can be more optimal.

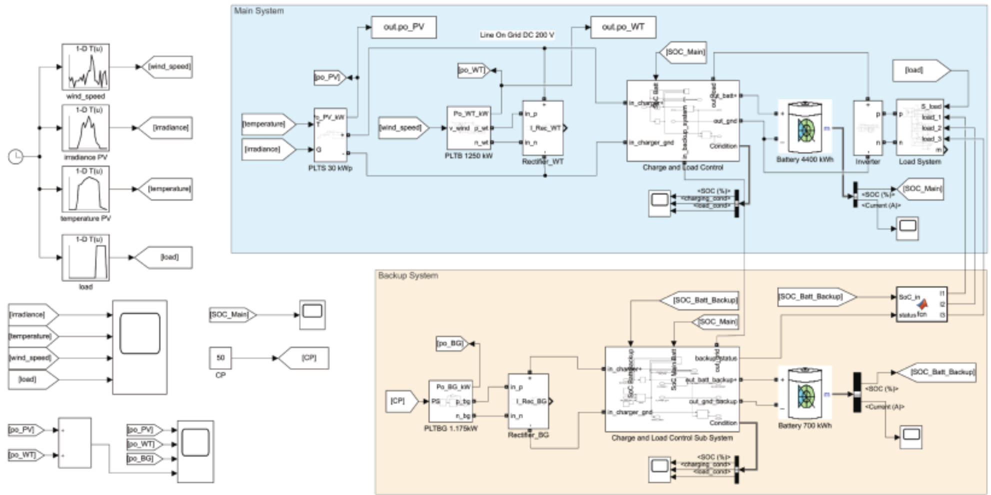

Figure 2. Biogas backup system on microgrid hybrid PV/WT

3. **Results.** The system is designed using data input scenarios of irradiance, temperature, wind speed, and load at Rongi in South Buton. The system can monitor the input from scenario data, the power output generated by PV and WT generators, the battery current in the main system, the load conditions on the main system battery, the load conditions on backup batteries, and the charging/discharging of backup batteries.

3.1. **Input monitoring.** Irradiance input, temperature, wind speed, and load were monitored hourly from 00.00 to 23.00. Irradiance and temperature reach a peak at 12.00 with an irradiance of 1000 W/m^2 with a temperature of 61°C. Wind speed monitoring shows that the wind speed reaches its peak at 14.00 with a wind speed of 14 m/s. Load monitoring is conducted to see the peak load conditions where at the base load the power consumption is 156 kW and at the peak load, the power consumption is 312 kW which occurs from 17.00 to 22.00. Input monitoring irradiance, temperature, wind speed, and load are shown in Figure 3.

3.2. **Output power monitoring.** PV peaks at 12.00 with a power output of 20.82 kW, wind output peaks at 14.00 with a power output of 674.82 kW, biogas output with a constant power of 1.175 kW, and the total output of microgrid hybrid PV and the wind is 693.87 kW as shown in Figure 4.

3.3. **Main system battery current monitoring.** The graph of monitoring battery currently in the main system is shown in Figure 5. The battery charging process starts from 08.00 to 15.00. The charging process is indicated by a negative current graph. After this process, the battery will be used again by the load system, marked with a positive graphic value.

3.4. **Main system battery charging monitoring.** In the main battery, SoC control, charging, and discharging is carried out. The battery will charge when the SoC is at a level of 30% until it reaches a level of 80%. This charging and discharging condition will occur continuously as shown in Figure 6.

3.5. **Backup system battery charging monitoring.** For the backup battery charge and discharge state, the charging system will continue until the battery SoC level reaches 100%. This condition will also continuously repeat as shown in Figure 7.

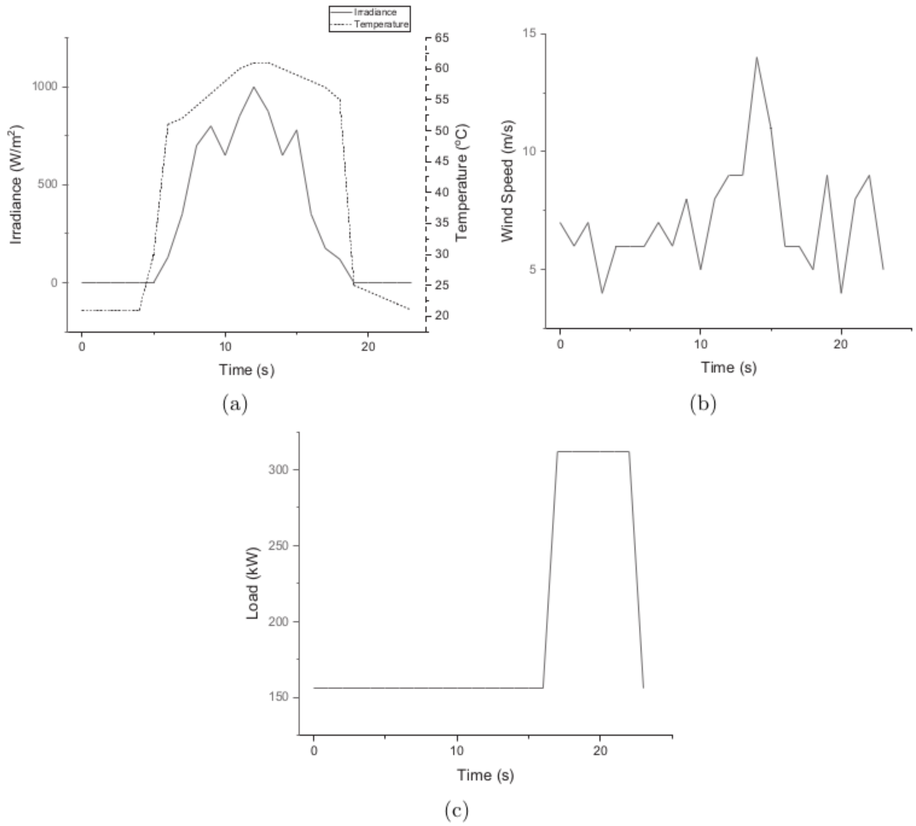

FIGURE 3. Input monitoring: (a) Irradiance and temperature; (b) wind speed; (c) load

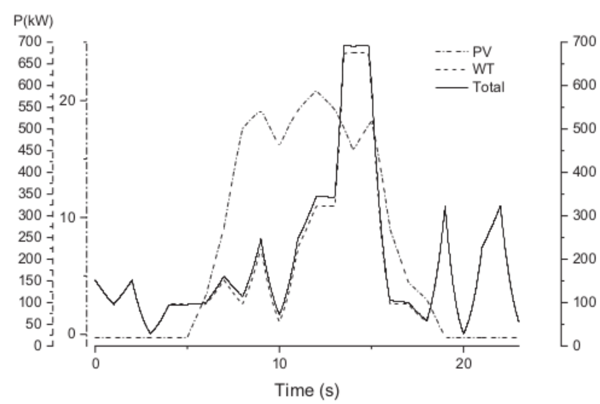

FIGURE 4. Monitoring of PV output power, WT, and total power

3.6. **Main system battery SoC and load monitoring.** The main battery will supply the load when the SoC is above 25%. When the main battery SoC is below 25%, the load supply will be shifted to the backup battery. This condition will be maintained until (PV and WT generating systems supply to charge the main battery) are charged again at the

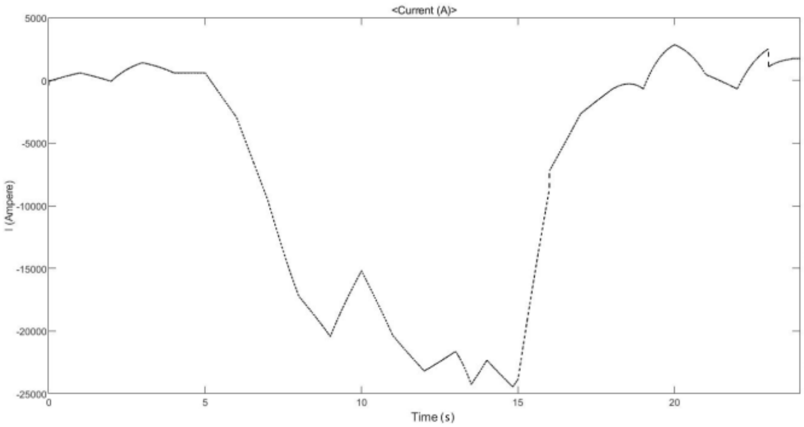

FIGURE 5. Main system battery current monitoring

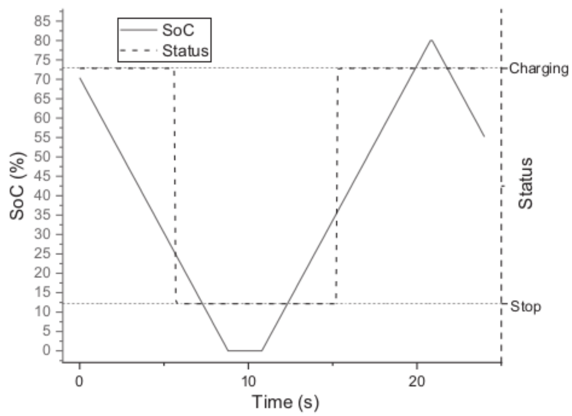

FIGURE 6. Main system battery charging monitoring

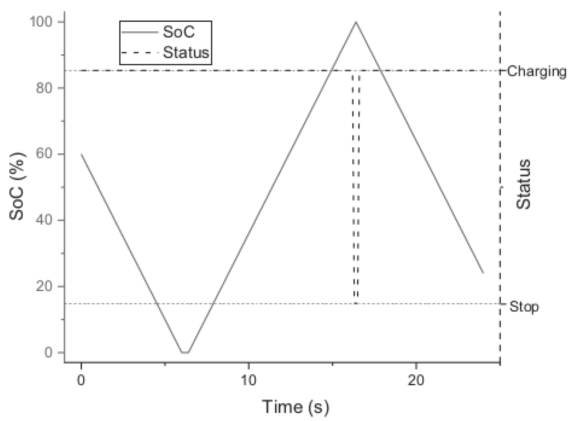

FIGURE 7. Backup system battery charging monitoring

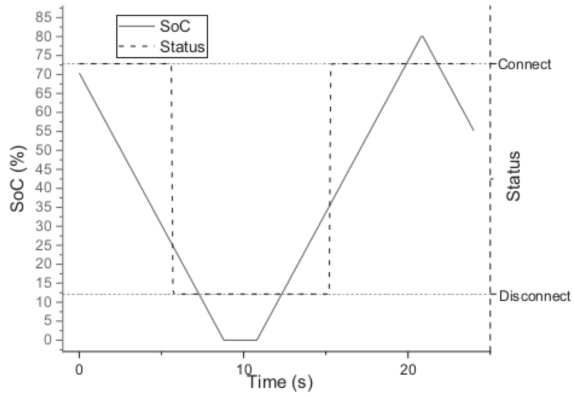

FIGURE 8. Main system battery SoC and load monitoring

35% SoC level. Also in this condition (main battery SoC below 25%), the backup battery will continue to supply power to the load until the backup battery runs out as shown in Figure 8.

4. **Conclusions.** The configuration of the biogas backup system on a PV/WT hybrid microgrid with a battery and load system is designed to consist of a main system and a backup system. The main system consists of a PV generator with a capacity of 30 kWp, WT with a capacity of 1250 kW, using a battery with a capacity of 4400 kWh. In the main system, the blade pitch control is conducted on the WT to adjust the power output generated by the WT to match the settings. The backup system consists of a biogas generator with a capacity of 1.175 kW and a battery with a capacity of 700 kWh to store the power generated by the biogas generator.

The total power output produced by PV/WT is 693.87 kW. The power generated by biogas is constant at 1.175 kW which is stored in the backup battery until the battery level reaches 100%. The condition of the main system battery is affected by the peak irradiance on the PV and the wind speed on the WT. The backup system battery will connect to the load when the main system battery is at a 25% level. The battery backup system will supply power to the load until the battery condition is at 0% level or when the main system battery is at a level above 25% to 80%.

With the design of a biogas generator as a backup system on a PV/WT hybrid microgrid with a battery system, the continuity of energy distribution in this microgrid system will be more optimal. The future work of this research is the design of a larger biogas generator capacity by optimizing the use of a backup battery so that the charging time for the backup battery could be faster and the utilization of biogas potential could be more effective. Optimization uses some of the best optimization algorithms to compare the results.

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