elb-14-04-05_asminar.pdf

by

Submission date: 08-Mar-2023 05:27AM (UTC+0700)
Submission ID: 2031535739
File name: elb-14-04-05_asminar.pdf (1.29M)
Word count: 4843
Character count: 23736

ICIC Express Letters
Part B: Applications
Volume **14**, Number **4**, April **2023**

ICIC International ©2023 ISSN 2185-2766
pp. **369–378**

IMPROVED BATTERY EFFICIENCY WITH BLADE PITCH CONTROL OF WIND TURBINE

Asminar[1,2], Ansar Suyuti[1], Sri Mawar Said[1] and Syafaruddin[1,*]

[1]Department of Electrical Engineering
Universitas Hasanuddin
Jl. Poros Malino Km. 6, Bontomarannu, Gowa, Sulawesi Selatan 92171, Indonesia
asminar20d@student.unhas.ac.id; { asuyuti; srimawarsaid }@unhas.ac.id
[*]Corresponding author: syafaruddin@unhas.ac.id

[2]Department of Electrical Engineering
Universitas Halu Oleo
Kampus Hijau Bumi Tridharma Anduonohu, Jl. HEA Mokodompit Kendari
Sulawesi Tenggara 93232, Indonesia
asminar.ft@uho.ac.id

Received October 2022; accepted December 2022

Abstract. *The photovoltaic (PV)/wind/biogas hybrid microgrid system with a battery system is designed with a PV capacity of 30 kWp, wind 1250 kW, and biogas 1.175 kW. The type of battery used is Lithium-Ion, with a capacity of 4900 kWh. The base load served in Rongi South Buton is 156 kW, and the peak load is 312 kW. Partial control is carried out on the wind turbine with blade pitch control to adjust the speed of the wind turbine generator to produce constant output power. The battery system also controls the state of charge (SoC), charging and discharging of the battery, and modeling using MATLAB Simulink 2020a. The results of the speed control of the wind turbine generator in this hybrid microgrid system have an impact on the efficiency of battery use. The same system without using blade pitch control on a wind turbine, requires a battery with a capacity of 5800 kWh for the energy storage system generated by a PV/wind/biogas generator. In contrast, after using blade pitch control on a wind turbine and battery control, only a battery with a capacity of 4900 kWh is needed for energy storage systems generated by PV/wind/biogas generators.*

Keywords: Microgrid hybrid PV/wind/biogas, Blade pitch control, Battery efficiency, WT control

1. Introduction.

The use of renewable energy that is not yet optimal in the implementation of energy conservation encourages the development of a renewable energy-based power generation system to meet the community's need for energy based on government policies. The microgrid system is a solution for areas not reached by electricity utility services by utilizing local renewable energy sources available in each region. With different intermittent supply patterns of renewable energy sources but different intermittent patterns, it is often possible to achieve a better overall supply pattern by integrating two or more sources [1,2]. Renewable energy generation (diesel, wind, etc.) is 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 electrical energy and safety [3,4]. Energy storage can increase fluctuating renewable energy output and ensure that the power generated by renewables can be reliably released and delivered on-demand. In addition, it allows the energy produced to be stored when demand is low and supplied when demand is high. It can stabilize the power grid with a high penetration rate of renewable energy [5,6].

DOI: 10.24507/icicelb.14.04.369

Some problems of battery energy storage systems on microgrids are intermittent, poor power quality, high capital costs, and energy imbalance between supply and demand. Research on microgrids' energy storage systems [7-12] discusses optimization and control of battery energy storage systems, energy management strategies using several optimization methods, and backstepping control designs for power systems and energy storage. The control structure of the microgrid varies depending on the integrated source, load, and rating [13]. Some studies are related to the control of the microgrid system: [14-16] discuss the multilevel microgrid control system (MMCS) to optimize the performance of the microgrid system, control MPPT using several types of algorithm methods, and control wind turbines, and [17-19] discuss the design of a blade pitch controller (BPC) for a wind energy conversion system (WECS) application with a hybrid control technique based on a combination of RI-RH/RL and Kharitonov's Theorem (Kh), coordinated control of blade pitch angles of wind turbine generators and vehicles electric plug-in hybrids (PHEVs) for frequency control of microgrid loads using model predictive control (MPC), coordinating blade pitch controllers with battery storage systems. Blade pitch control is essential in the overall wind turbine control system. Blade pitch control reduces hazardous turbine structural loads from spatially variable and temporarily unstable incoming winds [20].

Research related to energy storage systems and microgrid control mentioned in the previous paper only discusses energy management and optimization of battery storage systems using several optimization algorithm methods. As for the research related to microgrid control systems and wind turbine control, the previous paper only discusses microgrid control for system performance, MPPT control with several algorithms, and blade pitch controller. For blade pitch control, the last article only discusses control model design with hybrid control technique and coordination of blade pitch controller with battery system. There has been no discussion on controlling the PV/wind/biogas/battery hybrid microgrid combination by partially controlling the wind turbine, which has an impact on the efficiency of battery use.

In this paper, blade pitch control regulates wind speed so that the power output produced by the wind turbine remains constant. The results of the blade pitch control on the wind turbine can increase the efficiency of the battery used in the PV/wind/biogas hybrid microgrid. In addition, the SoC control, charging, and discharging is also carried out as an energy management strategy and as a control to increase the battery life used in this hybrid microgrid system. The simulation of blade pitch control on a wind turbine in a microgrid hybrid PV/wind/biogas resulted a total power output of 693.87 kW using a Li-ion battery with a capacity of 4900 kWh. Battery control manages SoC 30% to 80%. The charging process occurs when the SoC level is below 30% and the discharging when the SoC level is at 80% to 30%.

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, wind turbine control, and blade pitch control; Section 2 shows the configuration design of PV, wind, biogas, and battery systems on a hybrid microgrid; Section 3 consists of the results and analysis that present a graph showing the results of a hybrid microgrid control system and a comparative study of battery efficiency used in systems with and without control; and Section 4 is a conclusion consisting of several important conclusion points.

2. Configuration of Microgrid Hybrid PV/Wind/Biogas/Battery Control System. The control system design on the PV, wind power, and biogas hybrid microgrid with a battery system is divided into two control parts, namely partial control on the wind turbine (WT) and control on the battery system in the form of SoC control, charging, and discharging the battery as shown in Figure 1. In this study, the biogas generator is constant and also stable. PV input is radiation and temperature, wind input is wind speed, and biogas input is cattle population to calculate biogas potential. The PV output

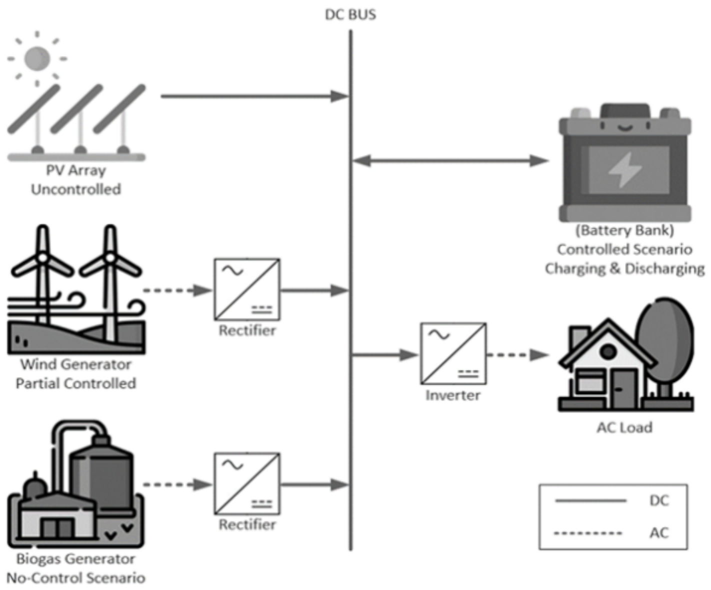


FIGURE 1. Hybrid microgrid control system design

is direct current (DC), directly stored in the battery system. While the output of wind and biogas is alternating current (AC), so it must be rectified first and then stored in the battery system. Before being supplied to the load, all the energy output stored in the battery system is converted to alternating current (AC) by using an inverter.

The data input used in this system is actual data taken in Rongi South Buton, Southeast Sulawesi, as shown in Table 1. Irradiance data shows the irradiance peak of 1000 W/m^2 occurs at 12:00, 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 from 17:00 to 22:00. The output of PV system and wind generator is integrated with biogas plants and battery system according to the actual input data.

2.1. **PV model.** The PV capacity of 30 kWp consists of PV cells connected in parallel. The PV input in the form of irradiance and temperature calculates the current and then models mathematically. The PV current is connected to the generator to produce the power output. This system is designed to monitor the input irradiance and temperature as well as to monitor the output power generated by PV. The PV model is designed as shown in Figure 2(a).

2.2. **Wind power model.** The technical information of wind power in this study is provided as follows. The total output power capacity is 1250 kW with specifications of 3-blades horizontal axis wind turbine of NE-400m2. Furthermore, the rated power of single wind turbine is 400 W and maximum power is 500 W with the rated voltage of 12/24/48 V. Meanwhile, this type of wind turbine can be start-up at a speed of 2 m/s and be able to reach the rated wind speed at 11.5 m/s. Figure 2(b) shows the control design of the wind turbine model. The wind speed input is connected to the wind speed transducer. Then the blade pitch control is carried out to adjust the speed of the wind turbine generator so that the resulting output follows a predetermined power output value.

2.3. **Biogas power model.** The capacity of the biogas generator used is 1.175 kW. The biogas generator model is shown in Figure 2(c). The biogas input is the cow population.

TABLE 1. Data input of PV system, wind power, and 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

The cow population calculates how much biogas potential can be produced by the biogas generator and the output power produced by the biogas generator.

2.4. **Battery control model.** The battery control model is shown in Figure 2(d). The battery inputs are PV, wind, and biogas power. SoC control, charging, and discharging. The battery management system charges and discharges the battery only partially, from 30% to 80% [21].

Battery model during charging and discharging state follows in [22].

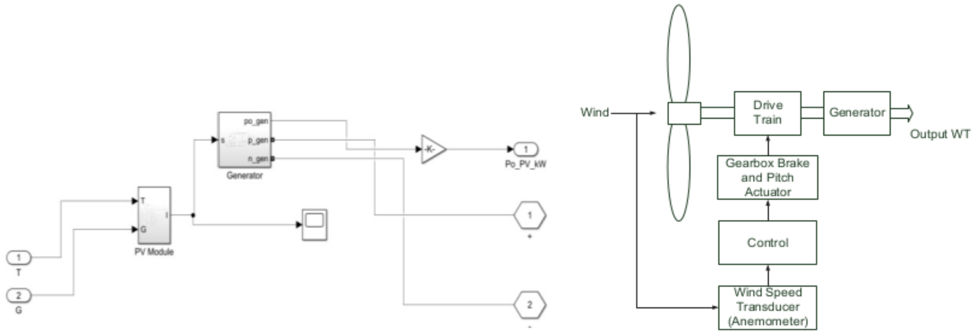
Charging model ($i^* < 0$) is shown as follows in (1).

$$V_{batt} = E_0 - Ri - K\frac{Q}{it - 0.1Q}i^* - K\left(\frac{Q}{Q - it}\right)it + Ae^{-Bit} \tag{1}$$

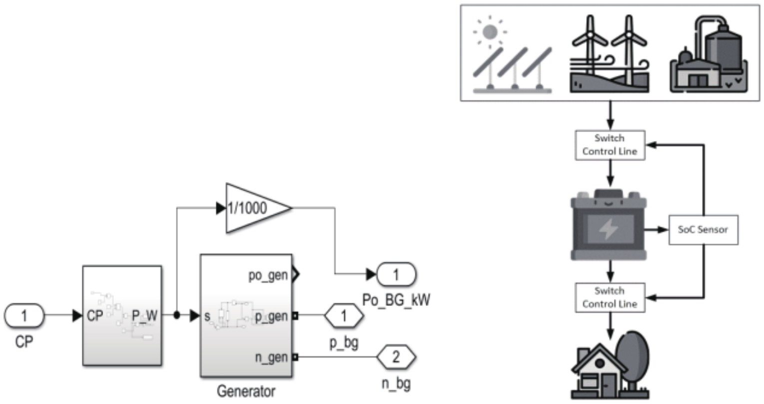
While discharge model ($i^* > 0$) shows as follows in (2).

$$V_{batt} = E_0 - Ri - K\frac{Q}{Q - it}i^* - K\left(\frac{Q}{Q - it}\right)it + Ae^{-Bit} \tag{2}$$

where E_0 is the constant voltage in Volt, R is internal resistance in Ohm, i is current in Ampere, i^* is filtered current in Ampere, K is polarization constant in Volt (Ampere-hour) or polarization resistance in Ohm, t is time in second, Q is capacity in Ampere-hour, A is exponential voltage in Volt, and B is exponential zone time constant in $(\text{Ah})^{-1}$. The type of battery used is Lithium-Ion, with a capacity of 4900 kWh. The additional information of the usage battery regarding the nominal voltage and rated capacity is 200 V and 24500 Ah, respectively with 30% of initial state of charge and 1 second of battery time response.



(a) PV model (b) Wind turbine model



(c) Biogas generator model (d) Battery model

FIGURE 2. Control design

The battery system controls the SoC, charging, and discharging. The initial condition of the battery will be associated with the charging system and the load system with memory condition 1. The memory condition aims to remember the last events that occurred in the system. When the battery is low or at 80% level with memory condition = 1 which means, the battery is connected to the charging system, and the control system will disconnect the battery from the charging system to stop charging. This condition also changes the memory state to 0 which means there is a discharge condition on the battery, so even if the battery SoC drops to a level of less than 80%, the system will not connect to the charging system because the discharge condition will be carried out until the battery capacity remains 30%. Charging conditions will occur when the battery SoC reaches 30% to 80%.

For load control, the initial condition of the battery will be connected to the load system with memory condition 1. When the battery is low, or the SoC is at 20% level with memory condition = 1 which means the battery was previously connected to the load system, the control system will disconnect the battery from the system, load to stop the use of the battery by the load (discharging). This condition also changes the memory state to 0 which means the battery is disconnected from the load, so even if the SoC rises to a level of less than 25%, it will not connect to the load because it will discharge to 25% battery capacity. Extending the battery life can be done by reducing the battery charging and discharging with load conditions that remain optimally serviced. The load state will be connected to the battery system when the battery SoC reaches a 25% level.

In the wind turbine generator, blade pitch control is used to control the speed before the cut-in speed and reach the rated speed point until the cut-out speed condition. The power generated by the wind is as in (3), and the power generated by the generator is as in (4) [23].

$$P_{wind} = \frac{1}{2} A\rho V^3 \tag{3}$$

$$P_{gen} = P_{wind}\, C_p N_g N_b \tag{4}$$

where A is the cross-sectional area, ρ is the wind density of 1.225 kg/m^3, V is the wind speed, C_p is the performance coefficient with a theoretical maximum of 0.59 Betz limit, N_g is the generator efficiency of 85%, and N_b is the gearbox efficiency of 95%.

The speed control scenario is designed for a wind turbine generator. The wind turbine is not spinning when the wind speed is less than 2 m/s. The wind turbine will rotate when the wind speed is more than 2 m/s to 25 m/s. At wind speeds of 11.5 m/s to 25 m/s, the control system will maintain the wind turbine speed so that the power output will be flat. The characteristics of the wind turbine are as shown in Figure 3. The cut-in system is at a wind speed of 3 m/s until it reaches a rated speed of 11.5 m/s. The control will maintain a wind speed of 11.5 m/s to 25 m/s, so the power output will be flat at 674.8 kW.

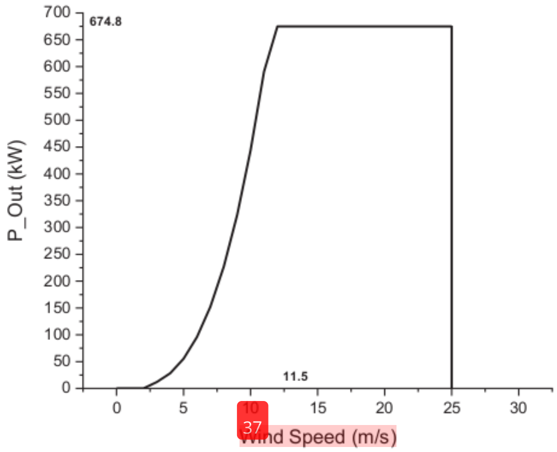


FIGURE 3. Wind turbine characteristics

The hybrid PV, wind, and biogas microgrid models are connected in parallel to the battery and load system. The PV generating capacity is 30 kW, wind generator 1250 kW, biogas generator 1.175 kW, and battery 4900 kWh with a base load of 156 kW and a peak load of 312 kW. In WT, partial control is carried out in the form of installing a limiter that functions to regulate the speed of the WT generator so that the output produced is not over current and over voltage which will affect the efficiency of battery use. The battery system will be disconnected from the charging system when the SoC reaches 90% and recharges when the SoC is at 30%. The load will be disconnected from the battery system when the SoC is below 21% and will be reconnected when the battery SoC is above 25%. The power generated by PV, WT, and biogas plants will be stored in the battery system and distributed to the load. The load served is 400 kW with a base load of 156 kW and a peak load of 312 kW from 17:00 to 22:00. Each generator produces an output voltage of 200 V DC, connected in parallel to the battery system and load. Microgrid hybrid PV, wind, biogas with battery and load are shown in Figure 4.

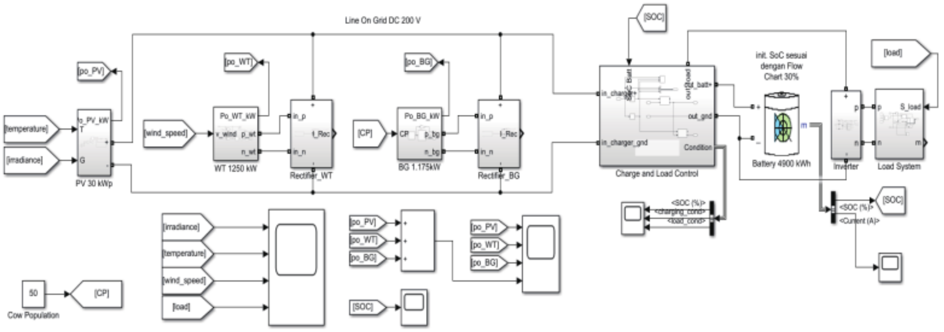


Figure 4. Microgrid hybrid PV, wind, biogas with battery and load

3. Results and Analysis.

In the microgrid hybrid PV, wind, biogas with batteries, and loads are controlled on the wind turbine to increase the efficiency of the battery used. The system can monitor input and load conditions, the power output of each hybrid generator (PV, wind, biogas), battery condition, and load.

3.1. Input monitoring.

Irradiance input, temperature, wind speed, and load are monitored every hour from 00:00 to 23:00. Irradiance and temperature peaked 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 carried out to see the peak load conditions where at the base load, the power consumption is 156 kW, and the peak load power consumption is 312 kW occurring from 17:00 to 21:00. Monitoring input irradiation, temperature, wind speed, and load is shown in Figure 5(a).

3.2. Output power monitoring.

PV peaked at 12:00 with a power output of 20.82 kW, wind output peaked at 14:00 with a power output of 674.82 kW, biogas output with a constant power of 1175 kW, and the total output of the microgrid was 693.87 kW. Monitoring the power output is shown in Figure 5(b).

3.3. SoC, charging and discharging control.

Graph of battery condition on the SoC, charging and discharging battery control monitoring is shown in Figure 5(c). SoC battery is from 30% to 80%. When the SoC is below 30%, the system will automatically carry out the charging process until the battery condition reaches 80%. When the battery condition is at 80% level, the system automatically disconnects the battery with the charging system, and the discharging process will occur until the battery condition is at 30% level.

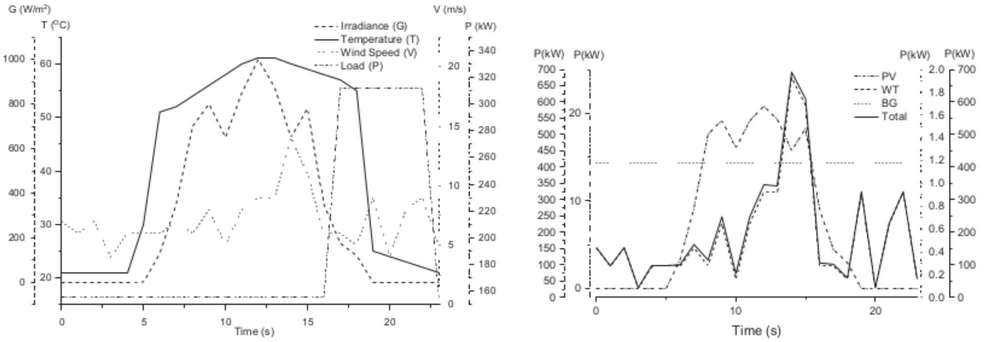
3.4. SoC and load control.

SoC control graph and load is shown in Figure 5(d). When the SoC battery condition is at a 20% level, the battery control system will automatically disconnect the supply to the load (disconnect). The system will automatically connect to the load (connect) when the SoC battery condition is at a level above 25%.

3.5. Analysis.

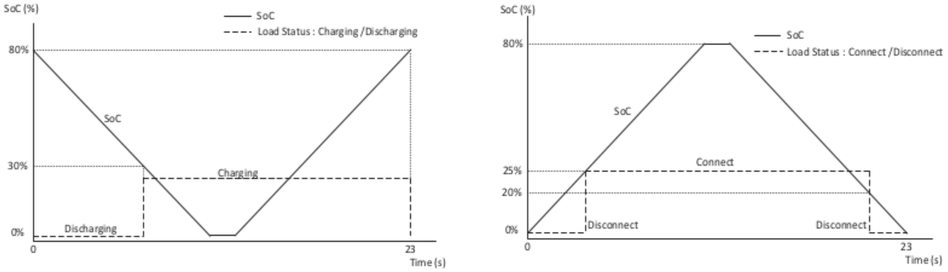
Comparative analysis of the efficiency of battery uses in the same system without using the control obtained differences in the use of battery capacity where in the system without control, it takes a battery with a capacity of 5800 kWh for the energy storage system. In comparison, a system with control only takes a battery with a capacity of 4900 kWh.

Comparative analysis of the efficiency of battery uses in the same system without using the control obtained differences in the use of battery capacity where the system without control requires a battery with a capacity of 5800 kWh for its energy storage system.



(a) Input monitoring

(b) Monitoring power output



(c) SoC, charging and discharging control

(d) SoC and load control

FIGURE 5. Simulation results of microgrid hybrid PV, wind, biogas with battery and load

In comparison, in a controlled system, only a battery with a capacity of 4900 kWh is needed. Analysis of the power output is generated by the generator in an uncontrolled system for a 1217.5 kW peak wind turbine and a total peak power output of 1234 kW microgrid system. While the power generated by the generator in the control system for the peak wind turbine is 674.82 kW, and the total peak power output for the microgrid system is 693.87 kW. The total output power generated by the microgrid with control is smaller than the total output power generated by the uncontrolled microgrid. The total power output generated by the microgrid with control is smaller because the blade pitch control works to regulate the speed of the wind turbine generator so that the power produced is evenly distributed according to the provisions. Partial control of the wind turbine generator has an impact on increasing the efficiency of the battery used in this hybrid microgrid system.

4. **Conclusions.** The hybrid PV/wind/biogas microgrid system with battery and load is designed with a PV generation capacity of 30 kWp, wind 1250 kW, and biogas 1.175 kW. Partial control was carried out on the wind turbine generator and battery control in the form of setting SoC, charging, and discharging to serve a base load of 156 kW and a peak load of 312 kW. The control of the wind turbine generator is in the form of controlling the speed of the wind turbine generator to regulate the output of the wind turbine so as not to over current and over voltage to increase the efficiency of battery use. Control the battery by setting the SoC from 30% to 80%. Emptying the system (connect load) occurs when the SoC is at the 80% level until it reaches the 30% level. At level 30%, the system will automatically fill (disconnect the load). The charging process will occur until the battery level reaches 80%. Charging and discharging settings are intended

to extend battery life by reducing the charging and discharging conditions of the system with optimally serviced load conditions.

The future work of this research is the control design on the side of the biogas generator to increase the production of biogas produced by the generator due to considering the nature of the intermittent solar and wind energy sources and biogas as a backup system. With the design of biogas control as a backup system, the process of discharging the battery to the load can be reduced, so that it will impact the battery life and reduce the capacity of the battery used in the system.

Acknowledgment. This research is a part of the doctoral dissertation and granted with the research scheme of *Penelitian Disertasi Doktor* (PDD) 2022 sponsored by the Ministry of Education, Culture, Research, and Technology of the Republic of Indonesia.

REFERENCES

[1] A. Parida and D. Chatterjee, Stand-alone AC-DC microgrid-based wind-solar hybrid generation scheme with autonomous energy exchange topologies suitable for remote rural area power supply, *International Transactions on Electrical Energy Systems*, vol.28, no.4, pp.1-13, 2018.

[2] G. A. Xavier, J. H. Martins, P. M. B. Monteiro and A. Diniz, Simulation of distributed generation with photovoltaic microgrids – Case study in Brazil, *Energies*, vol.8, no.5, pp.4003-4023, 2015.

[3] P. Hochloff and M. Braun, Optimizing biogas plants with excess power unit and storage capacity in electricity and control reserve markets, *Biomass and Bioenergy*, vol.65, pp.125-135, 2014.

[4] Secretariat General of the National Energy Council, *Indonesia Energy Outlook (IEO)*, 2019.

[5] T. Sarkar, A. Bhattacharjee, H. Samanta, K. Bhattacharya and H. Saha, Optimal design and implementation of solar PV-wind-biogas-VRFB storage integrated smart hybrid microgrid for ensuring zero loss of power supply probability, *Energy Conversion and Management*, vol.191, pp.102-118, 2019.

[6] S. Kewat, B. Singh and I. Hussain, Power management in PV-battery-hydro based standalone microgrid, *IET Renewable Power Generation*, vol.12, no.4, pp.391-398, 2018.

[7] M. S. H. Lipu, S. Ansari, M. S. Miah and K. Hasan, A review of controllers and optimizations based scheduling operation for battery energy storage system towards decarbonization in microgrid: Challenges and future directions, *Journal of Cleaner Production*, vol.360, 132188, 2022.

[8] R. S. Sreeleksmi, A. Ashok and M. G. Nair, A fuzzy logic controller for energy management in a PV-battery based microgrid system, *International Conference on Technological Advancements in Power and Energy (TAP Energy)*, pp.1-6, 2017.

[9] M. M. Ismail, A. F. Bendary and M. Elsisi, Optimal design of battery charge management controller for hybrid system PV/wind cell with storage battery, *International Journal of Power and Energy Conversion*, vol.11, no.4, pp.412-429, 2020.

[10] B. Benlahbib, N. Bouarroudj, S. Mekhilef, D. Abdeldjalil, T. Abdelkrim, F. Bouchafaa and A. lakhdari, Experimental investigation of power management and control of a PV/wind/fuel cell/battery hybrid energy system microgrid, *International Journal of Hydrogen Energy*, vol.45, no.53, pp.29110-29122, 2020.

[11] S. Vasantharaj, V. Indragandhi, V. Subramaniyaswamy, Y. Teekaraman, R. Kuppusamy and S. Nikolovski, Efficient control of DC microgrid with hybrid PV-fuel cell and energy storage systems, *Energies*, vol.14, no.11, 3234, 2021.

[12] A. Kanchanaharuthai and E. Mujjalinvimut, Finite-time command filtered backstepping control design for power systems with superconducting magnetic energy storage system, *International Journal of Innovative Computing, Information and Control*, vol.17, no.3, pp.873-885, 2021.

[13] S. Ishaq, I. Khan, S. Rahman, T. Hussain, A. Iqbal and R. M. Elavarasan, A review on recent developments in control and optimization of micro grids, *Energy Reports*, vol.8, no.4, pp.4085-4103, 2022.

[14] F. Dubuisson, M. Rezkallah, A. Chandra, M. Saad, M. Tremblay and H. Ibrahim, Control of hybrid wind-diesel standalone microgrid for water treatment system application, *IEEE Transactions on Industry Applications*, vol.55, no.6, pp.6499-6507, 2019.

[15] N. Priyadarshi, S. Padmanaban, D. M. Ionel, L. Mihet-Popa and F. Azam, Hybrid PV-wind, microgrid development using quasi-Z-source inverter modeling and control – Experimental investigation, *Energies*, vol.11, no.9, 2277, 2018.

[16] T. Lukasievicz, R. Oliveira and C. Torrico, A control approach and supplementary controllers for a stand-alone system with predominance of wind generation, *Energies*, vol.11, no.2, 411, 2018.

[17] M. A. Ebrahim, H. S. Ramadan and M. Soliman, Robust non-fragile approach to resilient design of PID-based blade pitch control for wind energy conversion system, *Asian Journal of Control*, vol.21, no.4, pp.1-14, 2019.

[18] J. Pahasa and I. Ngamroo, Coordinated control of wind turbine blade pitch angle and PHEVs using MPCs for load frequency control of microgrid, *IEEE Systems Journal*, vol.10, no.1, pp.97-105, 2016.

[19] T. A. Nugroho, R. S. Wijanarko and H. Setiadi, Coordination of blade pitch controller and battery energy storage using firefly algorithm for frequency stabilization in wind power systems, *Telkomnika (Telecommunication Computing Electronics and Control)*, vol.17, no.2, pp.1014-1022, 2019.

[20] W. H. Lio, *Blade-Pitch Control for Wind Turbine Load Reductions*, Springer International Publishing, Cham, Switzerland, 2018.

[21] R. Korthauer, *Lithium-Ion Batteries: Basics and Applications*, Springer Berlin Heidelberg, 2018.

[22] L. H. Saw, K. Somasundaram, Y. Ye and A. A. O. Tay, Electro-thermal analysis of Lithium Iron Phosphate battery for electric vehicles, *Journal of Power Sources*, vol.249, pp.231-238, 2014.

[23] H. F. Mubarak, *Hybrid Wind-Solar Electric Power System*, Bachelor Thesis, University of Khartoum, khartoumspace.uofk.edu, 2013, Accessed on Aug. 04, 2022.

elb-14-04-05_asminar.pdf

ORIGINALITY REPORT

16%	11%	12%	4%
SIMILARITY INDEX	INTERNET SOURCES	PUBLICATIONS	STUDENT PAPERS

PRIMARY SOURCES

1	www.researchgate.net Internet Source	2%
2	www.icicelb.org Internet Source	1%
3	Wind Turbines, 2006. Publication	1%
4	www.mdpi.com Internet Source	1%
5	Isminarti, Syafaruddin, Amil Ahmad Ilham, Ardiaty Arief. "Modeling and Simulation of Long Range (LoRa) Communication System on Smart Grid", 2022 Seventh International Conference on Informatics and Computing (ICIC), 2022 Publication	1%
6	etd.astu.edu.et Internet Source	1%
7	strathprints.strath.ac.uk Internet Source	1%

8	Submitted to Universitas Hasanuddin Student Paper	1 %
9	ijrer.ijrer.org Internet Source	<1 %
10	mafiadoc.com Internet Source	<1 %
11	K. M. Bhargavi, N. S. Jayalakshmi, D. N. Gaonkar, Ashish Shrivastava, Vinay Kumar Jadoun. "A Comprehensive Review on Control Techniques for Power Management of Isolated DC Microgrid System Operation", IEEE Access, 2021 Publication	<1 %
12	M.S. Hossain Lipu, Shaheer Ansari, Md Sazal Miah, Kamrul Hasan et al. "A review of controllers and optimizations based scheduling operation for battery energy storage system towards decarbonization in microgrid: Challenges and future directions", Journal of Cleaner Production, 2022 Publication	<1 %
13	Manoj Datta. "Photovoltaic Output Power Fluctuations Smoothing by Selecting Optimal Capacity of Battery for a Photovoltaic-Diesel Hybrid System", Electric Power Components and Systems, 01/2011 Publication	<1 %

14	Ayas Shaqour, Hooman Farzaneh, Yuichiro Yoshida, Tatsuya Hinokuma. "Power control and simulation of a building integrated stand-alone hybrid PV-wind-battery system in Kasuga City, Japan", Energy Reports, 2020 Publication	<1 %
15	ideas.repec.org Internet Source	<1 %
16	Kanhaiya Kumar, Ganesh B. Kumbhar. "A review on impact of distributed generation and electrical vehicles on aging of distribution transformer", 2017 3rd International Conference on Condition Assessment Techniques in Electrical Systems (CATCON), 2017 Publication	<1 %
17	Submitted to University of Newcastle upon Tyne Student Paper	<1 %
18	scholars.uow.edu.au Internet Source	<1 %
19	Y. Fujino, M. Ito, H. Yamaguchi. "Three-dimensional behavior of galloping in telecommunication cables of figure-8 section", Journal of Wind Engineering and Industrial Aerodynamics, 1988 Publication	<1 %

20	uis.brage.unit.no Internet Source	<1 %
21	Submitted to Victoria University Student Paper	<1 %
22	Wahyu Haryadi Piarah, Zuryati Djafar, Ahmad Salman Rosali, Abdul Halim, Mustofa, Bagus Hayatul Jihad. "The Effect of Copper Coating on the Hot-Side on the Performance of a Thermoelectric Generator Using the Electroforming Method", International Journal of Design & Nature and Ecodynamics, 2022 Publication	<1 %
23	bura.brunel.ac.uk Internet Source	<1 %
24	fr.mathworks.com Internet Source	<1 %
25	Domenico Mazzeo, Nicoletta Matera, Pierangelo De Luca, Cristina Baglivo, Paolo Maria Congedo, Giuseppe Oliveti. "A literature review and statistical analysis of photovoltaic-wind hybrid renewable system research by considering the most relevant 550 articles: an upgradable matrix literature database", Journal of Cleaner Production, 2021 Publication	<1 %
26	akademiabaru.com Internet Source	<1 %

27	jeeeccs.net Internet Source	<1 %
28	macsphere.mcmaster.ca Internet Source	<1 %
29	www.ijarbest.com Internet Source	<1 %
30	Satish Kumar Ramoji, Lalit Chandra Saikia. "Comparative Performance of Multiple Energy Storage Systems in Unified Voltage and Frequency Regulation of Power System Including Electric Vehicles", Energy Storage, 2022 Publication	<1 %
31	Saw, L.H., Y. Ye, and A.A.O. Tay. "Electro-thermal analysis and integration issues of lithium ion battery for electric vehicles", Applied Energy, 2014. Publication	<1 %
32	arc.aiaa.org Internet Source	<1 %
33	link.springer.com Internet Source	<1 %
34	mdpi-res.com Internet Source	<1 %
35	openaccess.iyte.edu.tr Internet Source	<1 %

36	sbu.ac.ir Internet Source	<1 %
37	www.mek.dtu.dk Internet Source	<1 %
38	D.A. Haralambopoulos, Th. Lekkas, G. Haloulakos. "An investigation of wind electricity production to cover the energy needs of a solar evaporation salt plant", Renewable Energy, 1997 Publication	<1 %
39	Tomonori Goya, Eitaro Omine, Tomonobu Senjyu, Motoki Tokudome et al. "Torsional torque suppression of decentralized generators using H∞ observer", 2009 IEEE International Symposium on Industrial Electronics, 2009 Publication	<1 %

Exclude quotes	On	Exclude matches	< 5 words
Exclude bibliography	On		