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Potential microgrid model based on hybrid photovoltaic/wind turbine/generator in the coastal area of North Sumatra

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ABSTRACT

The high potential for renewable energy in the North Sumatra region, especially the coast of the Belawan area, needs to be exploited properly. The design will be carried out to explore the potential in coastal areas by carrying out simulation models of microgrid systems and hybrid system-based electricity installations. The method that will be used is to find the accuracy of strategic location points by considering the weather around the plant. The aim of determining strategic and ideal microgrid installation location points is useful in building a reliable system when fluctuating climate conditions occur so that it will have a significant effect on energy balance and energy conversion. The potential for installation construction will be carried out with a hybrid system using power sources from photovoltaic (PV), wind turbines and diesel generators assisted by HOMER pro software. Real measurement results in the field were obtained for the installation of a hybrid-based microgrid system on PV with a DC output power of 618.80 W with measurements in sunny weather conditions, then the potential wind speed on the wind turbine reached 5 m/s and the potential use of a diesel generator reached 40% with a power output capacity 1 kW.

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1. INTRODUCTION

The high potential for developing renewable energy source installations in the Sumatra region should be exploited appropriately [1]–[3]. This is inseparable from the depletion of fossil fuels in the future and the shift of the world community towards awareness of environmental impacts that are cleaner than pollution [4]–[7]. The most efficient technology is installed according to community needs in meeting current electricity availability with an integrated system in operation and control using a microgrid system [8]–[11]. Then, to develop the electrical power supply to be more optimal, a hybrid system was added, which means it is the most ideal combination in supporting the power increase system and reliability system in the microgrid. [12]–[15]. The coastal area of the city of Medan, especially in the North Sumatra region, is a strategic area if a hybrid model-based microgrid system is installed involving the integration of photovoltaics (PV) sourced from solar energy, wind turbine installations sourced from wind energy and also the installation of diesel generators [16]. Coastal areas include areas that have quite high intensity of sunlight and also have wind speeds which can later be a solution in moving wind turbines continuously [17]–[19]. However, irregular weather fluctuations in the city of Medan based on data from the meteorology climatology and geophysics council (BMKG), have caused the percentage of potential power output of renewable energy installations to decrease. Therefore, the study for the installation was diverted to the point with the most potential, namely the coastal area, for the installation of an integrated hybrid system from renewable energy [20]. The potential impact that will result is the stability of electrical power which is very influential in the use of electrical energy and also the effect of being free from shadows which will make the conversion of energy from the sun more optimal [21]–[23]. The microgrid technology that will be used is compatible with inputting potential local renewable energy resources such as solar and wind power. Then this system will be able to provide distributed generator connectivity as a buffer unit, and the loads are interconnected with each other [24]–[26]. The hybrid microgrid installation system also has advantages in terms of economy and efficiency compared to other microgrid architectures [27], [28]. However, microgrid injection on microgrid performance must be reviewed because it affects the overall dynamic performance of the microgrid [29]–[31]. Then also, it should be noted that with the increasing need for electricity every year and conventional energy reserves getting smaller, it is impossible to depend completely on conventional energy [32]. Therefore, it is necessary to conduct an analysis first on new and renewable energy power plants to find out whether the power plants are efficient and able to replace conventional energy power plants in the future [33]. The potential that will be reviewed is the PV installation system, wind turbine and diesel generator installations carried out in the coastal area of the city of Medan.

2. METHOD

The model simulation will be carried out with 3 power generation system configurations, namely, PV system configuration, wind turbine and diesel generator. Meanwhile, the battery is used as backup storage when there is a voltage drop caused by the intensity of sunlight. The method is carried out by serving in the field using a lux meter, anemometer with validation margin of error testing using an Android application. Then the experimental data is carried out in real time in the field by installing PVs in the coastal zone. In a diesel generator installation, it operates and produces electrical power using fuel injection, with estimates not being the main generator. PV systems and wind turbines are the main energy supply sources for residential areas. The simulation used uses HOMER pro software and for PV energy conversion analysis uses real field data with a PV output power installation of 650 Wp. HOMER Pro software is used to design and simulate microgrid systems with the advantage of being able to estimate the technical feasibility and energy conversion of previous developments in renewable energy production. Simulations using HOMER pro software for microgrid system configuration in the coastal area of Belawan, North Sumatra are shown in Figure 1.

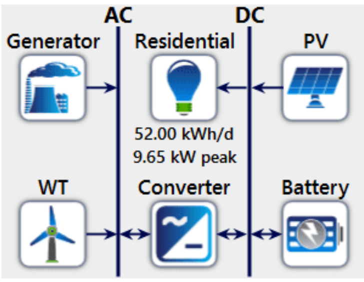


Figure 1. Microgrid system in a hybrid model of renewable electricity generation in coastal areas

3. RESULTS AND DISCUSSION

Configuration and analysis of energy production operating using a renewable energy system with a hybrid integrated microgrid system in coastal areas in North Sumatra, Indonesia. The microgrid system with a hybrid model is research targeting the Belawan area, located on the coast of North Sumatra. In terms of natural resource potential and enriched with the availability of wind and solar power, energy conversion can be carried out optimally. To operate the HOMER pro software simulation, it is necessary to prepare several required data, including load requirement data, weather condition data and technical data for each system component. The tracking location for microgrid sites on the coast of North Sumatra is shown in Figure 2.

Figure 2. Microgrid system tracking location in the coastal region of North Sumatra

3.1. Potential of the Belawan coastal area

The coastal area is a very strategic location in the development and design of integrated microgrid systems. To fulfill the supply of electrical energy and optimize the supply of electrical power, the target area for optimization is the coast of the Belawan area. Simulation design of renewable energy that will be supplied to meet electrical energy needs in coastal areas with alternative energy sources, namely PVs, wind turbines and integrated diesel generators. The research that will be carried out is specifically regarding the use of solar energy to produce maximum electrical energy using solar cells by reviewing the layout position and tilt angle of the PV. Measurements of the tilt angle of the PV panel, the direction of the angle of incidence of the sun, the current and output voltage of the solar cells need to be carried out using spatial solar eclipse simulation. The results of testing the optimal potential intensity of sunlight showed that the maximum intensity of sunlight was from 10.00 am to 03.00 pm. The location of potential points of sunlight intensity on the coast of North Sumatra is shown in Figure 3.

The cartesian coordinate system point location was installed to show accuracy in finding installation points for the proposed Belaewan coastal microgrid system from the five main components of PV, wind turbine, converter and diesel generator while the battery as power storage remains optimal. All integrated components installed are connected via AC or DC bus. This type of demand load is connected to the AC bus for residential loads. Cartesian coordinate system is used to determine the accuracy of microgrid systems and two-dimensional coordinates used to represent points in a flat plane. This coordinate system simulation can determine the position of a point in a flat plane with more optimal accuracy as shown in Figure 4.

Figure 3. Location of potential points of sunlight intensity on the coast of North Sumatra

3.2. Potential sources of solar energy

The importance of measuring solar potential by looking at the intensity of sunlight or measuring the amount of incoming light is needed by simulating the surface temperature of Medan cities and also global irradiation. Using this simulation helps to see the intensity of sunlight in various conditions such as sunny, cloudy and overcast. The accepted temperature for the intensity of solar radiation for the coastal areas of Medan city is almost 40 degrees Celsius, but this temperature will of course affect the energy conversion generated by PVs as shown in Figure 5.

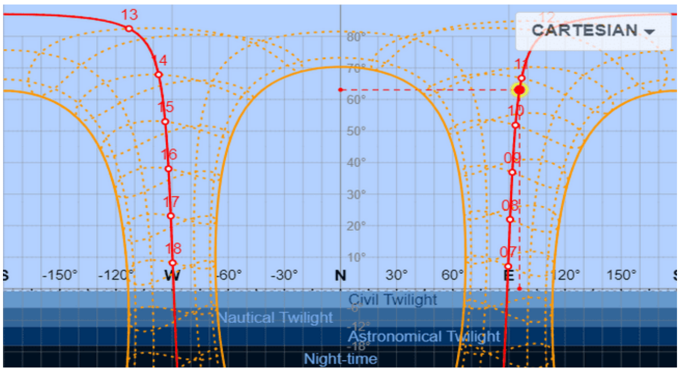


Figure 4. Cartesian coordinate system location point

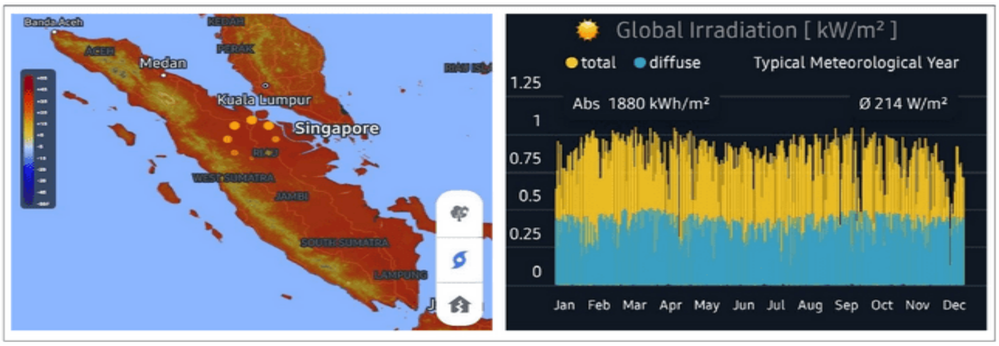


Figure 5. Potential for hot surface temperatures in the coastal area of Belawan, North Sumatra

3.3. Potential speed of wind energy

The drive for a wind turbine requires wind with a vertical axis of rotation or a horizontal axis. The potential for wind energy is very abundant, especially in the coastal areas of Belawan, North Sumatra. This can of course be used as a renewable energy source to fill electricity needs if exploited properly. One of the effects of the number of wind turbine angles on power and coefficient of power (COP) can increase electrical energy conversion d. The measurement results using wind speed simulations are still relatively low with a force reaching 5 m/s. Simulation of test results using a horizontal wind turbine. Figure 6 shows the potential location of wind speed and wind turbine installations in the coastal area of the Belawan area.

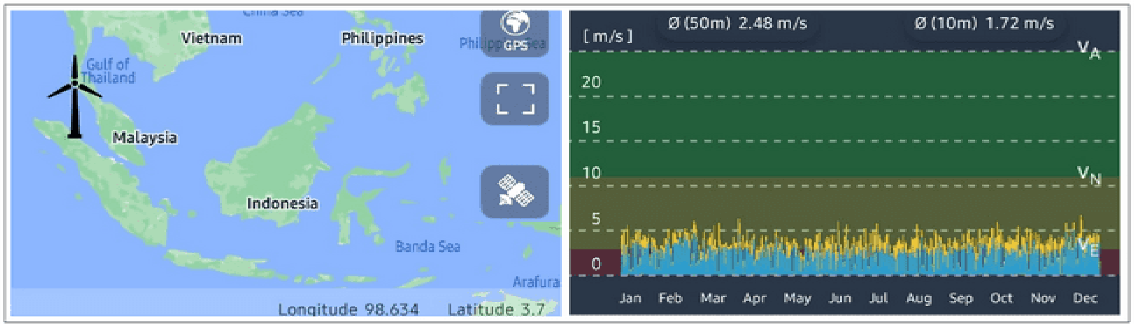


Figure 6. Potential wind speed and wind turbine installation in the coastal area of the Belawan area

3.4. Potential fuel generator installation

Microgrid specifications in the Belawan coastal area use fuel price adjustments with a capacity of 1 kW with an estimated usage of 40% due to prioritizing renewable energy generation. Then the high cost of diesel generators further reduces generator fuel consumption as well as reducing gas emissions to help supply power to the load. Therefore, the design of a hybrid system in a microgrid is a particular choice as a better option than a system using a generator. Diesel generator utilization and fuel efficiency curve are shown in Figure 7.

The use of diesel generators does not reach 100% because it is a supporting factor as a backup electricity source that can be used to meet electricity needs that cannot be met by renewable energy sources. Therefore, the efficiency fuel consumption calculation is calculated using output power estimates for a reference capacity of 1 kW with the application of household electricity supply in the coastal area of Belawan, North Sumatra. The components used in the configuration are analyzed in the utilization of the fuel consumption efficiency curve shown in Figure 8.

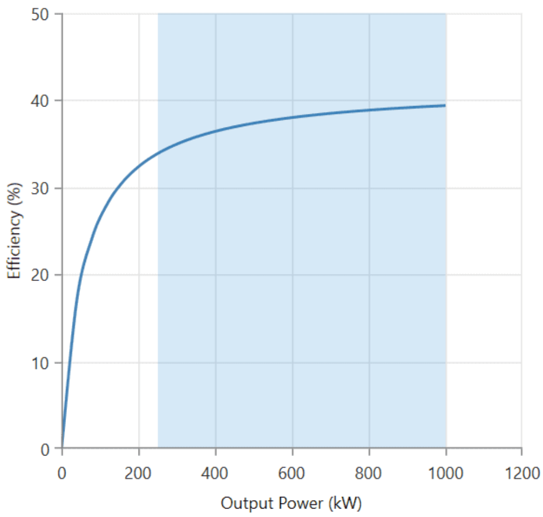


Figure 7. Fuel curve efiiciency

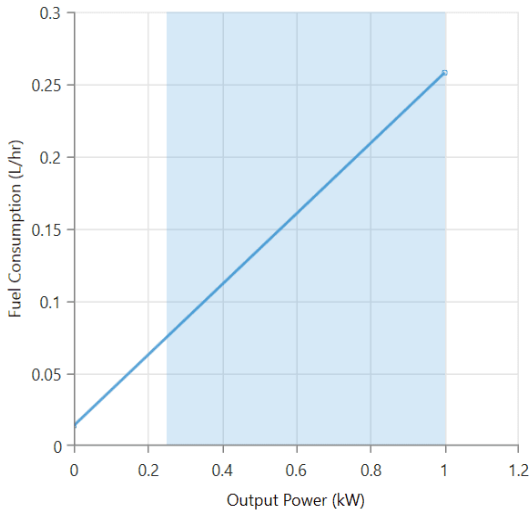
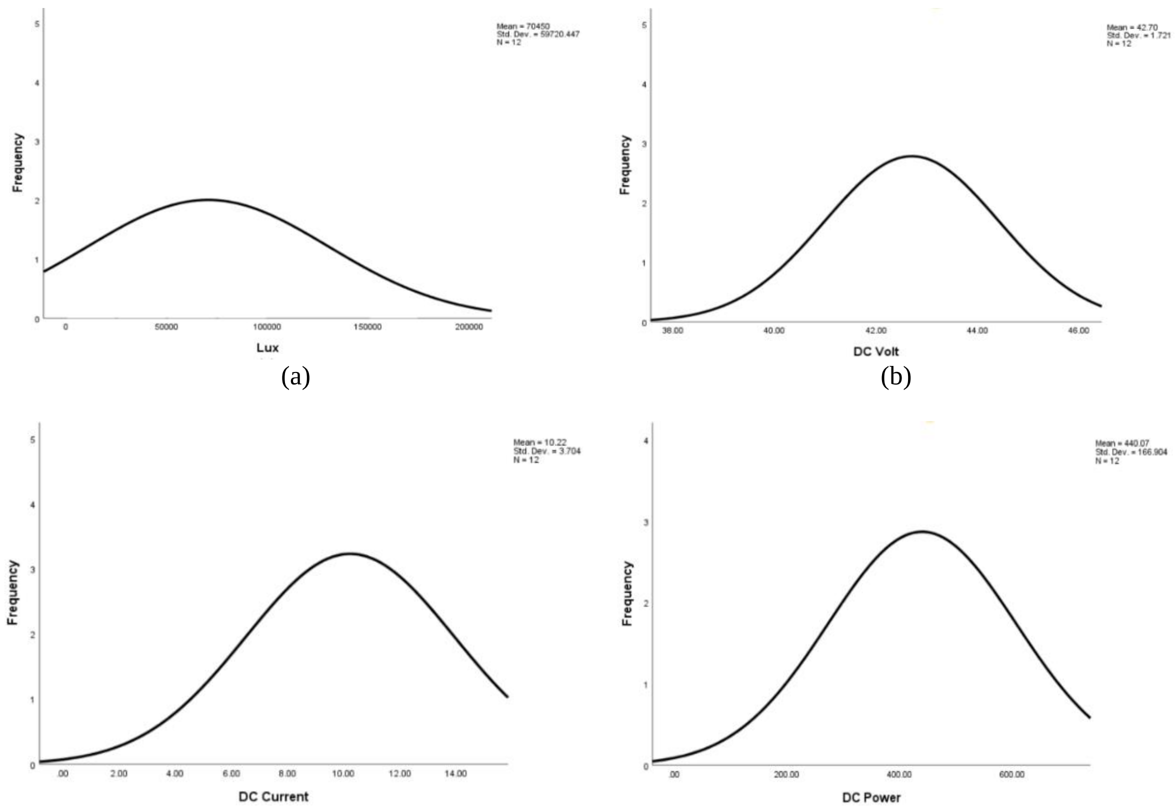


Figure 8. Curve Efficiency fuel consumption

3.5. Photovoltaic energy conversion testing

Retrieving solar energy conversion system data from PVs aims to monitor the conversion and system reliability resulting in a more optimal microgrid system output. The panel used has a capacity of 650 Wp with a polycrystalline type connected in parallel. The optimization system still uses the PV position when conditions are flat. This energy conversion is still not optimal, but the initial research was set with PV conditions at 90^o to the direction of the sun, but later to make the PV installation conditions more optimal, a tracker system will be used and supported by calculating azimuth angles and elevation angles. The data entered is the coordinates of the Belawan Coastal area, North Sumatra, taking into account longitude and latitude. The results of energy conversion in coastal areas using real field measurement data and then converted using assisted applications are shown in Figure 9.

Based on the graph of the accumulated output frequency of PV energy conversion installations in the coastal area of Belawan, North Sumatra, the DC voltage frequency graph in Figure 9(a), the output results from the intensity of sunlight using lux meter reached 162,000 lux. Then in Figure 9(b), when measuring PV conditions in a flat position, the DC voltage output is 45.4 Volts with a standard deviation of 1.72. During the monitoring period, the output voltage on the PV showed irregularities in the coastal areas of the Belawan area due to weather fluctuations. Then the data is displayed as in Figure 9(c). In the current graph, the peak DC current is 13.63 A with a standard deviation of 3.704. For the last image, Figure 9(d), it is a source of energy conversion using maximum conditions occurring at 2.00 pm, amounting to 618.80Watt DC with a standard deviation of 166,904 with flat PV installation conditions. During the monitoring period, the output power of the PV showed irregularities due to climate change, resulting in changes in power caused by sunlight not being focused on the surface of the PV.



(a) (b) (c) (d)

Figure 9. Graph of accumulated output frequency of PV energy conversion installations in the coastal area of Belawan, North Sumatra; (a) frequency of lux meter output, (b) frequency of PV voltage, (c) frequency of PV current, and (d) frequency of PV power

4. CONCLUSION

Based on the potential of the microgrid system by modeling hybrid PVs, wind turbines and diesel generators using simulation results in the HOMER Pro software, the greatest potential is by installing PVs because the intensity of sunlight is very high. This is still in a flat position, where energy conversion should be more optimal by using an active tracking system to find the sun's focal point. Then the potential of wind is also very promising as an energy reserve to supply more electricity loads than diesel generators. The results of real data measurements in the field obtained data for the intensity of sunlight reaching 162,000 lux, measuring PV conditions in a flat position with a DC voltage output of 45.4 Volts with a standard deviation of 1.72, a peak DC current of 13.63 A with a standard deviation of 3.704 and also the output power Maximum conditions occurred at 2.00 pm at 618.80 Watt DC with a standard deviation of 166,904. This is still not optimal because when the sun is perpendicular to the surface of the PV panel, clouds cover the surface of the panel so that peak power is obtained at 2.00 pm which should occur in the time range from 11.00 am to 1.00 pm. The intensity of the wind speed measured in the Belawan coastal area reaches 5 m/s so that the installation of a wind turbine can produce optimal electrical energy.

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REFERENCES

[1] H. Satria, S. Nisworo, J. Windarta, and R. B. Y. Syah, "Performance of single axis tracker technology and automatic battery monitoring in solar hybrid systems," *Bulletin of Electrical Engineering and Informatics*, vol. 12, no. 6, pp. 3247–3255, Dec. 2023, doi: 10.11591/eei.v12i6.5506.

[2] B. Modu, M. P. Abdullah, M. A. Sanusi, and M. F. Hamza, "DC-based microgrid: Topologies, control schemes, and implementations," *Alexandria Engineering Journal*, vol. 70, pp. 61–92, May 2023, doi: 10.1016/j.aej.2023.02.021.

[3] M. W. Altaf, M. T. Arif, S. N. Islam, and M. E. Haque, "Microgrid protection challenges and mitigation approaches-a comprehensive review," *IEEE Access*, vol. 10, pp. 38895–38922, 2022, doi: 10.1109/ACCESS.2022.3165011.
[4] E. T. Sayed *et al.*, "Renewable energy and energy storage systems," *Energies*, vol. 16, no. 3, p. 1415, Feb. 2023, doi: 10.3390/en16031415.
[5] A. G. Olabi and M. A. Abdelkareem, "Renewable energy and climate change," *Renewable and Sustainable Energy Reviews*, vol. 158, p. 112111, Apr. 2022, doi: 10.1016/j.rser.2022.112111.
[6] H. B. Tambunan, N. W. Priambodo, J. Hartono, I. A. Aditya, M. Triani, and Rasgianti, "Research trends on microgrid systems: a bibliometric network analysis," *International Journal of Electrical and Computer Engineering*, vol. 13, no. 3, pp. 2529–2545, Jun. 2023, doi: 10.11591/ijece.v13i3.pp2529-2545.
[7] T. Meenual and P. Usapein, "Microgrid policies: a review of technologies and key drivers of Thailand," *Frontiers in Energy Research*, vol. 9, Mar. 2021, doi: 10.3389/fenrg.2021.591537.
[8] M. Ahmed, L. Meegahapola, A. Vahidnia, and M. Datta, "Stability and control aspects of microgrid architectures-a comprehensive review," *IEEE Access*, vol. 8, pp. 144730–144766, 2020, doi: 10.1109/ACCESS.2020.3014977.
[9] D. E. Olivares *et al.*, "Trends in microgrid control," *IEEE Transactions on Smart Grid*, vol. 5, no. 4, pp. 1905–1919, Jul. 2014, doi: 10.1109/TSG.2013.2295514.
[10] K. Gao, T. Wang, C. Han, J. Xie, Y. Ma, and R. Peng, "A review of optimization of microgrid operation," *Energies*, vol. 14, no. 10, p. 2842, May 2021, doi: 10.3390/en14102842.
[11] D. Akinyele, E. Olabode, and A. Amole, "Review of fuel cell technologies and applications for sustainable microgrid systems," *Inventions*, vol. 5, no. 3, pp. 1–35, Aug. 2020, doi: 10.3390/inventions5030042.
[12] B. Dey, S. Misra, and F. P. Garcia Marquez, "Microgrid system energy management with demand response program for clean and economical operation," *Applied Energy*, vol. 334, p. 120717, Mar. 2023, doi: 10.1016/j.apenergy.2023.120717.
[13] Z. Ullah *et al.*, "Implementation of various control methods for the efficient energy management in hybrid microgrid system," *Ain Shams Engineering Journal*, vol. 14, no. 5, p. 101961, May 2023, doi: 10.1016/j.asej.2022.101961.
[14] M. H. Alabdullah and M. A. Abido, "Microgrid energy management using deep Q-network reinforcement learning," *Alexandria Engineering Journal*, vol. 61, no. 11, pp. 9069–9078, Nov. 2022, doi: 10.1016/j.aej.2022.02.042.
[15] H. Satria, R. Syah, N. A. Silviana, and Syafii, "Sensitivity of solar panel energy conversion at sunrise and sunset on three weather fluctuations in equatorial climate," *International Journal of Electrical and Computer Engineering*, vol. 13, no. 3, pp. 2449–2458, Jun. 2023, doi: 10.11591/ijece.v13i3.pp2449-2458.
[16] A. S. Madona and Y. Nora, "Development of an interactive multimedia-based IPS module for grade IV elementary school students (in Indonesian)," *Jurnal Pelangi*, vol. 8, no. 2, Jun. 2016, doi: 10.22202/jp.2016.v8i2.1048.
[17] A. P. Abidoye and B. Kabaso, "Energy-efficient hierarchical routing in wireless sensor networks based on fog computing," *Eurasip Journal on Wireless Communications and Networking*, vol. 2021, no. 1, p. 8, Dec. 2021, doi: 10.1186/s13638-020-01835-w.
[18] S. Ali, Z. Zheng, M. Aillerie, J. P. Sawicki, M. C. Péra, and D. Hissel, "A review of dc microgrid energy management systems dedicated to residential applications," *Energies*, vol. 14, no. 14, p. 4308, Jul. 2021, doi: 10.3390/en14144308.
[19] A. A. Kumar and N. A. Prabha, "A comprehensive review of DC microgrid in market segments and control technique," *Heliyon*, vol. 8, no. 11, p. e11694, Nov. 2022, doi: 10.1016/j.heliyon.2022.e11694.
[20] M. Mungkin, H. Satria, D. Maizana, M. Isa, Syafii, and M. Y. Puriza, "Analysis of the feasibility of adding a grid-connected hybrid photovoltaic system to reduce electrical load," *International Journal of Power Electronics and Drive Systems*, vol. 14, no. 2, pp. 1160–1171, Jun. 2023, doi: 10.11591/ijpeds.v14.i2.pp1160-1171.
[21] Y. Jia, P. Wen, Y. Yan, and L. Huo, "Joint operation and transaction mode of rural multi microgrid and distribution network," *IEEE Access*, vol. 9, pp. 14409–14421, 2021, doi: 10.1109/ACCESS.2021.3050793.
[22] J. P. C. Silveira, P. J. dos Santos Neto, B. C. Moura, E. R. Filho, and T. A. dos S. Barros, "Power management with BMS to modified interlinking converter topology in hybrid AC/DC microgrid," *Energy Reports*, vol. 9, pp. 1743–1765, Dec. 2023, doi: 10.1016/j.egyr.2022.12.082.
[23] S. A. Shezan *et al.*, "Effective dispatch strategies assortment according to the effect of the operation for an islanded hybrid microgrid," *Energy Conversion and Management: X*, vol. 14, p. 100192, May 2022, doi: 10.1016/j.ecmx.2022.100192.
[24] A. Muhtadi, D. Pandit, N. Nguyen, and J. Mitra, "Distributed energy resources based microgrid: review of architecture, control, and reliability," *IEEE Transactions on Industry Applications*, vol. 57, no. 3, pp. 2223–2235, May 2021, doi: 10.1109/TIA.2021.3065329.
[25] Y. Huang, G. Li, C. Chen, Y. Bian, T. Qian, and Z. Bie, "Resilient distribution networks by microgrid formation using deep reinforcement learning," *IEEE Transactions on Smart Grid*, vol. 13, no. 6, pp. 4918–4930, Nov. 2022, doi: 10.1109/TSG.2022.3179593.
[26] İ. Çetinbaş, B. Tamyürek, and M. Demirtaş, "Design, analysis and optimization of a hybrid microgrid system using HOMER software: Eskişehir osmangazi university example," *International Journal of Renewable Energy Development*, vol. 8, no. 1, pp. 65–79, Feb. 2019, doi: 10.14710/ijred.8.1.65-79.
[27] S. K. Sahoo, A. K. Sinha, and N. K. Kishore, "Control techniques in AC, DC, and hybrid AC-DC microgrid: a review," *IEEE Journal of Emerging and Selected Topics in Power Electronics*, vol. 6, no. 2, pp. 738–759, Jun. 2018, doi: 10.1109/JESTPE.2017.2786588.
[28] M. Warneryd and K. Karltorp, "Microgrid communities: disclosing the path to future system-active communities," *Sustainable Futures*, vol. 4, p. 100079, 2022, doi: 10.1016/j.sftr.2022.100079.
[29] L. Che, M. Shahidehpour, A. Alabdulwahab, and Y. Al-Turki, "Hierarchical coordination of a community microgrid with AC and DC microgrids," *IEEE Transactions on Smart Grid*, vol. 6, no. 6, pp. 3042–3051, Nov. 2015, doi: 10.1109/TSG.2015.2398853.
[30] E. Bullich-Massagué, F. Díaz-González, M. Aragüés-Peñalba, F. Girbau-Llistuella, P. Olivella-Rosell, and A. Sumper, "Microgrid clustering architectures," *Applied Energy*, vol. 212, pp. 340–361, Feb. 2018, doi: 10.1016/j.apenergy.2017.12.048.
[31] W. Yang, X. Kang, X. Wang, and M. Wang, "MPC-based three-phase unbalanced power coordination control method for microgrid clusters," *Energy Reports*, vol. 9, pp. 1830–1841, Dec. 2023, doi: 10.1016/j.egyr.2022.12.079.
[32] Mansur, S. Manjang, A. Arief, and Y. S. Akil, "Optimal hybrid renewable energy generation planning based on BSG-starcraft radius particle swarm optimization," *Przeglad Elektrotechniczny*, vol. 99, no. 2, pp. 82–87, Feb. 2023, doi: 10.15199/48.2023.02.13.
[33] Z. Liu, X. Xu, H. A. Abdelsalam, and E. Makram, "Power system harmonics study for unbalanced microgrid system with PV sources and nonlinear loads," *Journal of Power and Energy Engineering*, vol. 03, no. 05, pp. 43–55, 2015, doi: 10.4236/jpee.2015.35004.

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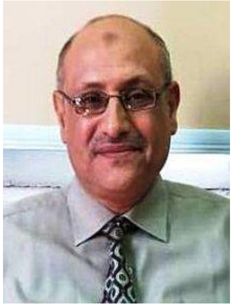

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