Performance of a Portable Small Hybrid Renewable Power Plant

1st Ramadoni Syahputra
Department of Electrical Engineering
Universitas Muhammadiyah Yogyakarta
Yogyakarta, Indonesia
E-mail: ramadoni@umy.ac.id

2nd Yudha Agung Subarkah
Department of Electrical Engineering
Universitas Muhammadiyah Yogyakarta
Yogyakarta, Indonesia
E-mail: yudha.agungsubarkah@gmail.com

3rd Kunnu Purwanto
Department of Electrical Engineering
Universitas Muhammadiyah Yogyakarta
Yogyakarta, Indonesia
E-mail: kunnu_p@umy.ac.id

4th Indah Soesanti
Department of Electrical and Information Engineering
Universitas Gadjah Mada
Yogyakarta, Indonesia
E-mail: indahsoesanti@ugm.ac.id

2022 2nd International Conference on Electronic and Electrical Engineering and Intelligent System (ICE3IS) | 978-1-6654-6541-0/22/$31.00 ©2022 IEEE | DOI: 10.1109/ICE3IS56585.2022.10010317

***Abstract*— The popularity of energy is getting higher as the availability of fuel oil, and coal is running low and environmental issues are getting stronger. Two potential renewable energy sources in Indonesia are solar and hydro energy. Utilization of solar and hydro energy can be carried out simultaneously to serve small temporary electrical loads. Therefore, this study designed a portable hybrid solar and micro hydro power plant. The portable nature that is easy to carry and move according to the needs is the novelty and essential contribution of this research. This power plant, with a maximum capacity of 1100 watts, can be used in open areas with irrigation canals, ditches, or small rivers. Rice fields with irrigation canals or small rivers are suitable locations for the application of this power plant. In modern agriculture, it is necessary to supply electricity for lights that are useful for eradicating insect pests. Electrical energy can also be used to pump water in rice fields. The designed hybrid power plant has been tested in a natural environment. The test results have shown adequate power plant performance as an essential solution to supply small-scale electricity loads while promoting environmentally friendly energy.**

Keywords—Solar PV energy, hydro energy, hybrid system, portable power plant

I. INTRODUCTION

Depleting fossil fuel reserves and increasingly vital environmental issues are the causes of the increasing popularity of renewable energy in recent times. The use of fossil energy sources on a large scale, such as oil, natural gas, and coal, is a severe threat facing the world today [1]-[2]. The resulting impact is the decreasing availability of fossil fuels and carbon emissions that cause environmental damage [3]-[4]. Dependence on conventional or fossil energy will not last long because it is expected to run out in the next few decades, so it is necessary to switch conventional or fossil energy to non-fossil energy, which is called renewable energy sources [5]-[6]. Solar and hydro are two renewable energy sources abundant in Indonesia [7]-[9]. This potential should be utilized to develop power generation technology so that dependence on fossil energy can be further reduced [10]-[11].

In this research, the design and performance test of a hybrid power plant based on micro-hydro and solar was carried out. This hybrid power plant utilizes irrigation canals or small rivers located in the open so that the power plant can utilize water and solar energy at the same time. The nature of this hybrid power plant is portable, so it can be easily carried and moved as needed. The need for electrical energy in rice fields is one of the critical applications of this power plant.

Several studies related to micro-hydro and solar power plants have been carried out by other researchers, which are used as reference materials in the development of this research, among the studies conducted by researchers in [12]. They conducted research on planning a grid-connected hybrid power plant with a case study in Kebumen, Central Java province, Indonesia. This research aims to plan a hybrid power generation system model with the help of HOMER software based on environmentally friendly renewable energy as an alternative energy source to reduce the use of fossil fuels. The method used in this research is the descriptive method. The results of this study are the energy production of the two plants, namely 1,301,169 kWh per year, the lowest total NPC is -$941,597, the cost of electricity generation (COE) is -$0,056/kWh with energy production from full PV for one year.

In [13] and [14], research on the design and construction of micro-hydro power plants for hybrid power plants based on hydro and solar energy was conducted. This research aims to determine and choose what components are used, the power capacity, and the performance of the MHP system for hybrid power plants based on water and solar energy. The method used is to design and measure the electrical power generated. The results obtained are that the MHP was built with a measurable design discharge of 0.075 m3/s using a generator with a capacity of 100VA, and the generator output was measured using a load of 100 watts. The measurement results obtained, the maximum power capacity of the generator is 86 watts. The generator can only run for about 1 hour and then stop. This fact is caused by garbage disturbance in the turbine.

In [15], the design of a portable micro hydro power plant has been created. The purpose of this research is to become research material for the construction of power plants in irrigation canals, where the construction of power plants in irrigation canals can meet electricity needs in areas that are difficult to reach. The method is to design and measure variations in water discharge and electrical power produced. The results show that the potential hydro power in irrigation canals in Bantul is 179 watts. The research can be developed with other renewable energy power plants such as solar or wind power.

II. Methods

In this study, the design and testing of a small hybrid renewable power plant were carried out. The hybrid power plant is based on hydro and solar power. The hybrid power plant components consist of a hydro turbine and dc generator with a capacity of 900 watts, two solar panels with a capacity of 100 watt-peak each, a solar charge controller with a capacity of 20 amperes, a battery with a capacity of 100 Ah, an inverter with a capacity of 1500 watts, and an electrical load. The electrical loads used are LED lights and electric motors. This LED light load is intended to match the actual application in the rice fields. In rice fields, this power plant can be used to supply LED lights. This LED light serves to catch insect pests that often attack rice fields. The electric motor's load is intended to simulate if it is used to pump water in rice fields. Figure 1 shows this study's small hybrid renewable power plant schematic diagram.

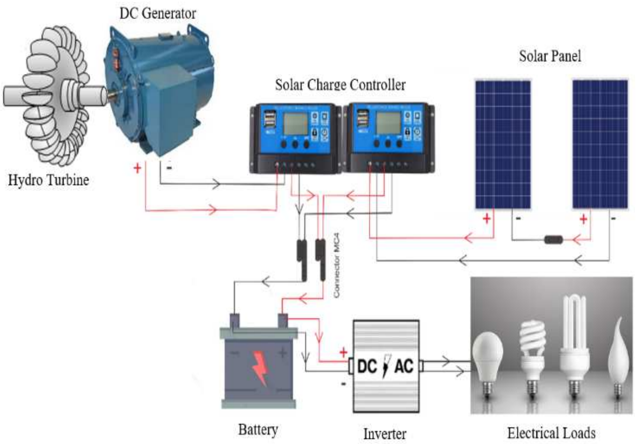

Fig. 1. Small hybrid renewable power plant schematic diagram.

Fig. 2. Testing of a small hybrid renewable power plant in an irrigation canal

Fig. 3. Location of a small hybrid renewable power plant testing (*source: Google Maps*)

In order to test the performance of a small hybrid renewable power plant, this study tested its performance in the actual environment. The test location is in Tamantirto village, Bantul, Indonesia. Figure 2 shows the situation of testing a small hybrid renewable power plant in an irrigation canal. Location of a small hybrid renewable power plant testing was shown in Figure 3.

III. Results and Discussion

The research results, which are direct experiments on the actual environment, are described comprehensively in this section. The research results described in this section include solar energy potential, hydro energy potential, and hybrid power plant performance, which includes solar panel output voltage, dc generator output voltage at micro hydro generators, and dc generator output power at micro hydro plants.

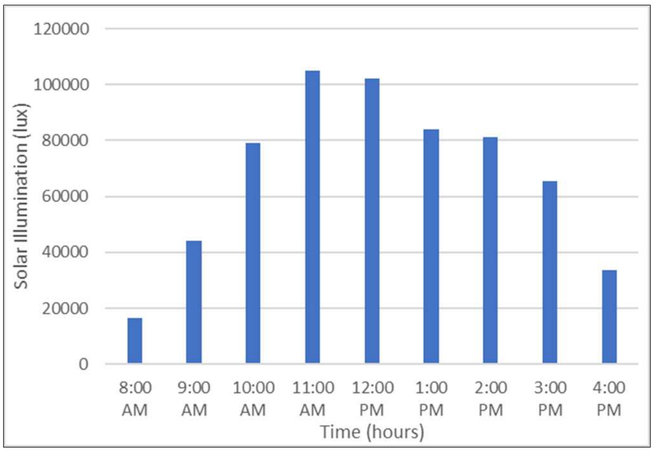

Fig. 4. Solar illumination in location of a small hybrid renewable power plant testing.

Figure 4 shows solar illumination in a small hybrid renewable power plant testing location. The solar illumination measured in lux was observed for six days. Every day, observations started at 8 AM and ended at 4 PM, with data collection intervals every hour. Observations, as shown graphically in Figure 4, show that at 8 AM, the solar illumination was 18,432 lux. Illumination at this time is the lowest value obtained during the measurement because the exposure to sunlight is still low in the morning. The highest illumination was obtained at 11 AM, which was 104,345 lux.

An hour later, the solar illumination decreased slightly because the weather was rather cloudy at the time of measurement. Furthermore, observations were made every hour and ended with measurements at 4 PM. The results of observations in the last hour obtained 32,213 lux.

The next step is to measure the flow rate of irrigation water at the research site. The irrigation channel, the test location for this hybrid power plant, comes from the Bedog river in Tamantirto village, Bantul, Indonesia. In order to obtain valid results, two measurement methods were carried out. The two methods are manual measurement using a stopwatch and a ping pong ball, and a flowmeter measuring instrument. The water flow measured in m/s was observed for six days. Every day, observations started at 8 AM and ended at 4 PM, with data collection intervals every hour. The results of measurements manually and using a flowmeter are shown in Figure 5.

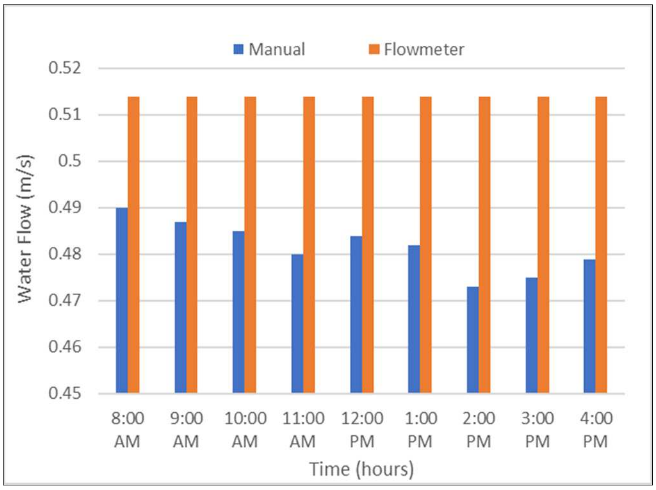

Fig. 5. Hydro water flow in location of a small hybrid renewable power plant testing.

Figure 5 shows differences in the results of measuring the flow rate of irrigation water using the manual method and a flowmeter. The measurements using a flowmeter obtained data on the flow rate of irrigation water, which is relatively constant, namely 0.514 m/s. Manually measuring the water flow rate produces data that varies, from the first measurement at 8 AM to 4 PM. The highest water flow rate occurs at 8 AM, which is 0.490 m/s, while the lowest water flow rate occurs at 2 PM, which is 0.473 m/s. Based on the manual measurement data, the average water flow rate is 0.484 m/s.

This water flow rate data is essential information to determine the water discharge in the irrigation canal, which is the location of this research. The average water discharge is 4.9325 m3/s. Based on this water discharge data, the potential electrical energy that can be obtained from the irrigation canal can be estimated.

The following procedure measures the output voltage of a small hybrid renewable power plant. The output voltage of solar panels and dc generators from micro hydro generators is measured separately. The output voltage of the solar panel of a small hybrid renewable power plant is shown graphically in Figure 6. In contrast, the result of measuring the output voltage of a dc generator from a micro-hydro is shown in Figure 7.

Figure 6 shows that the output voltage of two solar panels with a total capacity of 200 watt-peak varies from 8 AM to 4 PM. The lowest voltage occurs at 8 AM, 38.3 volts, while the highest voltage occurs at 11 AM, which is 42.4 volts. The output voltage of the solar panel after the 11 o'clock measurement decreased according to the intensity of solar light hitting the solar panel. This continued until the afternoon. The results of the measurement of the solar panel output voltage follow the solar illumination data, as shown in Figure 4. The two solar panels used in this study are connected in series so that the output voltage is the accumulation of the output voltage of each solar panel.

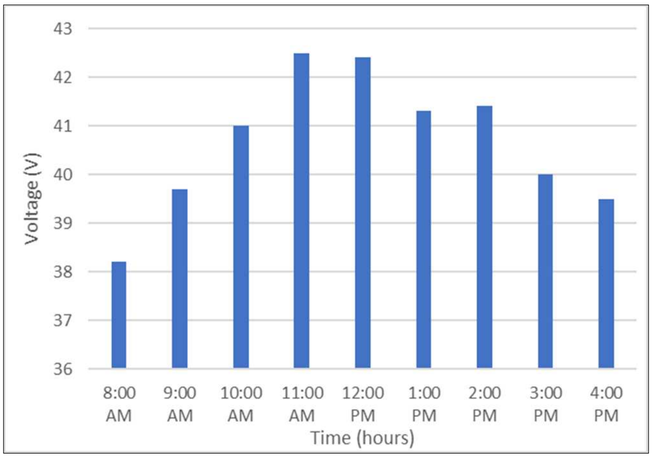

Fig. 6. The output voltage of solar panel of a small hybrid renewable power plant.

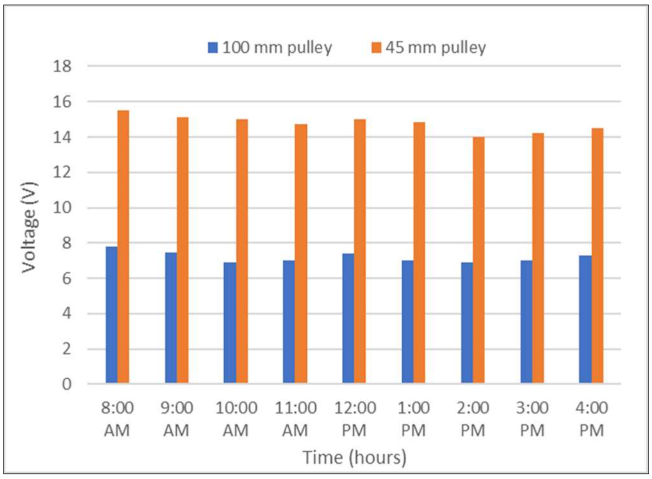

Fig. 7. The output voltage of dc generator of a small hybrid renewable power plant.

In Figure 7, it can be seen that there are two sizes of pulleys that are applied to the micro hydro turbine to rotate the generator, namely pulleys measuring 100 mm and 45 mm. Similar to the measurement of the solar panel's output voltage, the output voltage of the dc generator at the micro hydro power plant is also carried out from 8 AM to 4 PM with a measurement interval of 1 hour. The measurement results show that the generator output voltage using a 45 mm pulley is higher than the generator using a 100 mm pulley. This fact is caused by the rotation of the generator on the 45 mm pulley, which is faster than the 100 mm pulley. This faster rotation results in a higher output voltage, as shown in Figure 7. The highest output voltage with a 100 mm pulley is

7.8 volts which occurs at 8 AM, while the lowest voltage occurs at 2 AM, which is 6.9 volts. . This output voltage is in line with manual water flow rate measurements, where the higher the water flow rate, the faster the micro-hydro turbine purists which result in a higher generator output voltage. Corresponding results were obtained from voltage measurements with a 45 mm generator pulley. The results of the higher average voltage compared to the 100 mm pulley generator are also shown in Figure 7. The highest voltage was also obtained at 8 AM, 15.4 volts, when the water flow rate was 0.490 m/s. Meanwhile, the lowest voltage was obtained at 2 AM, which was 14.0 volts, at which time the flow rate of irrigation water was 0.473 m/s.

Based on the results of this study, it can also be seen that the average voltage produced by a dc generator using a 100 mm pulley for one day is 7.2 volts. This output voltage is lower than that of a dc generator that uses a 45 mm pulley. The average voltage using a 45 mm pulley is 14.8 volts. This fact shows that the 45 mm pulley produces approximately double the output voltage compared to the 100 mm pulley.

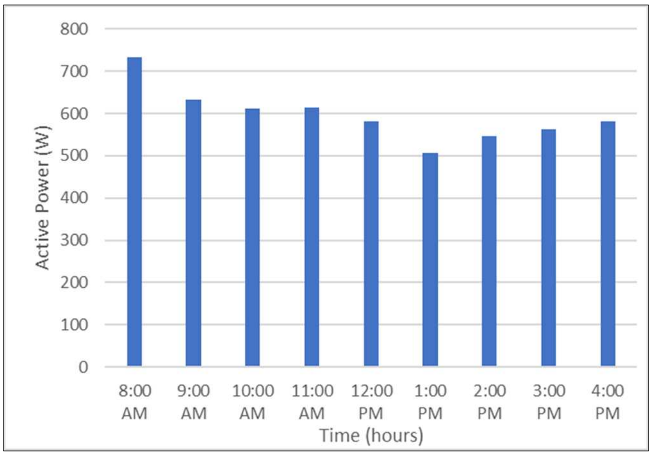

Fig. 8. The output power of dc generator of a small hybrid renewable power plant.

The last performance test of a portable small hybrid renewable power plant is testing its output power. The measurement of this output power is determined by the electrical load carried by it. In this research, the output power performance test is measured based on the output voltage of the dc generator that goes to the solar charge controller and the electric current that passes through it. In this case, this process involves charging the battery, which requires a large amount of electric power to charge it fully.

Based on the observations as shown in Figure 8, the highest output power of the dc generator is 732 watts which occurs at 8 AM, while the lowest power is 500 watts which occurs at 1 PM. The result of observing the electrical power output of the dc generator from the micro hydro power plant shown in Figure 8 is a generator with a 45 mm pulley. This is because a 45 mm pulley generator produces a higher output power than a generator with a 100 mm pulley. Therefore, this paper shows that the best results are obtained using a 45 mm pulley only. The generator's output power in this study is influenced by the flow rate of water and the charging current in the battery, which is the burden of this renewable energy power plant—the prominent charging current causes the measured generator power output to be significant as well.

IV. Conclusion

In order to test the performance of a micro-hydro and solar-based hybrid power plant. Performance tests were carried out for six days in a natural environment. The test location is the irrigation canal of Tamantirto village, Bantul district, the province of the Special Region of Yogyakarta, Indonesia. The performance test of this power plant is observed separately, whereas the output of micro-hydro and solar power plants is measured separately. The results of measuring the electrical power output of a micro-hydro power plant with a pulley generator measuring 100 mm for six days is 459 watts, while for a pulley generator measuring 45 mm, it is 588 watts.

Furthermore, observations were made on measuring the performance of solar power plants. The measurement results for six days obtained that the average power of two solar panels with a total capacity of 200 watts-peak is 165 watts. The test, which was conducted from 8 AM to 4 PM, produced a reasonably optimal electrical power with an average sunlight intensity of 67923 lux. The intensity of sunlight produces an average solar panel output voltage of 35.5 volts.

Based on the test results, the micro-hydro and solar-based hybrid power plants designed in this study can generate higher power with a combination of solar power plants and micro-hydro generators with a pulley size of 45 mm, where the total electrical power generated is 732 watts.

Acknowledgment

The authors express their deepest gratitude to the DRTPM Directorate General of Higher Education, Research, and Technology of the Ministry of Education, Culture, Research, and Technology for providing funding support for this research.

References

[1] Alhasibi, R.A, A. Kurniawan, and Yusmar. Challenges and Strategies to Reduce Cost of Production in Isolated Electricity Systems with Optimization of Renewable Energy at Central Sulawesi, 2020 International Conference on Technology and Policy in Energy and Electric Power (ICT-PEP), 23-24 Sept. 2020.

[2] I.A. Ayad, E. Elwarraki, and M. Baghdadi, “Intelligent Perturb and Observe Based MPPT Approach Using Multilevel DC-DC Converter to Improve PV Production System,” Journal of Electrical and Computer Engineering, vol. 2021, pp. 1-13, 2021.

[3] Ardiyanto, Y., I.T Sujoko, W.A. Wibowo, V.D.H. Nugraha, and F.E. Saputra. Prototype Design of Unmanned Surface Ship to Detect Illegal Fishing Using Solar Power Generation Technology, Journal of Electrical Technology UMY, Vol 3, No 1 (2019), pp. 14-18.

[4] S.D. Al-Majidiab, M.F. Abboda, and H.S. Al-Raweshidya, "A novel maximum power point tracking technique based on fuzzy logic for photovoltaic systems," International Journal of Hydrogen Energy, vol. 43, no. 31, 2018, pp. 14158-14171.

[5] Munawer, Perancangan dan Pembangunan Pembangkit Listrik Tenaga Mikrohidro Untuk Pembangkit Listrik Tenaga Hibrid Berbasis Energi Air dan Surya, Skripsi S1 Program Studi Pendidikan Teknik Elektro, FPTK, Universitas Pendidikan Indonesia, 2017.

[6] A. Ali, K. Almutairi, S. Padmanaban, V. Tirth, S. Algarni, K. Irshad, S. Islam, M.H. Zahir, M. Shafiullah, and M.Z. Malik, “Investigation of MPPT Techniques Under Uniform and Non-Uniform Solar Irradiation Condition–A Retrospection,” IEEE Access, vol. 8, 2020.

[7] Nur Azizah, A., & Purbawanto, S. Perencanaan Pembangkit Listrik Tenaga Hibrid (PV dan Mikrohidro) Terhubung Grid (Studi Kasus

Desa Merden, Kecamatan Padureso, Kebumen), Jurnal Listrik, Instrumentasi, dan Elektronika Terapan, Vol 2, No. 1, 2021.

[8] M. Mohammadinodoushan, R. Abbassi, H. Jerbi, F.W. Ahmed, H.A.K. Ahmed, and A. Rezvani, "A new MPPT design using variable step size perturb and observe method for PV system under partially shaded conditions by modified shuffled frog leaping algorithm- SMC controller," Sustainable Energy Technologies and Assessments, vol. 45, 2021, p. 101056.

[9] Sirad, M.A.H. Analysis of the Potential of Renewable Energy in South Sulawesi as Power Electrical Needs, Journal of Electrical Technology UMY, Vol 1, No 4 (2017), pp. 196-201.

[10] Solihat, I. Rancang Bangun Prototipe Pembangkit Listrik Tenaga Mikrohidro (PLTMH), Jurnal Inovasi Ilmu Pengetahuan dan Teknologi, Vol. 1, No. 2, 2020.

[11] Suripto, S., R.A. Al Hasibi, R.O. Wiyagi, Sanupal, Y. Jusman, and D. Aribowo. Analysis of the Utilization of Putri Cempo Landfill Waste for Power Plants and Their Effects on the Surakarta Electric Power Distribution Network, Journal of Electrical Technology UMY, Vol 3, No 4 (2019), pp. 125-134.

[12] Suyono, H., M. Shidiq, A.N. Ferdianzah, T. Utomo, I. Musirin, and L.J. Awalin. Dynamic Stability Impact of the Hybrid Wind and Microhydro Renewable Energy Sources on the Distribution System, 2018 Electrical Power, Electronics, Communications, Controls and Informatics Seminar (EECCIS), 9-11 Oct. 2018.

[13] Syahputra, R., and I. Soesanti. Planning of Hybrid Micro-Hydro and Solar Photovoltaic Systems for Rural Areas of Central Java, Indonesia, Journal of Electrical and Computer Engineering, 2020.

[14] Gunawan, L.A., Agung, A.I., Widyartono, M., dan Haryudo, S.I. Rancang Bangun Pembangkit Listrik Tenaga Surya Portable, Jurnal Teknik Elektro, Vol. 10, No. 1, 2021.

[15] Tri Atmojo, S. Perancangan Pembangkit Listrik Tenaga Micro Hydro Portable, Skripsi S1 Program Studi Teknik Elektro Fakultas Teknik, Universita Muhammadiyah Yogyakarta, 2021.