DESIGN AND DEVELOPMENT OF A HYBRID SYSTEM FOR PICOHYDRO POWER PLANT AND SOLAR POWER PLANT

Yosi Apriani
Electrical Engineering, Universitas Muhammadiyah Palembang, Indonesia
yosi_apriani@um-palembang.ac.id

Soni Andika Pratama
Electrical Engineering, Universitas Muhammadiyah Palembang, Indonesia
sonyandikapratama23@gmailcom

Marliyus Sunarhati
Electrical Engineering, Universitas Palembang, Indonesia
marlius@gmail.com

Zulkiffli Saleh
Electrical Engineering, Universitas Muhammadiyah Palembang Indonesia
zulkifflisaleh64@gmail.com

Ian Mochamad Sofian
Polteknik Pelayaran Banten, Indonesia
ianmsof@gmail.com

Abstract

The use of renewable energy sources has great potential for generating electricity. This potential can be realized through the use of hybrid power systems. The development of this hybrid power plant features two power sources: Picohydro and solar power generation. Solar Power Plants (PLTS) and Picohydro Power Plants (PLTPH) are the most suitable renewable energy developments for Indonesia due to its highly potential tropical climate. The aim of this research is to develop a control system for a hybrid solar and picohydro power plant by creating a relay switch control system to connect and disconnect one power source to another. After the design was implemented, it was found that the device was capable of backing up electricity. When the picohydro system dims or shuts down, the PLTS battery will back it up, and vice versa.

Keywords: picohydro – PLTS – energy – hybrid

1. INTRODUCTION

The limited number of power plants cannot advance the industrial or socio-economic conditions of a country. Then this infrastructure project is the most significant endeavor undertaken by the current government. On the other hand, the increase of electric power development for local areas, especially in rural areas is too expensive. The purpose of electricity development is to stabilize people's economy through equitable distribution of electricity development. (Wardana, 2016), (Wiranata, 2020)(Zulkiffli Saleh, Yosi Apriani, Feby Ardianto, 2019)

Renewables are clean, non-polluting, secure and unlimited supply alternatives. An example of this type of energy is solar energy. Over time, the use of electrical energy from traditional fuels such as petroleum and coal has become a problem because the supply of traditional fuels in nature is decreasing. To solve this, steps are being taken to switch to new and renewable energy sources such as solar which will always be available indefinitely. (Bandri, Premadi, & Andari, 2021) (Ramadhan, Diniardi, & Mukti, 2016)

Solar energy is an unlimited and inexhaustible energy source, and can be used as an alternative to generate electrical energy through the use of solar cells. As an alternative power plant, solar panels can be used by those who need electricity, especially when the supply of electricity from PLN (State Electricity Company) is limited. (Purwoto, 2018)

Water is also an unlimited source of energy and can be used as an alternative to generate electrical energy by using water flow and altitude Picohydro power plants (PLTPH) utilize the potential of water energy with a very low head and water flow adjusted to the flow of the river. PicoHydro uses simple turbines that can be installed easily and are environmentally friendly to aquatic creatures such as fish. PicoHydro systems are also easy to use and maintain. This generator's maximum output is about 1000 Watts. The Picohydro Power Plant (PLTPH), which is capable of generating electricity with a capacity of less than 5 kW and is included in the group of small power plants. The principle of operation of PLTPH is to convert water energy at a certain height and flow it into electrical energy through turbines and generators. A pico-scale hydropower plant operates by using the difference in elevation and water flow per second in a river stream. The water flow is used to run a turbine, which in turn runs a generator to produce electricity. (Uyun dkk, 2020), (Juni Yanda, Abubakar, & Studi Teknologi Rekayasa Pembangkit Energ Jurusan Teknik Elektro Politeknik Negeri Lhokseumawe, 2021)(Bosowa, Azis, Mustafa, Muhammad Ibnu Munsyir, & Lutfi, 2021)(Saepul Uyun & Novianto, 2020)

By combining both plants as alternative energy (hybrid) Hybrid power plants generate electricity by combining different types of power plants that rely on renewable energy. In general, these power generation systems include solar power plants (PLTS), micro-hydro power plants and picohydro power plants (PLTPH). Photovoltaic plants are capable of operating for 24 hours, but their performance is highly dependent on water flow, so the power output varies from time to time. (Heryanto Eryk, Nabiel Akbar, & Giffari, 2023)

This makes solar energy and hydro energy a promising energy alternative for Indonesia. Solar power plants (PLTS) and Picohydro power plants (PLTPH) are types of renewable energy development that are very suitable to be developed in Indonesia due to its tropical climate.

Optimal utilization of hybrid generation can be achieved by adopting a control system that will regulate when the generator is connected or disconnected to power the load. This research aims to develop a hybrid generation model that combines solar and picohydro energy. Both energy sources use different energy conversion concepts so it is interesting to investigate how they are combined and regulated in a control system.

2. LITERATURE REVIEW

The hybrid power plant generates electricity by combining different types of power plants that rely on renewable energy. In general, these power generation systems include solar power plants (PLTS), micro-hydro power plants and picohydro power plants (PLTPH). Picohydro power plants are capable of operating for 24 hours, but their performance is highly dependent on water flow, so the power output varies from time to time. The following formula is used to calculate the PWM controller load.

$$\text{Rscc} = \frac{Vin - Vout}{Iout} \quad (1)$$

$$\text{Rtotal} = 2 \,.\, \text{Rconductor} + \text{Rscc} \quad (2)$$

$$\text{Ploss} = \text{Iout}^2 \,.\, \text{Rtotal} \quad (3)$$

$$Efisiensi = \frac{Potput}{Pinput} \text{ x } 100\% \quad (4)$$

2.1. Automatic Transfer Switch (ATS)

The Automatic Transfer Switch (ATS) is a series of automatic inverter control switches with PLN. The operating principle of the ATS is to automatically turn on the inverter and connect to the load when PLN is not connected. When PLN power returns to the "on" position, the appliance transfers PLN power to the load, from the inverter to the PLN grid. The use of ATS panels varies according to energy consumption.



Figure 1. ATS (Atomatic Transfer Switch)

The higher the power consumption, the higher the specifications of the components, especially the small circuit hub (MCB) and the size of contactors and cables. Electrical energy generated by the ATS is the result of the output voltage and current of the battery or PLN current.

2.2. Solar Charge Cotroller (SCC)

SCC (Solar Charge Controller) is a regulator of the entry of sunlight energy absorbed by solar panels into the battery, to keep the charging from being excessive which makes the battery damaged, Solar charge controller is an important component in solar power generation systems Solar charge controller is responsible for regulating the voltage and current flowing from solar panels to batteries and those used by loads. Its main purpose is to prevent the battery from being overcharged.



Figure 2. SCC (Solar Control Charge)

In its implementation, the Solar Charge Controller uses Pulse Width Modulation (PWM) technology to control the battery charging function and prevent over-charging of the battery. In the Solar Charge Controller (SCC), there is a display screen that displays the voltage flowing from the solar panel to the battery. In addition, this component also has the ability to provide notification if the battery condition charged by the solar panel has reached full capacity.

2.3. Baterai

Batteries, also known as accumulators (accumulators), process chemical energy into direct current (DC) electrical energy. The battery is a form of electrochemistry, subject to the effect of chemical reactants, so it is often called a secondary battery. There are several ways to calculate battery life.



Figure 3. baterai

To determine the time required to charge the battery (t), compare the battery capacity I with the average current produced by the DC generator (I). As the battery supplies current to the load, electrical energy previously stored in the form of chemical energy is released. When supplying power, it is also necessary to pay attention to the DOD (deep discharge) or the maximum and minimum acceptable limits.

3. METHOD

This power generation system is hybridized between picohydro power plants and solar panel power plants using batteries as a storage area for electrical energy that has been generated. The following is a picture of the wiring diagram of the hybrid generation system of picohydro power plants and solar panel power plants.

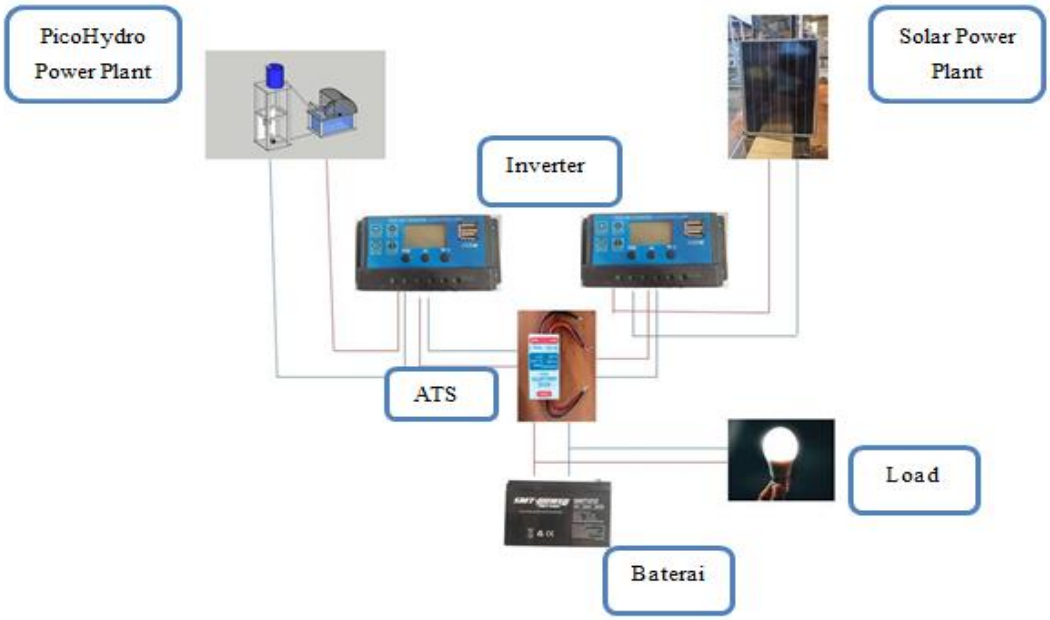


Figure 4. wirring diagram hybrid sistem

Electrical energy generated by solar panels will be stored in batteries or directly fed into the electricity distribution system. Picohydro power plants use water energy drawn from low-altitude streams or waterfalls. The system utilizes a small turbine to convert the kinetic energy of the water into mechanical energy. This mechanical energy is then converted into electrical energy through a generator.

The steps of the working principle of hybrid power generation between solar panel power plants and picohydro power plants are shown in the following flowchart.

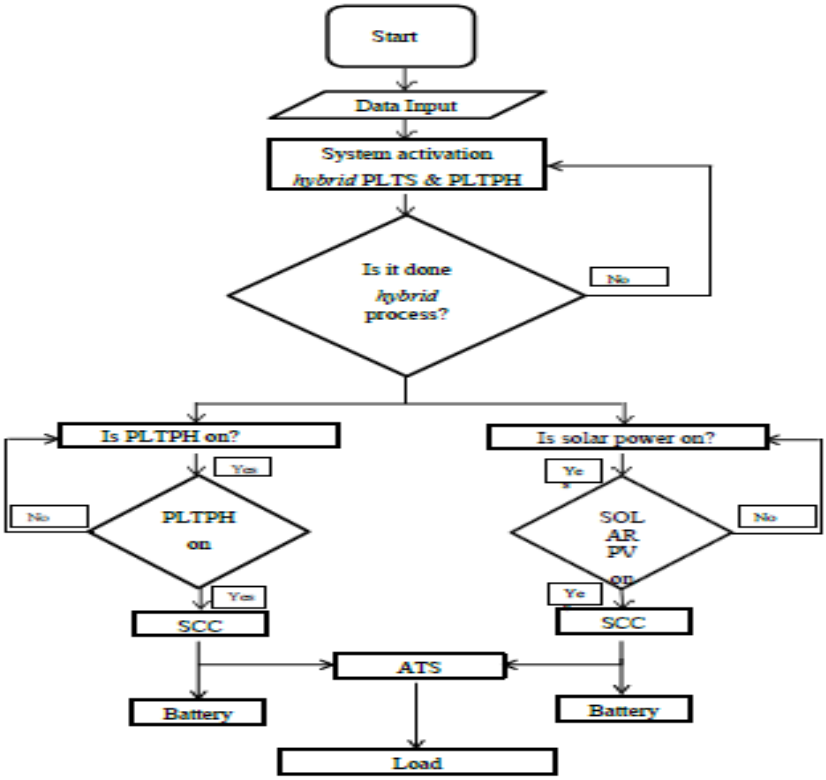


Figure 5. flowchart diagram of how the hybrid generation system works

A control system will monitor the energy availability of both resources. If there is sufficient sunlight, then priority will probably be given to solar power generation. However, if the weather is cloudy or at night, the system may switch to the picohydro power plant. In addition, there is also a possibility to use both resources simultaneously if the energy availability is sufficient to meet the electricity demand.

4. RESULTS

4.1 Solar power plant testing chart July 8, 2023

From the chart below, it can be seen that the battery capacity in this test increased by 5.9 volts with weather that tends to be hot, the highest average voltage is 13.28 volts at 11:00 - 11:30, the lowest voltage is 13.17 volts. constant current of 0.016 amperes at 11:00 - 14:30.

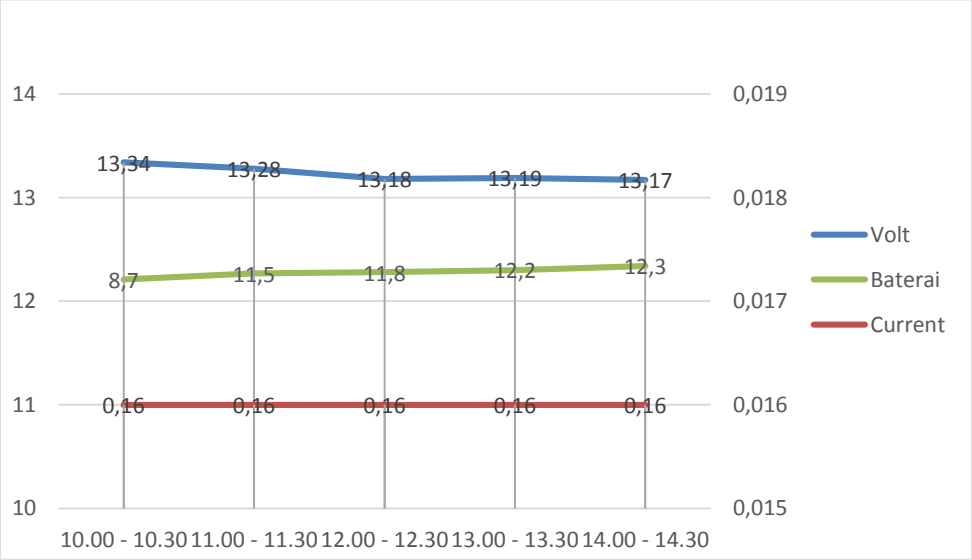


Figure 6. Solar power plant baterai charging 8-Juli-2023

4.2 Solar power plant testing chart July 10, 2023

From the chart below it can be seen that the highest average voltage in this test is between 13.24 volts at 10.00 - 11.30 and the lowest average in this test is 13.23 volts at 12.00 -13.30, the highest average current is 0.017 amperes from 11.00 - 11.30 and the battery capacity has increased to 0.47 from charging today less than before because on this day there was rain.

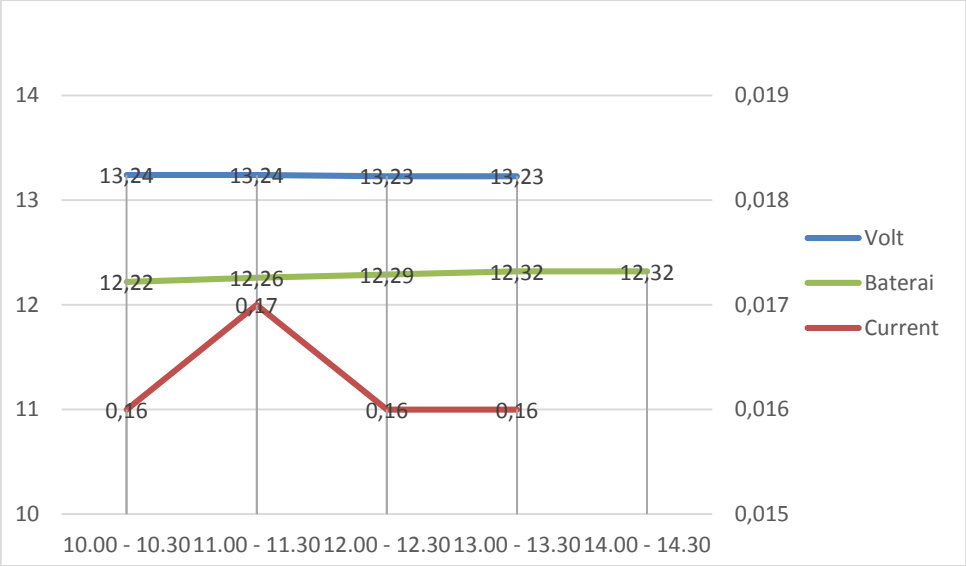


Figure 7. Solar power plat baterai charging 10-Juli-2023

4.3 Solar power plant testing chart July 12, 2023

From the graph below, it can be seen that the battery capacity generated by solar panels is 0.25 volts, the results of battery charging today are more than yesterday because the weather did not experience rain. The highest average voltage is 13.24 volts at 10:00 -11:30 and the lowest voltage is 13.23 volts at 12:00 - 12:30, the highest average current is 0.017 amperes at 12:00 to 14:30 and the lowest average current is 0.016 amperes at 10:00 to 11:30 weather tends to be hot.

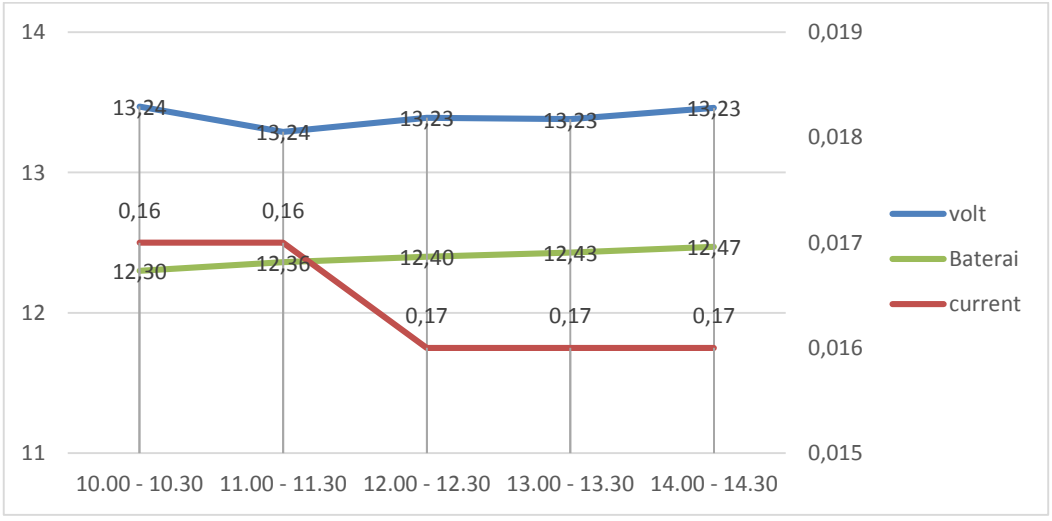


Figure 8. Solar power plant baterai charging 12-Juli-2023

4.4 Solar power plant testing chart July 14, 2023

From the chart below it can be seen that today's testing weather tends to be cloudy the voltage capacity increases by 0.56 volts the average current in today's test is still the same as the previous test stable between 0.016 amperes from 11:00 to 14:30 the highest current is between 0.017 amperes from 10:00 - 10:30 and the highest average voltage is 13.43 volts at 10:00 - 10:30 and the lowest voltage is 13.21 volts at 13:00 - 13:30.

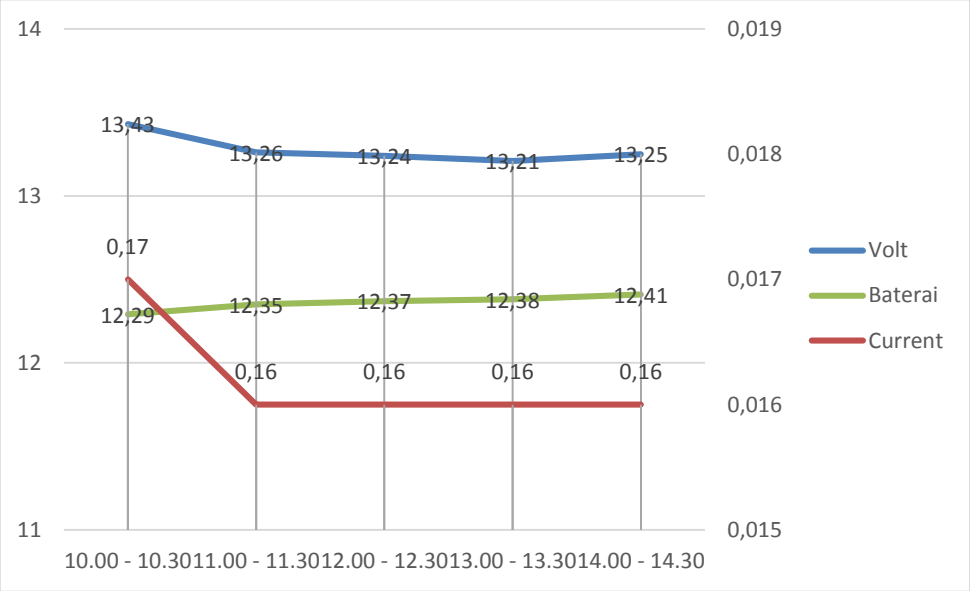


Figure 9. Solar power plant baterai charging 14-Juli-2023

4.5 Testing table of picohydro power plant in battery charge state.

From the table below, we can see how changes in turbine speed affect voltage, current, and battery condition. In general, increasing turbine speed tends to increase the voltage and current produced by the turbine. In addition, the final state of the battery tends to be slightly higher than its initial state, indicating that the turbine successfully charged the battery during the test.

Table 1. Testing table system of picohydro power plant in battery charge state

Testing	Turbine velocity (rpm)	(V)	(I)	battery starting condition	battery final state
1	428	12,98	0,54	12,04	12,06
	430	13,11	0,54	12,06	12,11
	425	12,89	0,54	12,11	12,15
2	425	12,90	0,54	12,15	12,19
	428	12,98	0,54	12,19	12,22
	422	12,87	0,54	12,22	12,25
3	430	13,09	0,54	12,25	12,27
	419	13,81	0,54	12,27	12,29
	423	12,85	0,54	12,29	12,31

Based on the table above, this is the data of the first test results of PLTPH in a state of battery charging, also obtained the highest rotation generated in the generator of 12.98 V, also obtained the

highest rotation generated by the turbine of 428 rpm, and the current when charging the battery is 0.535 A, the initial battery capacity of 12.04 until the first test is completed, the final battery capacity is 12.15 V.

Based on the table is also the data of the second test results of PLTPH in the battery charger state, obtained the highest voltage generated by the generator of 12.98 V, also obtained the highest rotation generated by the turbine 428 rpm and the current at the time of battery charge battery of 0.53 A, the initial battery capacity of 12.15 until the first test is completed, obtained the final battery capacity of 12.25 V.

According to the table is also the data of the third test results of battery charging, obtained the highest voltage generated by the generator of 13.09 V, also obtained the highest rotation generated by the turbine 428 rpm and the current at the time of battery charge battery of 0.53 A, the initial battery capacity of 12.25 until the first test is completed obtained the final battery capacity of 12.31 V.

From the above test, it can be seen that the battery only increases from the beginning to the end by 0.06 - 0.11, because the turbine rotation is not too long and there is a time lag for recharging the reservoir. It takes 21 hours for PLTPh to charge the battery from empty to full.

4.6 The Hybrid generation system testing in the battery charge state

from the table bellow we can see that turbine speed has a direct impact on the voltage and current produced. The higher the turbine speed, the higher the voltage and current produced. In addition, we can also see that the difference between the initial and final battery levels is not very large, indicating that the energy production from the turbine is fairly consistent and that the battery has a small power leakage rate or power demand balanced with the turbine production.

Based on formulas 1 - 3, the efficiency of the charge controller, for example, 1 data is taken from the table of measurement results and Vin is known to be 18V, Vout is 13.234V, Iout is 0.166A and R penghantar is 0.3 Ohm. The following are the results of the PWM type charge controller calculation.

$$Rscc = \frac{Vin - Vout}{Iout}$$
$$= \frac{18 - 13{,}234}{3{,}7}$$
$$= 1{,}28 \text{ Ohm}$$

Table 2. Testing Hybrid generation system in battery charge state

Turbine velocity (rpm)	volt (v)	Current (I)	battery starting condition	battery final state
425	12.9	0.54	11.85	11.93
422	12.9	0.54	11.93	12.02
418	12.8	0.54	12.02	12.04
422	12.8	0.54	12.04	12.05
415	12.6	0.53	12.05	12.05
425	12.9	0.54	12.05	12.12
415	12.6	0.54	12.12	12.13
410	12.4	0.53	12.13	12.13
421	12.8	0.53	12.13	12.16
412	12.4	0.52	12.16	12.16

After knowing Rscc of 1.28 Ohms, the next step is to find Rtotal as follows.

$$Rtotal = 2 \cdot Rconduct + Rscc$$
$$= 2 \cdot 0{,}3 + 1{,}28$$
$$= 1{,}88 \text{ Ohm}$$

After knowing Rtotal of 1.88 Ohms, the next step is to find Ploss (lost power) as follows.

$$Ploss = Iout^2 \cdot Rtotal$$

$=3{,}7^2$. 1,88
= 25,7 W

After knowing Rscc, Rtotal and Ploss from the charge controller, the next step is to calculate the efficiency as follows.

$Efisiens$i = Potput/Pinput x 100%
= 13,234/18 x 100%
= 73%

After calculating the charger controller, the Rscc value of 1.28 Ohm and Rtotal of 1.88 are obtained. From the calculations that have been done the Ploss value is 25.7 W with an efficiency of 73%.

5. CONCLUSION

from the research results obtained that, the power generation system that has been designed is able to back up the electrical power when the picohydro power plant dims or dies then the battery on the solar panel power plant will back up it.

On battery charging tests that have been carried out, it can be seen that testing Solar Power Plants that are hybridized with Picohydro Power Plants produces more final battery charging capacity than single systems.

6. ACKNOWLEDGEMENTS

The team and authors would like to express their deepest gratitude for the assistance and support provided by Universitas Muhammadiyah Palembang (especially LPPM and the Rector of Universitas Muhammadiyah Palembang), which has contributed greatly to the successful completion of this research.

REFERENCES

Bandri, S., Premadi, A., & Andari, R. (2021). STUDI PERENCANAAN PEMBANGKIT LISTRIK TENAGA PICOHYDRO (PLTPh) RUMAH TANGGA. *Jurnal Sains Dan Teknologi*, *21*(1).

Bosowa, P., Azis, F., Mustafa, S., Muhammad Ibnu Munsyir, A., & Lutfi, S. (2021). Rancang Bangun Prototipe Pembangkit Listrik Tenaga Picohydro Menggunakan Turbin Impuls. *Journal Of Electrical Engineering (Joule)*, *2*(1).

Heryanto Eryk, I., Nabiel Akbar, D., & Giffari, A. (2023). Analysis of Dual Input Charge Controller on Hybrid Solar Photovoltaic and Picohydro Power Plant. *Prosiding Seminar Nasional Teknik Elektro*, *8*, 50–55.

Juni Yanda, A., Abubakar, S., & Studi Teknologi Rekayasa Pembangkit Energ Jurusan Teknik Elektro Politeknik Negeri Lhokseumawe, P. (2021). PERANCANGAN TURBIN CROSS-FLOW PADA PEMBANGKIT LISTRIK TENAGA PICO HYDRO (PLTPH) DI DESA WIH TENANG UKEN BENER MERIAH. *JURNAL TEKTRO*, *5*(1).

Purwoto, B. H. (2018). Efisiensi Penggunaan Panel Surya Sebagai Sumber Energi Alternatif. *Emitor: Jurnal Teknik Elektro*, *18*(01), 10–14. https://doi.org/10.23917/emitor.v18i01.6251

Ramadhan, A. I., Diniardi, E., & Mukti, S. H. (2016). Analisis Desain Sistem Pembangkit Listrik Tenaga Surya Kapasitas 50 WP. *Teknik*, *37*(2), 59. https://doi.org/10.14710/teknik.v37i2.9011

Saepul Uyun, A., & Novianto, B. (2020). *RANCANG BANGUN LOW HEAD TURBIN PIKO HIDRO*. *10*(1).

Uyun dkk, 2020. (2020). Rancang Bangun Low Head Turbin Piko Hidro. *Jurnal Sains & …*, *X*(1), 67–79.

Wardana, W. (2016). Perancangan Sistem Pensuplai Air Tambak Udang Dengan Sumber Tenaga Panel Surya. *Jurnal Teknik Mesin*, *4*(1), 32–34.

Wiranata, P. A. (2020). RANCANG BANGUN PROTOTYPE PEMBANGKIT LISTRIK TENAGA MIKRO HIDRO MENGGUNAKAN TURBIN CROSS-FLOW. *Jurnal SPEKTRUM*, *7*(4).

Zulkiffli Saleh, Yosi Apriani, Feby Ardianto, R. P. (2019). ANALISIS KARAKTERISTIK TURBIN CROSSFLOW KAPASITAS 5 KW. *JURNAL SURYA ENERGY*, *3*(2), 2001–2001.

Biodata

Yosi Apriani is a lecturer in the Department of Electrical Engineering at Muhammadiyah University of Palembang. She received a Bachelor's degree in Electrical Engineering from Universitas Gadjah Mada in 2005 and a Master's degree in the Chemical Engineering from Universitas Sriwijaya in 2014. Currently, interested in research related to the field of renewable energy and LoRa-IoT. Email: yosi_apriani@um-palembang.ac.id

Soni Andika Pratama is a student of the electrical engineering program at the University of Palembang,with his research focus on renewable energy. Email : sonyandikapratama23@gmailcom

Marliyus Sunarhati is a lecturer in the Department of Electrical Engineering at University of Palembang. He is Master's degree in the Chemical Engineering from Universitas Sriwijaya, Email : marlius@gmail.com

Zulkiffli Saleh is a lecturer in the electrical engineering program at Muhammadiyah University of Palembang with a research focus on the field of new renewable energy, Zulkiffli Saleh is an alumnus of the Faculty of Engineering, Gadjah Mada University, Yogyakarta. Email : zulkifflisaleh64@gmail.com

Ian Mochamad Sofian is a lecturer in the Department of Engine, Banten Merchant Marine. He received a Bachelor's degree in Physics of Instrumentation from Universitas Lampung in 2008 and a Master's degree in the Geophysics from Universitas Sriwijaya in 2018. Currently, interested in researching machine learning and allied fields. Email: ian.msof@gmail.com