Development of a 500-1000 watt Pico hydro Hybrid Solar Power Plant prototype

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Abstract. In this study a prototype of a Hybrid Power Plant (PLTH) will be built that integrates the Pico-hydro Power Plant (PLTPH) and the Solar Power Plant (PLTS). The prototype of the PLTH to be built has a capacity of 500-1000 watts. From the making of the prototype-1 it was discovered that the PLTPH produced a maximum power of 86 W (from a capacity of 100 W) and the PLTS produced a maximum power of 30 W during bright weather and 23 W when the weather was dim (from a capacity of 100 W). The results of testing on prototype-2, it is known that PLTPH with a capacity of 600 W produces maximum power of 257.48 W and PLTS with 3 x 200 Wp (watt-peak) solar panels producing maximum power of 176.4 watts. After some adjustments, the electrical energy from these two sources is then stored in the battery. Electrical energy from PLTS is stored on the battery after going through the MPPT Solar Charge Controller; while the electrical energy from the PLTPH is stored on the battery after the electricity voltage is lowered and rectified with the rectifier. From the results of observations and measurements during testing, these two sources of electrical energy can charge the battery normally. Electrical energy from batteries that are direct current electricity is then converted into electrical energy alternating current of the power frequency to be supplied to the load, especially the electric load of alternating current.

1. Introduction

According to the 2015 Electricity Statistics [1], as of the end of 2015 the installed capacity of electric power plants in Indonesia reached 55,528.10 MW, consisting of PLN generators of 38,314.23 MW and Non PLN of 17,213.87 MW; compared to 2014 which had a capacity of 53,065.50 MW, the installed capacity of electric power plants increased by 2,462.60 MW or 4.64%. The installed capacity of a national power plant based on the type of generator in 2015 can be seen in figure 1.
Based on the data in figure 1, it is seen that the dependence of electricity generation in Indonesia on fossil fuels (such as coal, petroleum and natural gas) is very large. In 2015, the installed capacity of fossil fuel-based power plants reached 48,779.87 MW or 87.85% of total installed capacity. In fact, as is known, fossil fuels are very limited in number so that one day they will run out, and the effects they can cause can pollute and even damage the environment. Based on this, it is necessary to think of finding alternatives to supply electrical energy that have characters [2]:

- can reduce dependence on fossil energy use, especially coal and petroleum;
- can provide electricity on a regional scale;
- able to utilize the potential of local / local energy resources, as well as
- environmentally friendly, in the sense that the production process and disposal of its products do not damage the surrounding environment.

The electricity supply system that can meet the above criteria is an energy conversion system that utilizes new renewable energy (EBT) resources. Energy resources classified as renewable energy, for example: geothermal, water, bio-energy, solar, wind, and currents / ocean waves; while those that include new energy include liquefied coal, methane gas, coal fired, nuclear, and hydrogen. Until 2015, the installed capacity of the new EBT-based power plant was around 6,748.23 MW or 12.15% of the total installed capacity.

To meet the electricity needs of the Indonesian people from Sabang to Merauke, the government has committed to realize the supply of electricity of 35,000 Megawatts (MW) within a period of 5 years (2014-2019) [3]. Within that period, the government together with PLN and the private sector will build 109 plants; each consists of 35 projects by PLN with a total capacity of 10,681 MW and 74 projects by the Independent Power Producer (IPP) with a total capacity of 25,904 MW. In 2015, PLN will sign a power plant contract of 10,000 MW as phase I of a total of 35,000 MW. In this 35,000 MW program, the share of EBT-based power plants is 25% or 8,750 MW, with details: 1,751 MW of geothermal energy (20%), 2,438 MW of hydro (28%), 1,156 MW of bioenergy (13%), and solar, wind, sea and other EBT 3,405 MW (39%). The budget needed is USD 29.8 billion or around Rp. 402 trillion [4].

In connection with new renewable energy sources, right behind the Electric Power Engineering Laboratory, Department of Electrical Engineering Education, Universitas Pendidikan Indonesia, there is a river that in plain view, the flow of water flow can be used for power plants with output power of tens to hundreds of watts. Based on this, in this study a study and trial will be carried out to build a power plant by utilizing this river water flow, in the form of Pico-hydro Power Plant (PLTPH). Furthermore, the PLTPH will be combined with a Solar Power Plant (PLTS) which will also be built at the site to form a prototype of a Hybrid Power Plant (PLTH).
2. Literature review

Hydro power plants are power plants that utilize water energy as their initial energy source. Mechanical energy contained in water energy is used to rotate turbines; this rotating turbine is connected to a generator so that electricity is generated. The development of a hydro power plant usually begins with a potential study (pre-feasibility study). Related to this, Ratnata, I.W., et al have conducted a study of the potential of microhydro power plants in the Cibatarua River, Pakenjeng Village, Kab. Garut. With a water discharge of around 5100 liters / second, and a head that reaches 63 m in one of the waterfalls, the hydraulic power that can be produced reaches 3248 kW [5].

A solar power plant is a power plant that converts solar energy into electricity. Electricity generation can be done in two ways, namely directly using photovoltaic and indirectly with concentrating solar energy. Photovoltaic converts light energy directly into electricity using a photoelectric effect. Concentration of solar energy uses a system of lenses or mirrors combined with a tracking system to focus solar energy to a point to move the heat engine. Related to the utilization of solar energy, especially for laboratory purposes, Dewi, A.Y. conducted a research on solar energy utilization as a backup supply at the Basic Electrical Laboratory at the Padang Institute of Technology. From her research, it was found that the installed solar panels could produce 431.55 watts of power for 9 hours of sun exposure for one day [6].

The Hybrid Power Plant (PLTH) is a power generation system that combines several types of power plants, generally between fuel-based power plants and renewable energy-based power plants. Generally, the power systems that are widely used for PLTH are diesel generators, solar power plants (PLTS), micro hydro, power plants (PLTB). PLTH is a solution to overcome the BBM crisis and the absence of electricity in remote areas, small islands and also in urban areas.

Figure 2. Example of Hybrid Power Plant: Solar–wind.

However, in its development there are various combinations of electricity sources that produce PLTH. Getnet Zewde Somano conducted a study on the design and modeling of a micro-hydro power plant in Ethiopia. Getnet uses HOMER optimization software, and selects 10 kW PV, 14 kW hydro, 14 kW and 32 battery converters as an option to power Coordinating Minister for Toli, Ethiopia, with an initial capital cost of 55,200 dollars, net total cost of 76,128 dollars and 0.045 dollars per unit cost [7]. Lakshmi, G. conducted a simulation of a hybrid solar-hydro-wind energy system as a source of electrical energy for remote areas [8]. Based on the simulation results, it is known that renewable energy sources or alternative energy sources will replace conventional energy sources and will be the right solution for independent electricity distribution applications for remote and remote areas.
3. Research methods
This research is a descriptive study that discusses the provision of renewable electricity through the prototype of the PLTPH-Surya hybrid electric energy generator, at the Electric Power Engineering Laboratory, DPTE, FPTK - UPI. This research was carried out through the prototype of the PLTPH-Surya electric energy generator by utilizing river water flow around the laboratory. Solar cell power plants are installed in the roof area of laboratory buildings, where the available land is sufficient for the installation of photovoltaic electrical panels.

Research related to the manufacture of prototypes of PLTPH-PLTS hybrid electric energy plants is carried out by the following steps:

- Literature review, analysis of potential and feasibility studies of Pico-hydro Power Plant (PLTPH);
- Literature review, analysis of potential and feasibility studies of solar power plants (PLTS);
- Collection of relevant data and information;
- Making a lay out of a hybrid power plant: PLTPH PLTS;
- Construction of civil construction for 100 watt and 600 watt open flume turbines;
- Procurement of 100 watt and 600 watt electricity generators and control systems;
- Pilot PLTPH;
- Procurement of 600 Wp solar cell modules
- Construction of civil construction for solar cell installation;
- Procurement of solar cells, control systems and batteries;
- PLTS testing;
- Analysis of energy forecasts to be generated from Hybrid PLT systems;
- Procurement of transformers and AC to DC converters, as well as DC to AC converters;
- Installation of Hybrid PLT installations: PLTPH-PLTS;
- Testing and Commissioning;
- Preparation of reports.

4. Results and discussion
This research is a follow-up study from previous research. In previous studies, Ratnata, I.W., et al. have developed PLTH that combines PLTPH using open flume turbines with a capacity of 100W, and PLTS that use solar cells (solar cells) with a capacity of 2 x 50 Wp (watt-peak). When operated, the PLTPH produces a maximum power of 86 W, while the PLTS produces a maximum power of 30 W in sunny weather and 23 W in dim weather [9].

In line research, PLTPH was designed using an open flume turbine propeller with a capacity of 600 W, while PLTS used a solar cell (solar cell) with a capacity of 3 x 200 Wp. The PLTH scheme designed can be seen in figure 3.
Figure 3. Scheme of Hybrid Power Plant PLTH: Solar-Hydro.

After some adjustments, the electrical energy from these two sources is then stored in the battery. Electrical energy from PLTS is stored on the battery after going through the MPPT Solar Charge Controller; while the electrical energy from the PLTPH is stored in the battery after the electricity voltage has been lowered and made into direct current electricity through the rectifier. From the results of observations and measurements during testing, these two sources of electrical energy can charge the battery normally. Electrical energy from batteries that are direct current electricity is then converted into electrical energy alternating current of the power frequency to be supplied to the load, especially the electric load of alternating current.

The results of testing the performance of each PLTPH and PLTS can be seen in Tables 1 and 2 below.

Table 1. The performance of Hybrid Power Plant.

| No. | Loads | Turbine speeds (rpm) | Voltage (V) | Current (A) | Frequency (Hz) | Power (watt) | Remarks |
|-----|-------|----------------------|-------------|-------------|---------------|--------------|---------|
| 1   | 0     | 1647                 | 224         | 0           | 54.2          | 0            | No load |
| 2   | 100   | 1650                 | 232         | 0.23        | 53.8          | 53.36        | 1 lamp   |
| 3   | 200   | 1609                 | 240         | 0.63        | 52.4          | 151.2        | 2 lamp   |
| 4   | 300   | 1650                 | 212         | 0.99        | 50.5          | 209.88       | 3 lamp   |
| 5   | 400   | 1538                 | 186         | 1.28        | 49.6          | 238.08       | 4 lamp   |
| 6   | 500   | 1554                 | 164         | 1.57        | 50.2          | 257.48       | 5 lamp   |
| 7   | 600   | 1332                 | 126         | 1.65        | 51.6          | 207.9        | 6 lamp   |
Figure 4. Performance Hybrid Power Plant.

Table 2. The Performance of Hybrid Power Plant (after inverter).

| No. | Loads (watt) | Voltage AC (V) | Current AC (A) | Power (watt) | Remarks |
|-----|--------------|----------------|----------------|--------------|---------|
| 1   | 0            | 245            | 0              | 0            |         |
| 2   | 100          | 200            | 0.25           | 50           |         |
| 3   | 200          | 200            | 0.65           | 130          |         |
| 4   | 300          | 180            | 0.98           | 176.4        |         |
| 5   | 400          | 120            | 1.03           | 123.6        |         |
| 6   | 500          | -              | -              | -            |         |

Figure 5. The Performance of Hybrid Power Plant (After inverter).

Based on PLTPH performance data in Table 1 and Figure 4, it is known that the generator has a relatively stable rotation. Likewise the output voltage and frequency. Especially for frequencies, the value is around the electric power frequency, 50 Hz. While the output voltage tends to decrease (below 220 V) when the load capacity is increased. In general, this PLTPH has been working normally, only the
efficiency of its load capacity is still low, in the range of 35-75%. The lowest efficiency occurs when the load capacity is close to the maximum capacity of the generator.

The PLTS performance is shown in Table 2 and Figure 5. The PLTS output voltage after being passed through the MPPT Charge Controller, Battery, and Inverter still tends to fluctuate. At no-load, the voltage reaches 245 VAC, but tends to decrease when the load is raised. Output power increases following the installed load capacity, but then decreases after passing a certain load capacity value.

5. Conclusion

- Utilization of waterways behind the Electric Power Engineering Laboratory, Department of Electrical Engineering Education, FPTK-UPI using TC-60 open flume propeller turbines with a capacity of 600 W producing electricity with a maximum power of 257.48 W. Barriers to the use of river water is sometimes cloudy and muddy water and a lot of garbage. Muddy and muddy water causes the generator rotation to decrease and the voltage generated is only around 130 V; while disruption of garbage can result in the generator not operating at all.
- The utilization of sunlight energy into electrical energy using 3 x 200 Wp solar cells in this study may not be optimal. The maximum total electric power produced is 176.4 W.
- In this study, electricity generated from the use of water flow in the form of Pico-hydro Power Plant (PLTPH) and utilization of sunlight in the form of Solar Power Plants (PLTS) are integrated into a Hybrid Power Plant (PLTH). After going through several settings and conversions, the energy from both sources is stored in the battery and then channeled to the load.

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