Design of a Laboratory Scale Pico Hydro Power Plant Trainer for Practical Experiments

Arwadi Sinuraya[1], Denny Haryanto Sinaga[2], Lastama Sinaga[3], Robbi Feri Randa Simamora[4], T. Afrian[5], Dito Yudisthira Nugroho[6]

{arwadisinuraya@unimed.ac.id[1], denny.sinaga@unimed.ac.id[2], lastamasinaga@unimed.ac.id[3], robbisimamora@mhs.unimed.ac.id[4], afrian@mhs.unimed.ac.id[5], ditoyudisthiranugroho@mhs.unimed.ac.id[6]}

[1,2,4,5,6]Department of Electrical Engineering, Universitas Negeri Medan,

[3]Department of Science Education, Universitas Negeri Medan,

Jl. Willem Iskandar Pasar V, Medan, North Sumatera, Indonesia

Abstract. Electrical energy conversion is a very important topic in the field of electrical engineering, especially in the development of renewable energy. One of the most popular renewable energy generators today is the pico-hydro power plant. This study aims to design trainers for Pico Hydro Power Plants as learning media and test the feasibility of trainers as learning media. The method used in this study is Research and Development which includes planning and making trainers for Pico Hydro Power Plants. The design results will then be given to students to be used as learning media. This study examines the feasibility and trials of trainers by awarding points to lecturers and students. The expected results from the Pico Hydro Power Plant trainer are very feasible to be used in carrying out experiments in the laboratory

Keywords: Pico Hydro, Pelton Turbine, Energy Conversion, Trainer, Laboratory Experiment

1 Introduction

The world is facing a huge energy crisis due to the depletion of non-renewable energy sources like coal, oil, and gas (Kamaruzzaman et al., 2021). The use of renewable energy sources has become increasingly important in today's world. Pico hydro power plant is one of the most promising technologies for the generation of electricity in remote areas [1]. Pico hydro power plants use the energy of falling water to generate electricity. The energy of falling water is converted into mechanical energy by a turbine, which is then converted into electrical energy by a generator. Pico hydro power plants are simple, reliable, and adaptable to various water sources. It can generate electricity even with a small head and flow rate [2]

Seeing the functions, benefits and increasing development of Hydro Power Plant systems makes knowledge about this type of power plant a subject that must be understood and comprehended by electrical engineering students. However, the lack of practical training facilities and limited knowledge about hydro power plants have hindered their widespread

ICIESC 2023, October 24, Medan, Indonesia

DOI 10.4108/eai.24-10-2023.2342129

adoption. There is a need for a trainer module about hydroelectric power generation systems that is suitable for use as a good learning medium so that it can increase students' knowledge about hydroelectric power plants. Media trainer is a set of equipment in the laboratory that is used as educational media which is a combination of working models and mock-ups. The trainer is intended to support students' learning in applying the knowledge/concepts they have acquired to real objects [3].

2 Method

The method used in this study is research and development. This method is a process or steps to develop a new product or improve an existing product.. There are three main components to this method, namely: Model development (procedural, conceptual and theoretical), research development procedures and product trials [4]. In this research, we conducted a thorough literature review to identify the key components and requirements of a laboratory scale pico-hydro power plant trainer. We designed and developed a prototype based on the literature review results. We tested and evaluated the prototype with a group of students and researchers from different backgrounds in renewable energy technologies. In this paper, we present the design of a laboratory scale pico hydro power plant trainer for practical experiments.

The trainer is designed to help students and researchers understand the working principles of pico hydroelectric power plants and conduct experiments to optimize the performance of these plants. This trainer includes a turbine, generator, control panel, and data acquisition system. The control panel allows students to regulate water flow rate, and turbine speed to optimize generator power output which can be monitored via measurement tools. Feedback received from the evaluation is used to improve the prototype design. The final version of this trainer was created based on the feedback and suggestions received.

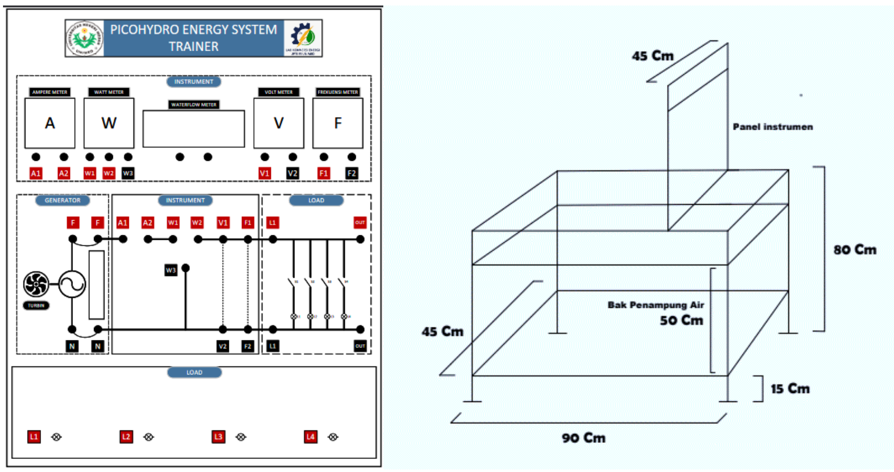

Fig 1. Picohydro Trainer Design

2.1 Pelton Turbine

One type of turbine commonly used for hydroelectric power plants is the Pelton turbine. The Pelton turbine is a type of impulse turbine that operates on the principle of high-speed water jets impacting the turbine blades, causing them to rotate. The unique design of the Pelton wheel blades is critical in determining turbine efficiency. Pelton turbines are generally used in small-scale hydroelectric power generation systems, especially in pico hydro systems [5], [6].

Pelton turbines are typically utilized in mountainous areas where fast-flowing water is present, or where there are limited water flow conditions in power plants[7]. Furthermore, Pelton turbines are recognized for their high efficiency in generating electricity; however, they may also have high maintenance costs, which result from the design's complex and delicate features.

Fig 2. Pelton Turbine

Pelton turbines are suitable for application in hydroelectric power plants with high heads and low flows. In a hydroelectric power generation system using a Pelton turbine, water is channeled from a height so that the water comes out at the end of the pipe through a narrow nozzle as a jet at very high speed towards the turbine blades. These turbines can have one, two, or more nozzles to produce higher output [6].

Table 1. Pelton Turbine Specifications

Part	Value
Pulley	10 cm
Belting	84 cm

2.2 Generator

A generator is an electrical component whose electrical voltage output is obtained by converting mechanical energy into electrical energy. The generator works based on the principle of electromagnetic induction, namely by rotating a coil in a magnetic field so that an induced EMF (Electro Motive Force) arises.[8]

Fig 3. Generator

The generator used for the hydroelectric power scheme is selected based on various aspects such as the following : [5]

1. Estimation of the power of a hydropower system.
2. Type of electrical supply system and load: AC or DC
3. Generating capacity available on the market
4. Cost effective generator.

Table 2. Generator Specifications

Specifications	Value
Type	Permanent Magnet
Pulley	3 cm
Max. Power	200 W

2.3 Water Pump

A jet water pump is a type of pump that uses the jet principle to move water. The basic principle of a water jet pump is that a stream of liquid (usually water) coming out of a jet nozzle at high speed will create a low pressure around it. This low pressure is then used to suck water from the source into the pump system, where the water is then pressed and channeled to the desired destination.

Fig 4. Water Jet Pump

In this research, a water pump is used as a turbine driver which can be adjusted according to experimental needs to see the effect of water speed and pressure on generator power. The container (water source) is a place to store water which is used here, namely potential energy. The pump is an element that functions to absorb and push the water contained in the water source so that it can circulate. Water pump specifications can be seen in table 3.

Table 3. Water Pump Specifications

Specifications	Value
Rated Power	700 W
Voltage	220 V
Working Pressure	70 Bar
Max. Pressure	120 Bar
Max.Flow	8,3L/min

3 Results

The results of this research are the design and construction of a laboratory-scale pico hydro training tool that can be used for practical experiments. This teaching aid covers the main components such as turbines, generators, control systems, and monitoring instruments so that users can understand the basic principles of pico hydropower plants.

The water in the reservoir will flow towards the turbine blades at high pressure. This pressure will spin a turbine connected to a generator so that it can produce electrical power. water from the turbine exhaust will re-enter the reservoir in a closed-cycle

Fig 5. Pico Hydro Trainer

From the trainer that has been designed, We test the performance of each trainer component to see whether the trainer functions properly. Through testing, all components can function and obtain the following test results:

Table 4. Testing Result

Speed (RPM)	Voltage (V)
443	18
500	20
555	21
576	22

From a trainer designed with a generator pulley of 4 cm and a turbine pulley of 10 cm and a belting length of 37 cm, the highest speed obtained was 576 RPM and the voltage obtained was 22 Volts. This number can be used as a parameter for a laboratory scale picohydro trainer system.

4 Discussion

The use of this laboratory-scale pico hydro training tool has great potential in increasing students' and researchers' understanding of renewable energy and pico hydro technology. Based on the test results that have been carried out, the Pico Hydropower plant trainer works well. By measuring the output voltage without load, the maximum voltage results were obtained at 22 V. When the water pump pressure was reduced, the generator output voltage dropped to 18 V at 443 rpm. For actual use, the generator output voltage needs to use a step-up transformer so that the resulting voltage matches the load requirements of 220 VAC.

5 Conclusion

The laboratory scale pico hydro power plant trainer is a valuable tool for students and researchers to understand the working principles of pico hydropower plants and conduct experiments to optimize the performance of the power plant.

Based on the results of the experiments that have been carried out, it can be concluded that the voltage produced by an alternator depends on the rotation of the alternator itself and the rotation of the turbine. The greater the rotation, the greater the voltage produced. This is influenced by the turbine's ability to rotate the alternator. The highest voltage is in no-load conditions with an excitation voltage value of 22V where a rotation of 576 rpm is obtained.

References

[1] D. Powell, A. Ebrahimi, S. Nourbakhsh, M. Meshkahaldini, and A. M. Bilton, “Design of pico-hydro turbine generator systems for self-powered electrochemical water disinfection devices,” *Renewable Energy*, vol. 123, pp. 590–602, Aug. 2018, doi: 10.1016/j.renene.2017.12.079.

[2] S. J. Williamson, B. H. Stark, and J. D. Booker, “Performance of a low-head pico-hydro Turgo turbine,” *Applied Energy*, vol. 102, pp. 1114–1126, Feb. 2013, doi: 10.1016/j.apenergy.2012.06.029.

[3] M. R. Faiz and D. T. Laksono, “Pengembangan Trainer Integrasi Pembangkit Listrik Skala Piko”.

[4] S. N. Fitri and S. Mustafa, “Rancang Bangun Prototype Pembangkit Listrik Pico-Hydro,” vol. 1, no. 2, 2020.

[5] H. Zainuddin, M. S. Yahaya, J. M. Lazi, M. F. M. Basar, and Z. Ibrahim, “Design and Development of Pico-hydro Generation System for Energy Storage Using Consuming Water Distributed to Houses,” 2009.

[6] M. A. A.-A. Syed, M. M. N. Ali, F. S. Hossain, S. A. Haque, and A. H. Siddique, “Prospect of a Pico Hydro power plant based on irrigation pump in perspective of rural areas in Bangladesh,” in *2011 2nd International Conference on Electric Power and Energy Conversion Systems (EPECS)*, Sharjah, United Arab Emirates: IEEE, Nov. 2011, pp. 1–6. doi: 10.1109/EPECS.2011.6126793.

[7] L. Han, Y. Wang, G. F. Zhang, and X. Z. Wei, “The particle induced energy loss mechanism of Pelton turbine,” *Renewable Energy*, vol. 173, pp. 237–248, Aug. 2021, doi: 10.1016/j.renene.2021.03.136.

[8] T. I. Kusuma, C. B. Prasetyo, M. A. Jabar, and G. V. Golwa, “Rancang Bangun Prototype System Pico Hydro pada Penampungan Air Perumahan dengan Metode VDI 222,” vol. 11, 2020.