



Research Article

## Design of Pico-Hydro Power Plant with Monitoring System Based on Internet of Things

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### ABSTRACT

Currently the electrification ratio in Banyumas Regency is around 79%. This means, of the 1.7 million residents of Banyumas Regency, only around 21% have not enjoyed PLN electricity. Those whose homes have not yet had electricity are on average residents who are on the slopes of the mountain slopes, and some residents in several groves in remote areas in Banyumas Regency which are very far from the PLN electricity network. This problem can be overcome by providing electrical energy by utilizing renewable alternative energy, one of which is micro hydro or pico hydro power plants on an individual or residential scale. Therefore, this research designed a simulation of a pico hydro power plant using a Pelton turbine which is expected to be able to provide benefits to the general public, this tool is equipped with remote monitoring using Google Firebase based on the Internet of Things which can be monitored via the Android application for monitoring Voltage, current and power use the INA219 sensor which has been programmed on Arduino Uno and Node MCU ESP8266. This tool uses a 12-24 Volt DC generator, produces DC electricity which is stored in a 12 Volt 5 Ah battery which is then converted using an inverter to become AC electricity. In this test using a 5 Watt AC lamp load, the battery voltage which was initially 12.6 Volts was reduced to 9.9 Volts, the lamp load was able to light up for 1 hour. In measuring the voltage and current, the generator produces an average voltage of 15.9 Volts and a current of 50.2 mA.

### INTRODUCTION

In Indonesia, the potential for micro-hydro hydro power has not been optimally utilized, while for remote areas power plants with micro-hydro power plants (micro-hydro power plants) are still more profitable than connecting these areas with the PLN network which is far away. With Indonesia's geographical condition which has the potential for water with adequate head for small-scale power plants, it is very potential to develop small-scale power generation technologies commonly known as micro-hydro power plants (PLTMH) and pico-hydro. This PLTMH technology continues to be developed both in terms of equipment and in terms of efficiency [1]. Currently the electrification ratio (RE) in Banyumas Regency is around 79 percent. This means that of the 1.7 million residents of Banyumas Regency, around 21 percent do not enjoy PLN electricity. Those whose homes have not yet had electricity are on average residents who are on the slopes of the mountain slopes, and some residents in several groves in remote areas in Banyumas Regency which are very far from the PLN electricity grid. This problem can be overcome by providing electrical energy by utilizing renewable alternative energy, one of which is PLTMH [2].

Micro-hydro utilizes the potential energy of falling water (head). The higher the water fall, the greater the potential energy of water

that can be converted into electrical energy. The relatively small amount of energy produced by micro-hydro compared to large-scale hydropower plants has implications for the relatively simple equipment and the small area required for micro-hydro installation and operation. Thus, the micro-hydro generation system is suitable for reaching the availability of electrical energy networks in remote and rural areas. Some of the advantages found in micro hydro power plants are as follows:

- Compared to other types of generators, this PLTMH is quite cheap because it uses natural energy
- It has simple construction and can be operated in remote areas by skilled local residents with little training.
- Does not cause pollution.
- Can be combined with other programs such as irrigation and fisheries.
- Can encourage the community to be able to maintain forest sustainability so that the availability of water is guaranteed.

Based on this background, a solution is needed to increase the electrification ratio (RE) for residents whose homes have not yet been electrified, the large number of residents who are on the slopes of the mountain will have an abundance of natural resources from mountain water flow, so it has great potential to be developed as a pico-hydro hydroelectric power plant, namely

By utilizing the surrounding water flow to be used as a pico-hydro power plant, this pico-hydro power plant is very suitable for use by individuals who can meet their daily needs because the construction is cheap and easy to find. to be equipped with sensors for remote monitoring which is very time-efficient due to the many activities that must be carried out by the community in their daily needs.

Pico hydro Power Plant is the term used for power plant installations that use water energy. The condition of water that can be utilized as a source of electricity has a certain flow capacity and height from the installation. The greater the flow capacity and the height of the installation, the greater the energy that can be used to produce electrical energy. Hydroelectric power plants are distinguished by:

1. Large hydro : More than 100 MW
2. Medium hydro : Between 15–100 MW
3. Small hydro : Between 1–15 MW
4. Mini hydro: Power above 100 kW, but below 1 MW
5. Micro hydro : Between 5kW–100 kW
6. Pico hydro: The power released is 5kW

In 2013 there was a study that discussed monitoring of Micro Hydro Power Plants (PLTMH). The only electrical parameters that are monitored are the amount of voltage, current, and rotational speed generated and can be accessed via access points from wifi [3]. As for other studies that test how much electrical energy is generated in the difference in the rotation of the water currents. Using a mini water pump as a source of sending water to the turbine by changing the jet of water produced through the sprayer gun as a water flow rectifier, by changing the rotation of the sprayer gun between the initial spray positions of 10 cm, medium 2 cm, and low 4 cm. The lowest voltage is found in the sprayer gun rotation at the 4cm rotation position, which is 27.90 Volt. The medium voltage obtained at the 2 cm rotation position is equal to 39.50 Volt and the highest voltage is found in the sprayer gun rotation at the initial rotation position of 0 cm which is equal to 40.25 Volt [4].

One of the advanced technologies today is IoT. Basically, IoT technology has been found since the 1990s. The first device used IoT technology for turning on and off remotely over the Internet was a cake toaster. In 2000, the giant company of LG made a smart refrigerator that has its capability to determine whether or not to replenish the food items stored [5]. Those make the IoT gaining significant interest from researchers due to its potential for information processing and data exchange in various aspects of our everyday life. Now, in around 20 years since Kevin Ashton introduced the IoT in a United Nations ITU report [6], the IoT became capable of intelligently monitoring, managing, tracking, or positioning some particular system. IoT technology is a concept in which the device can transfer data over an internet network without requiring human-and- computer interaction. In other words, the user (human) does not need to control or monitor an object or device directly by their hand. The control and monitoring process can be done remotely via a smartphone, PC, or laptop.

Recently, IoT has been widely used in many topics; some of them are in smart shopping system [7], for saving electrical energy [8], for school attendance system [9], etc. IoT has been also

considerably used in the field of small-scale electric power such as the Pico hydro power plant. Pico hydro is one of the alternative energy sources with relatively small potential energy that can be used to provide electrical energy in remote areas. As conducted by [10], the authors deal with the IoT in order to measure the level as well as the flow of water in the pico hydro power generation system. Another development has been proposed by Moreno et al. [11], which focused on a web-based data acquisition platform integrated with IoT techniques to retrieve data of river water levels through cellular networks. Kafli and Isa [12] have also been developed a water surface IoT-based monitoring system. Their platform was capable to monitor the air quality and water quality of a river as well as the water level of the river. As with the shift of the turbine shaft, over-speed, and changes in frequency, each failure has a major impact on the economy because of lost productive hours as well as working hours. As mentioned in [13] and [14], the Pico hydro power plant requires a governing system to limit the variation of water turbine speed due to the weather change and variation of consumer load. Accordingly, it needs a system that capable to monitor the river flow speed remotely based on IoT.

## METHOD

The main focus of this study is design and build pico hydro and the addition of a monitoring system based on IoT for the output of the PLTPH, namely the value of current, voltage, power. Requirements analysis in the design of this system includes software, hardware, and supporting hardware requirements.

### *Need Analysis*

Software Requirements Analysis. The software specifications used in this design are as follows:

- 1) Operating system used: windows 2007
- 2) Applications used to program Arduino:
- 3) Arduino IDE 1.8.12.
- 4) Software for creating applications: MIT App Inventor
- 5) Software to scan QR code : MIT App Inventor 2

Next, analysis of hardware requirements to create a system is as follows:

- 1) Laptops
- 2) Arduino Uno
- 3) INA219 sensor
- 4) NodeMCU ESP8266

The last one, analysis of other hardware support needs is as follows:

- 1) Generators
- 2) Solar Charge Controllers
- 3) Accumulator
- 4) Inverter
- 5) Lights

### *Design of Hardware*

The design of a pico hydro power plant through Figure 3.1 is as follows. Block diagram are used to facilitate the design of the input, process and output sections in this study. The working principle of this Pico Hydro Power Plant Simulation is that water

flows into the reservoir and reaches a minimum height. Water will flow through the pipe which is pumped through the AC pump and then channeled to the turbine via the DC pump and drives the Pelton turbine. Then when the turbine rotates and causes the generator rotor to also rotate so as to convert mechanical energy into electrical energy. The output of the generator is stabilized with a solar charge controller. Electricity is stored in the battery, from the battery the electric current is converted which is initially DC to AC current using an inverter which can be used to turn on the lights, then sensor data generated from the generator output is sent through the IoT process.

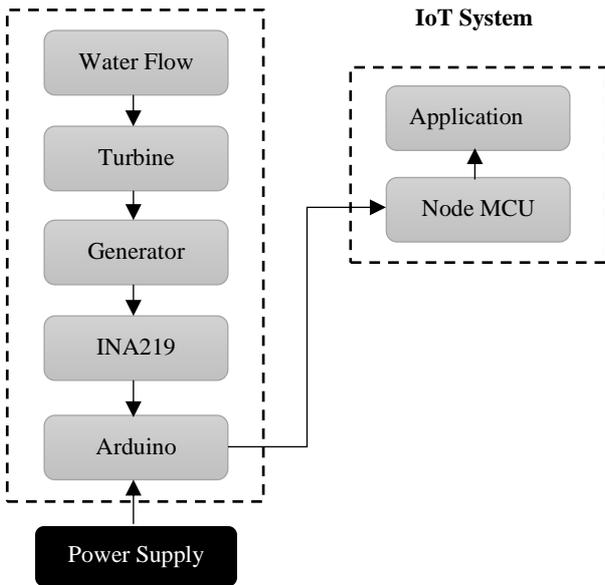


Figure 1. Diagram Block of the Proposed System

The digital data collected is then sent to the Arduino as microcontroller. Arduino will calculate the data and then sends it to the Node MCU as IoT module. The IoT module is a self-contained SoC (system on chip) with an integrated TCP/IP protocol that has the capability to connect to the internet network. This module will continuously send the data over the internet to the webserver. All the electronic components in the system are powered by the independent power supply that has a battery and portable solar cell for self-charging. Meanwhile, Figure 2 shows a wiring diagram of all components used in the monitoring system of this study.

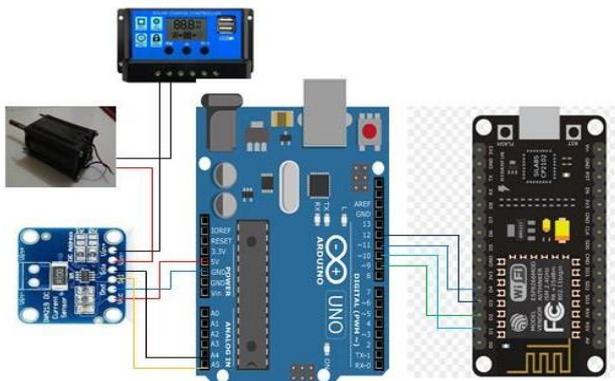


Figure 2. Wiring Diagram of the Proposed System

Electrical design, namely assembling from the output of the generator to the charge controller then to the battery, after to the battery, namely to the inverter to be changed from DC current to AC current then to switches and lights.



Figure 3. Wiring Electrical of the Proposed System

Next the process of installing the components of the pico-hydro power plant simulation begins with the installation of angle iron to form a rectangular table measuring 100cm x 50cm x 100cm and installation of the turbine housing, stands for the turbine axle and generator, then installation of the water flow path

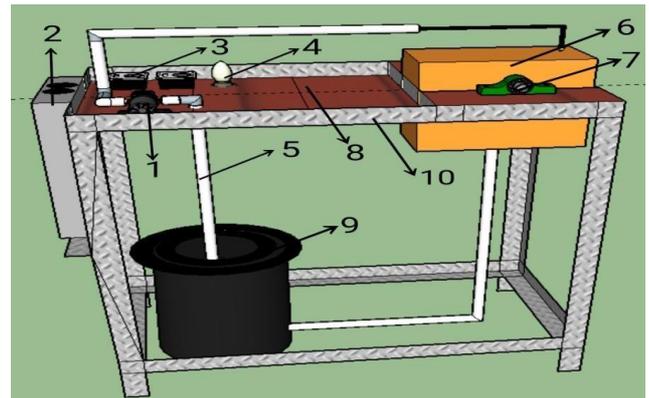


Figure 4. Design of Mechanical Components

Information:

1. Generator
2. Panel Box
3. Switching and Stop Contact
4. Light
5. PVC Pipe
6. Turbine House
7. Bearings
8. Wooden Board
9. Water Reservoir
10. Iron Elbow

**Design of Software**

*Design Board of NodeMCU and INA219*

So that NodeMCU and INA219 can be programmed and uploaded with Arduino IDE software, it is necessary to install the library board from NodeMCU and INA219:

1. Open the Arduino IDE Software.
2. Then go to File > Preferences.

3. After the Preferences tab opens, enter the following link (“http://arduino.esp8266.com/stable/package\_esp8266com\_index.json”) to the “Additional Board Manager URLs” section.
4. Enter the Board Manager (Tools> Board > Boards Manager).
5. Type "NodeMCU ESP8266" and INA219 in the search then install the board.
6. After that the Arduino IDE software can be used to program NodeMCU and INA219.

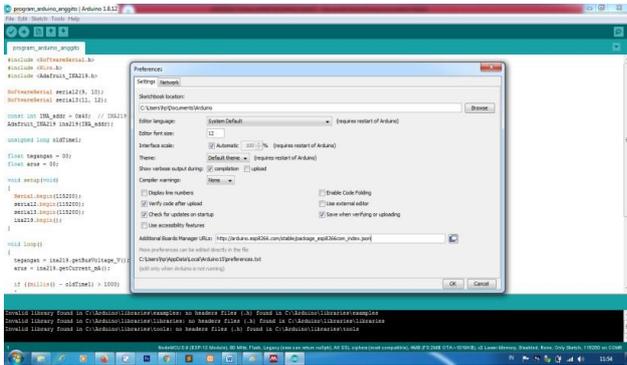


Figure 5. Additional Board Manager Board URL

7. Enter the Board Manager (Tools> Board > Boards Manager), as shown below:

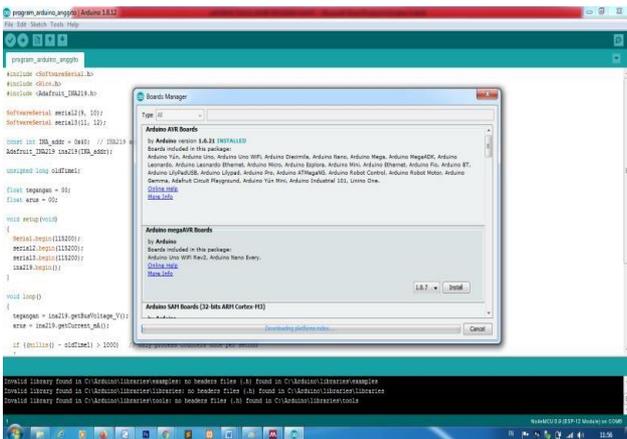


Figure 6. View of Board Manager Board

8. Type "NodeMCU ESP8266" and INA219 in the search then install the board, as shown in Figure 5.
9. After that the Arduino IDE software can be used to program NodeMCU and INA219.

*Design of Android Application Programming*

To create an android application that can monitor value data in the form of voltage, current and power, a platform is needed to create an android application, namely using MIT App Inventor:

1. Open a browser then enter the following link: <https://appinventor.mit.edu/>
2. After entering, click Create Apps!
3. Then sign in with a google account

4. After that, enter the application creation page by clicking "New Project".

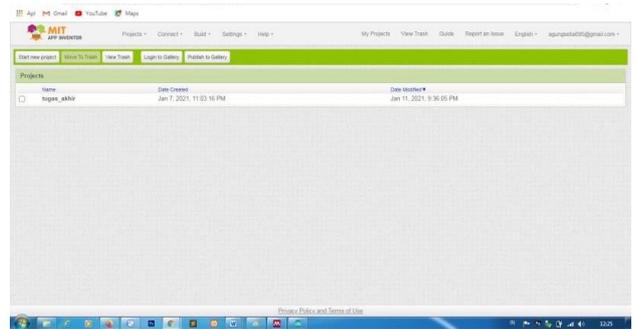


Figure 7.. Preview MITApp Inventor

5. Then set the design as desired

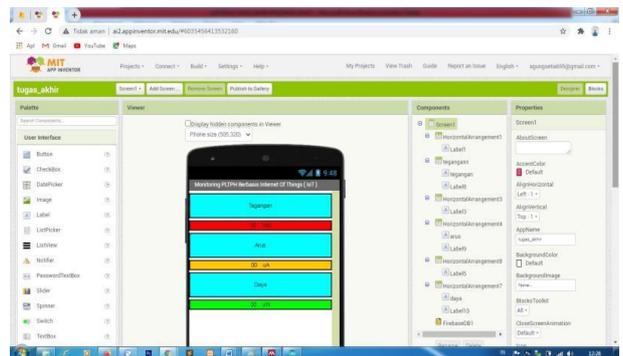


Figure 8. Project View for Android Application

6. Then for programming using block diagram programming to go to the programming page click blocks in the upper right corner, here is the block programming display as shown in Figure 8 below:



Figure 9. Display of Programming Block

After that, to export the application that has been made, click build then scan the QR code, following is the QR code display on MIT App Inventor.



Figure 10. Display of QR Code

This section will discuss the testing stage that should be conducted in order to ensure the water flow monitoring device may function as designed. In the development of software code, there is actually a debugging process. This debugging process is conducted to detect firstly and then subsequently remove the potential errors found in software code. The process is normally done by eliminating the language error or syntax error, the run-time error, and the logical error [15].

**RESULTS AND DISCUSSION**

Testing is carried out after the tool design is implemented with the aim of knowing and analyzing the success rate of a pico-hydro power plant. Besides that, testing is done to find out the weaknesses and limitations of the system that has been made. This is done to find out about the performance and function of the tool so that it can be used optimally. This section will discuss the testing was carried out to determine the output of the pico hydro power plant simulation.

In this test, two water pumps were used, namely an AC water pump and a DC water pump. The test used a 220 Volt PLN electricity source for the water pump source. The test starts with the water in the reservoir, then the pump plug is first installed in the socket that has been connected in series with the switch, then the pump is activated by pressing the switch. After that the AC and DC pumps will run. The AC pump will pump water from the reservoir to the DC pump, then the DC pump will flow the water to the turbine so that the turbine will rotate and activate the generator. The electricity generated by the generator will be adjusted first before entering the battery through the solar charge controller. The output voltage on the battery is in the form of DC electricity and then converted to AC electricity using an inverter. The output of the inverter enters the switch and is connected in series to the socket. The switch is activated to know the sensor data to be sent to Arduino and NodeMCU. The data from the sensor is current, voltage, and output power from the generator. The output of the generator will be processed on Arduino as a microcontroller then the data will be sent to NodeMCU via the Wi-Fi network and the results will be read in the application that has been made on the mobile phone.

The first test carried out in this design is a test of the generator output. The goal is to find out the output of the generator to be utilized in the generation system. The generator in the pico hydro power generation system that is made can work properly. The generator can provide electrical energy output to charge the battery and the results can be read on the charger controller. The

output of the generator at the pico hydro power plant produces an average voltage of 15.9 Volt, an average current of 50.2 mA. The overall summary of the current, voltage and speed data from the generator output can be seen in Table 1 below.

Table 1. Data Result of Output Generator

Testing (Minute-)	Voltage (Volt)	Current (mA)	Speed (Rpm)	Power (mW)
1	16.3	50.7	313.65	826.41
2	16.3	43.0	307.67	700.90
3	16.2	47.0	307.20	761.40
4	15.0	50.7	307.98	750.00
5	16.3	42.0	305.14	672.00
6	15.0	52.0	316.14	780.00
7	16.4	50.0	314.94	780.00
8	16.4	44.0	303.06	721.60
9	16.0	50.0	306.12	800.00
10	16.0	44.0	306.12	704.00
<b>Average</b>	<b>15.9</b>	<b>50.2</b>	<b>308.802</b>	<b>749.631</b>

Based on Table 1, the generator produces an average voltage of 15.9 Volt with the largest voltage output being 16.4 Volt and the smallest being 15 Volts. The output voltage on the generator tends to be stable. The average generator output current is 50.2 mA with the highest current being 52 mA and the lowest current being 42 mA. The output current on the generator tends to be stable. In testing the measurement of the output of the generator is carried out 10 times every 1 minute with the aim of whether the output of the generator for voltage and current will be stable.

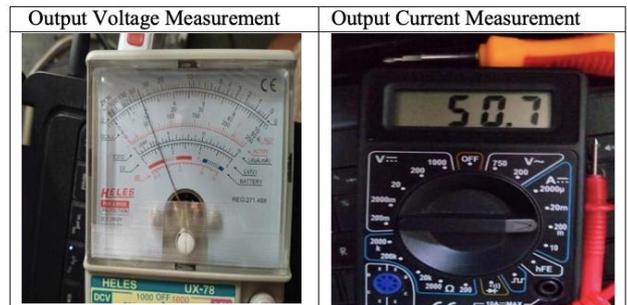


Figure 11. Generator Voltage and Current Measurement

The next test is testing the INA291 sensor data which is read on the android application. This test was carried out using a power supply as power with an output of 12 Volts DC and a mini fan as a load with a voltage specification of 12 Volts DC and a current of 0.15A. The following data has been read on the Android application:

Table 2. Data on Application Android

Testing (Minute-)	Voltage (Volt)	Current (mA)	Power (mW)
1	16.0	50.7	811.2
2	16.0	49.0	784.0
3	16.0	47.0	708.0
4	15.0	46.0	690.0
5	16.0	42.0	672.0
6	15.0	52.0	780.0
7	16.4	50.0	820.0
8	16.4	44.0	721.6
9	16.0	49.0	784.0
10	16.0	44.0	704.0
<b>Average</b>	<b>15.88</b>	<b>47.3</b>	<b>747.48</b>

The next test is testing the data that goes into Google Firebase. This test aims to find out the sensor value data sent to Google Firebase and compare the sensor value data from the application, following on the Table 3 which is the result of data testing on Google Firebase:

Table 3. Data on Google Firebase

Testing (Minute-)	Voltage (Volt)	Current (mA)	Power (mW)
1	16.0	50.7	811.2
2	16.0	49.0	784.0
3	15.0	47.0	705.0
4	15.0	46.0	690.0
5	16.0	42.0	672.0
6	15.0	52.0	780.0
7	16.4	50.0	820.0
8	16.4	44.0	721.6
9	16.0	49.0	784.0
10	16.0	44.0	704.0
<b>Average</b>	<b>15.78</b>	<b>47.3</b>	<b>747.18</b>

Data testing on google firebase was carried out ten times. This treatment is also the same as testing the data that appears on the android application. The data sent from both google firebase and the android application is accurate or exactly the same.

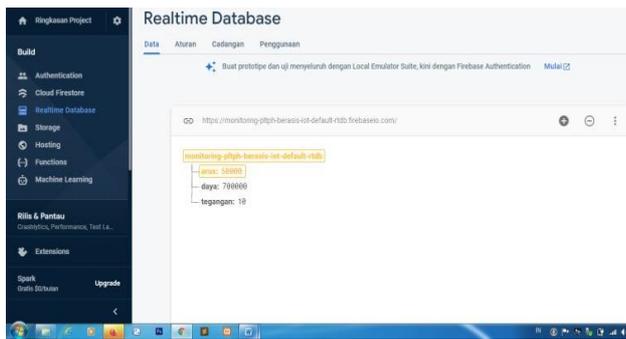


Figure 12. Display of Google Firebase

## CONCLUSIONS

The conclusion drawn from the design of a pico-hydro power plant accompanied by an IoT-based monitoring system is that the PLTPH that has been made works well as evidenced by a stable and constant turbine rotation. The selection of the pump and the calculation of the flowing water discharge greatly affect the turbine speed. This tool uses a 12-24 Volt DC generator, produces DC electricity which is stored in a 12 Volt 5 Ah battery which is then converted using an inverter to become AC electricity. In this test using the battery voltage which was initially 12.6 Volt was reduced to 9.9 Volt, the lamp load was able to light up for 1 hour. In measuring the voltage and current, the generator produces an average voltage of 15.9 Volt and a current of 50.2 mA, with an average generated power of 749.631 mW. Even in the Android application and Google Firebase, the value is not much different, the average voltage is 15.88 Volt (Android); 15.78 Volt (firebase), the average current rating is 47.3 mA, and the average power rating is 747.48 mW (android); 747.18 (firebase).

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