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Prototype Design of Micro Hydro Power Plant with Utilization of Irrigation Water in Rice Fields Based on IoT

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Abstract: Irrigation water on the rice field embankments aims to irrigate the rice fields properly, in this study irrigation water is increased not only as a source of water for rice growth but also as an electricity supply around the rice fields. Water will drive a turbine connected to a DC generator to produce a DC electricity source. Then the electricity generated will be monitored using the IoT (Internet of Things) application. The results obtained areof 12 volts, with a water height of 0.98 meters, a water volume of 0.22 m3, and from these results the system can provide electricity supply for smart farming which is applied around the rice fields, from these results it is hoped that rice production can increase and also farmer independence in electricity supply can be created.

Keywords: IoT; Irrigation; Micro Hydroelectric Power Plant

Introduction

As an agricultural country, agricultural success has a major impact on food security and community welfare. However, to achieve optimal agricultural results, it is necessary to pay attention to various aspects that support plant growth, including irrigation. Irrigation is one of the important efforts in agriculture to provide and manage water to support plant growth.

Energy consumption in Indonesia increases every year, this is due to the rapid growth of industry and population in Indonesia. Energy consumption in Indonesia in 2019 was 989.9 million Barrel Oil Equivalent (BOE) with an average growth of 3.5% per year from 2019 to 2050 (CNBC Indonesia, 2023). The energy crisis problem has resulted in efforts to increase domestic energy production by developing the potential of various energy sources in Indonesia to realize national energy independence and resilience. In addition to the problem of energy availability, the need for environmentally friendly energy is also increasing along with efforts to maintain environmental sustainability. One of the potentials being developed is energy resources that generally come from biomass and organic waste. New renewable energy in the primary energy mix in 2025 is set at a minimum of 23% and in 2050 at a minimum of 31% (Wahyuni & Ardiansyah, 2022).

Micro Hydro Power Plant (PLTMH) is a type of power plant that is classified as a new renewable energy source (Ofosu et al., 2019), which is one of the alternative sources of electrical energy for the community besides fossil energy. PLTMH brings many benefits, especially for rural communities throughout Indonesia, and has an impact on the environment. For those who live in remote and difficult-to-reach areas due to the installation of the State Electricity Company (PLN), PLTMH is a solution that guarantees independence of electrical energy for social activities and daily needs, but for the environment, PLTMH is an energy generator without disturbing the balance of nature because it does not cause pollution to the environment other than noise pollution which has little impact on the surrounding

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environment. At a time when other energy sources are running low and causing negative impacts, water is a very important energy source because it can be used as a cheap energy source to generate electricity and does not cause pollution. In addition, Indonesia is rich in water resources so it has great potential to generate electricity through PLTMH.

Micro Hydro Power Plant is a technology that utilizes the use of water which is then converted into electrical energy that can be used by the community. Hydropower has several advantages over most other resources. These advantages include high reliability, proven technology, high efficiency (around 90%), very low operating and maintenance costs, flexibility, and large storage capacity. In making a micro hydro power plant, it is highly recommended to know the location first. Examine where and how to divert the water flow, identify what components are needed in the landscape (JICA, 2003). Figure 1 shows the mapping process for MHP development.

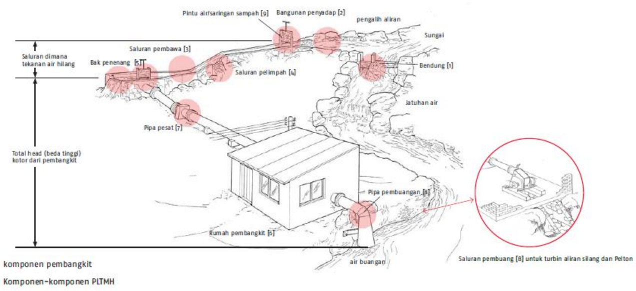


Figure 1. General Overview of PLTMH Development

This research is an integration of the IoT pest detection system where the power of the system uses minihydro.(Widanti et al., 2024)so that the system can stand independently and be integrated for monitoring rice productivity. From previous research, many parties have conveyed about making microhydro and how to monitor it.(Ardo et al., 2022; Ichsan Murtadlo, Tri Wrahatnolo, Subuh Isnur Haryudo, 2016; Mirmanto et al., 2022; Saputra et al., 2022; Kiki Kananda, Dean Corio, 2020; Suyanto et al., 2020; Dsl et al., 2021), then there is replacing the membrane protons for optimal results (Kalpana Bijayeeni Samal & Renu Sharma, 2024), by studying the efficiency of microhydro it will produce optimal energy (P. Marcon, I. Vesely, F. Zezulka, Z. Roubal, 2015), how to optimize microhydro (Yulianus Rombe Pasalli*, 2014; Joseph L, 2023; Roodsaria & EP Nowickia* and P. Freere, 2013; Jessica Hanafi* and Anthony Riman, 2015; Utomo, 2023), by utilizing IoT with the remote system method (Aulia et al., 2021; Sumiyarso et al., 2022; Sofyan et al., 2022; Firdaus et al., 2022; Agung et al., 2023; Salam et al., 2023; Asrafi et al., 2019; Herbelubun et al., 2017; Arief et al., 2021; ,Sumiyarso et al., 2022) design with 3000 to 5000 watts (Suryatna, 2020), and implementation in the field (Yastica et al., 2024).

The novelty of the system to be created is to create a mini MHP plant that can be monitored using a cellphone and its voltage will be stored in a battery to support lighting in the rice field area. This device also supports the provision of power for IoT-based agricultural systems to monitor pests and soil fertility, thus creating smart rice fields. The rice monitoring system which is also a monitoring device has resources from the use of irrigation water.

Method

Hardware Design

The working process of this tool begins with damming the water, then flowing it through a pipe and at the end of the pipe a turbine and generator are installed which will rotate if there is water flow, where the higher the water discharge that comes out, the higher the electrical voltage produced. The available electricity will be stored in the battery and will also be monitored with the application to determine the output voltage. The system block diagram is shown in Figure 2, while the complete system design is shown in Figure 3.

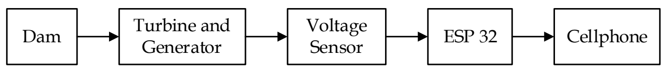


Figure 2. System block diagram

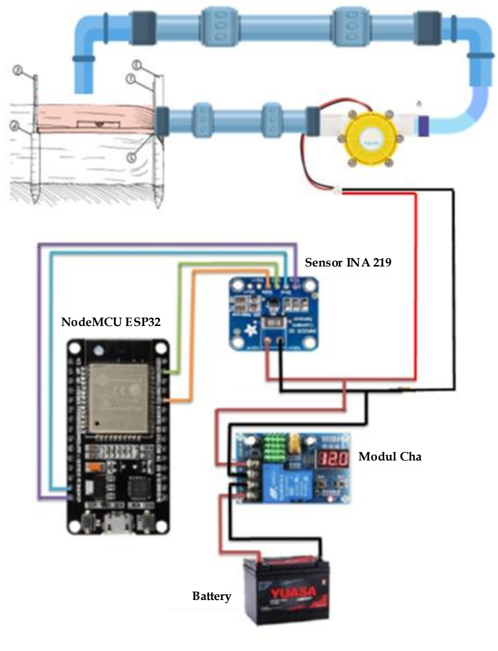
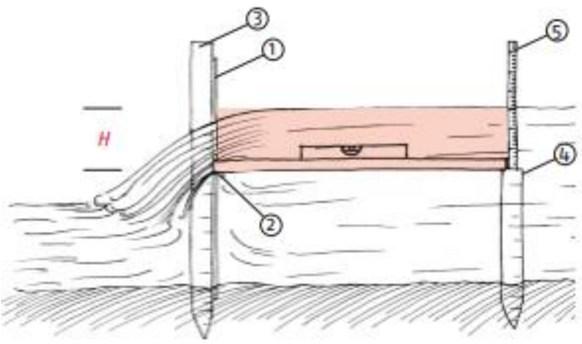


Figure 3. MHP System

Analysis

Analysis was performed on the output of the sensor values in the form of power and voltage. In addition, the first thing to do was to analyze the calculated water discharge value obtained (as seen in Figure 4), and the estimated discharge measured (as seen in Table 1).



1 = dam plate
2 = sharp lips
3 = bolt
4 = measuring pole
5 = measuring ruler
B = dam width (cm)
H = height of upstream weir flow (cm)

Figure 4. Dam analysis to determine discharge

Table 1. Water discharge measurement

High overflow	Width of the dam = B (cm)								
height (cm)	10	20	30	40	50	60	70	80	90
5	2	4	6	8	10	12	14	16	18
7.5	4	7	11	15	18	22	25	29	33
10	6	11	17	22	28	34	39	44	50
12.5	8	16	23	31	39	47	55	62	70
15	10	21	31	41	51	62	72	82	93
17.5	13	26	39	52	65	78	91	103	116
20	16	32	47	63	79	95	110	126	142
22.5	19	38	57	75	94	113	132	150	170
25	22	44	66	88	110	132	154	177	199
27.5	26	51	77	102	127	153	178	204	229

Results and Discussion

Data generatedThis study is related to the use of irrigation water, so the simulation is carried out by setting the water level at a certain height. This is done because of the conditions in the field where irrigation water sometimes overflows due to the influence of rain or when the water gates in the main river are opened, and will decrease if the water gates in the main river are closed or in other conditions it does not rain. The test results are in the form of voltage generated by a mini generator installed with a variable, namely the height of irrigation water.

Mini Generator Testing

This test is done by comparing the output with variations in water discharge and the DC voltage results produced by the installed microhydro. Figure 5 shows the realization of the tool made, and Table 2 shows the type of generator and the capacity produced, where we use the type of microhydro with a capacity of <100W, while Table 3 shows the results of measuring water discharge with the voltage produced.

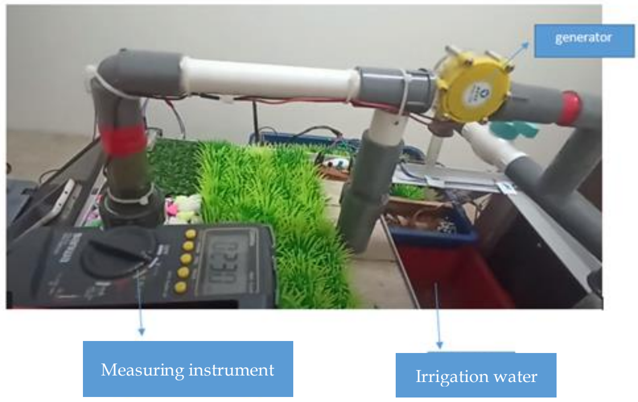


Figure 5. Device realization

Table 2. Generated Capacity

Power plant	Capacity
Big hydro	≥ 100 MW
Medium hydro	15–100 MW
Small Hydroelectric Power Plant	1–15 MW
Mini hydro	100 kW–1 MW
Micro hydro	< 100W
Pico hydro	Below 5 kW

Table 3. Measurement Data

Water level (m)	Water volume (m3)	Time (s)	Discharge (m3/s)	Micro hydro power capacity (W)	Voltage (VDC)
0.98	0.22	50	0.0044	28,649	12
0.98	0.22	49	0.0045	29,234	12.9
0.98	0.22	50	0.0044	28,649	12
0.5	0.11	25	0.0044	14,617	9
0.5	0.11	25	0.0044	14,617	9
0.5	0.11	23	0.0048	15,888	9.2
0.25	0.055	10	0.0055	9,136	5
0.25	0.055	10	0.0055	9,136	5
0.25	0.055	9	0.0061	10,151	6.3

The testing procedure with manual water filling is as follows:

a. Water is filled into the reservoir to a certain height, the height of which varies from 0.98 meters, 0.5 meters, 0.25 meters.
b. Next, fill the water manually by turning the water valve, then record the filling time using a stopwatch and calculate the amount of water in liters to get the volume of water at each height.
c. Water discharge is calculated using the formula:

$$Q = \frac{V_{air}}{t} \quad (1)$$

Where Q is the water discharge (m3/s), Vair is the water volume (m3) and t is the time (seconds).

d. Then the water is flowed to the installed generator and the resulting voltage can be seen.

e. Power capacity is calculated using the formula:

$$P = \eta \times \rho \times g \times Q \times h \quad (2)$$

Discharge is the result of dividing the input volume by time. The resulting water discharge will affect the mechanical energy that can rotate the turbine to produce electrical energy to light the lights and also the soil moisture monitoring device installed in the smart farm.

Figure 6 shows the relationship between discharge and power capacity obtained from monitoring results. Figure 7 shows the relationship between voltage and power capacity obtained.

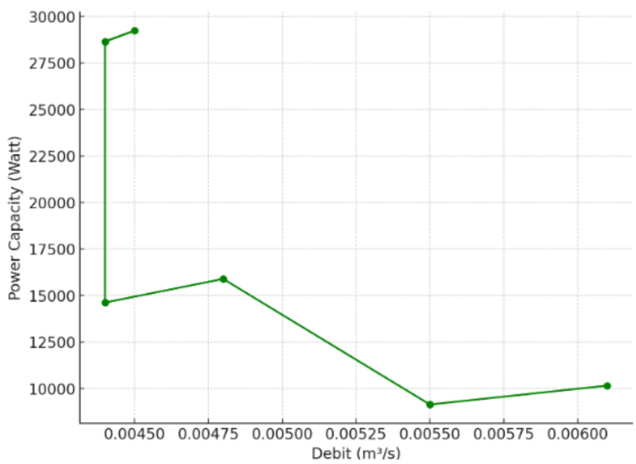


Figure 6. Relationship Between Power Capacity and Discharge

The graph shown illustrates the relationship between water discharge and power capacity in a micro hydro power plant.This graph shows that the power capacity changes with the variation in water discharge.

1. **Power Capacity at Low Flow (0.0044 m³/s)**: At a water discharge of around 0.0044 m³/s, the power capacity generated is around 28,649 Watts. This value is relatively stable even though there is a slight variation in discharge, such as at 0.0045 m³/s which produces 29,234 Watts of power. This shows that small changes in discharge do not have a major impact on power capacity, especially at low discharges.
2. **Power Capacity Decrease at Medium Discharge (0.0044 m³/s at lower elevation)**:When the discharge remains the same at 0.0044 m³/s, but the water height (head) decreases from 0.98 m to 0.5 m, the power capacity drops drastically to about 14,617 Watts. This shows that in addition to the discharge, the water height (head) greatly affects the power generated. At the same discharge, the higher the head, the greater the potential energy that can be converted into electricity.
3. **Fluctuations in Medium to High Flow**:At a flow rate of 0.0048 m³/s, the power generated slightly increases to 15,888 Watts, but at a higher flow rate (0.0055 m³/s), the power capacity drops to around 9,136 Watts. This power decrease could be due to other factors such as decreased turbine efficiency or decreased water level.
4. **Small Increase in Highest Discharge (0.0061 m³/s)**:Interestingly, when the discharge is further increased to 0.0061 m³/s, the power capacity increases again to 10,151 Watts. This may reflect that at higher discharges, the system starts to function more efficiently again, or that there is an adjustment in how the system handles the larger water flows.

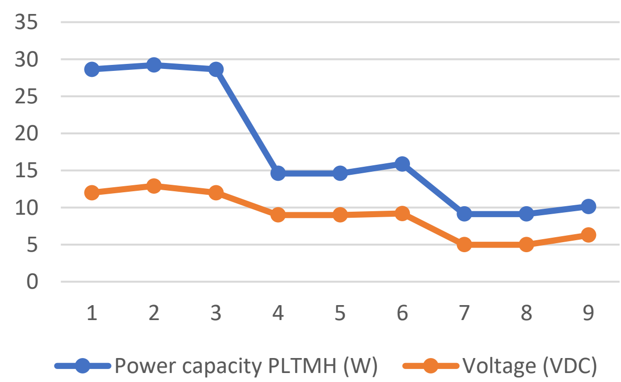


Figure 7. Relationship between power capacity and voltage

Low to medium power capacity (under 15,000 Watts): At the beginning of the graph, a low power capacity of around 9,136 Watts produces a voltage of 5 VDC. As the power capacity increases, the voltage starts to increase until it reaches around 6.3 VDC at 10,151 Watts. The voltage increase is quite significant at the higher power capacities, with a sharp jump from 5 VDC to 6.3 VDC. This shows that even though the power is relatively small, there is a fairly linear increase in voltage with increasing power.

Medium power capacity (approximately 14,617 to 15,888 Watts): At this point, the higher power (around 14,617 to 15,888 Watts) gives a voltage of around 9-9.2 VDC. Although there is a slight increase in power, the voltage only increases slightly from 9 VDC to 9.2 VDC. This shows that in the middle power range, the relationship between power and voltage is more stable or less linear than in the low power range.

High power capacity (above 28,000 Watts):At the highest power capacity (around 28,649 to 29,234 Watts), the voltage increases drastically to 12 to 12.9 VDC. This shows that at high power capacity, the MHP system produces much higher voltage, with a significant spike compared to medium power.

Non-linearity in some parts: The relationship between power and voltage appears to be non-linear, especially at low to medium powers. At low powers, the voltage increases significantly, but at medium powers, the increase is more stable. Then, a significant spike occurs again at higher powers.

System efficiency and limitations: A voltage increase that is not proportional to power at medium power may indicate that the efficiency of the turbine or generator system is limited to a certain power range. As the system passes a certain capacity point, efficiency may decrease or higher current may be required to compensate for the decrease in efficiency.

Voltage usage: Higher voltages at large power capacities are usually required to drive equipment with higher power, or to ensure the stability of the power generation and distribution system. Overall, this relationship shows that the greater the power generated by the MHP, the higher the voltage required or generated, but with some fluctuations at medium power levels.

User Interface Design

The design of this user interface begins with the use of blynk, where all parameters will be displayed in the application. Figure 8 shows the blynk application for monitoring.

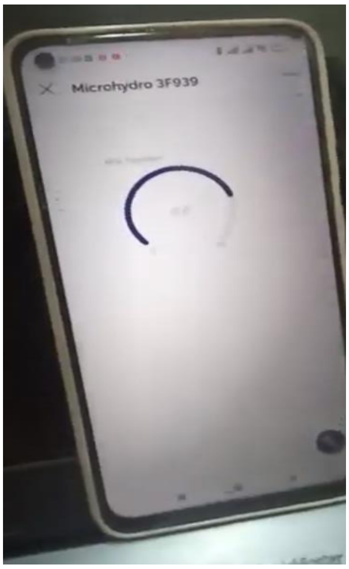


Figure 8. User interface

Conclusion

The water discharge produced will affect the mechanical energy that can rotate the turbine so that it produces electrical power to supply the lights and also the soil moisture monitoring device installed on the smart farming with a smart farming supply of 12 volts, with a water height of 0.98 meters, a water volume of 0.22 m3

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Author Contribution

Validation WH, NW, ARH, AH, BM, conceptual, data preparation, calibration; SWL data analysis and writing review; WH methodology and writing review

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Conflict of Interest

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