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Design and Development of Microhydro Power Plant Based on the Arduino Uno and Internet of Things (IoT)

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ABSTRACT

In this paper, we present a novel paradigm that leverages the potential of a micro-hydro power generation system. This system effectively utilizes the energy derived from the water bodies within fish ponds to power technological systems at a chicken egg farming establishment located in Padamulya Village, Ciamis, West Java, Indonesia. The conceptualization and implementation of this innovative framework have been meticulously orchestrated through the seamless integration of an Arduino Uno microcontroller and a NodeMCU ESP8266 module. These critical components serve as the cornerstone for the precise and efficient processing of voltage and current data streams, while also facilitating seamless connectivity to the Internet of Things (IoT) ecosystem, establishing a symbiotic relationship with the Blynk platform. The culmination of this research endeavour underscores the achievement of multifaceted objectives. First and foremost, it demonstrates the successful deployment of a micro-hydro power generation infrastructure, effectively harnessing the latent hydrokinetic energy potential within the aquacultural environment. Furthermore, our findings highlight the seamless and robust operation of the IoT-enabled ecosystem for real-time monitoring and data processing, ultimately resulting in the successful visualization and dissemination of crucial parameters related to electrical output, current, and voltage. Consequently, the synthesis of these elements and their concurrent execution exemplify the convergence of sustainable energy generation and advanced technological interfacing, marking a significant step towards the realization of eco-friendly and technologically advanced agricultural practices.

1. Introduction

The confluence of burgeoning energy demands and the imperative of environmental sustainability has spurred an array of innovative solutions across various domains [1,2]. Within the ambit of agricultural practices, this nexus is particularly pronounced, necessitating the exploration of

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novel approaches to concurrently augment productivity and minimize the ecological footprint [3,4]. In this context, the present research embarks upon a pioneering exploration into the realms of renewable energy utilization within the agricultural sector, with a specific focus on the integration of microhydro power generation technology [5-8]. The locus of this investigation is the idyllic Padamulya Village, nestled amidst the verdant landscapes of Ciamis, West Java, Indonesia, where a burgeoning chicken egg farm seeks to meld technological illumination with sustainable energy sources.

The relentless pursuit of sustainable energy sources has become an imperative in the contemporary world, driven by the twin challenges of dwindling fossil fuel reserves and environmental degradation [9,10]. In this context, the harnessing of small-scale hydropower, through the development of Microhydro Power Plants (MHPs), emerges as a pivotal solution to address these challenges. MHPs, characterized by their ability to generate electricity from the kinetic energy of flowing water, offer a promising avenue for decentralized and eco-friendly power generation [11-14].

In this section, we present a literature review encompassing a range of studies that have explored applications, difficulties, and prospects regarding the establishment of a proficient monitoring system for hydropower facilities. Ginting *et al.,* [15] elucidate the process of monitoring output power within microhydro power plants via an Internet of Things (IoT) system. This monitoring encompasses parameters such as voltage, current, and water volume, and employs a microcontroller. In a similar vein, Putri *et al.,* [16] undertake the design and analysis of the impact of nozzle angle and nozzle diameter on power generation in Pelton turbines within microhydro power plants. The IoT is utilized to monitor generator voltage and current as part of this analysis. Kumar and Saini [17] propose an architectural framework for an IoT-based cloud computing-enabled monitoring system for hydropower plants. Their emphasis lies in real-time performance monitoring, owing to the inherent complexity of predicting machine behaviour using existing models. Hazrina *et al.,* [18] engineer a simulation for a pico hydro power plant employing a Pelton turbine, with an aim to provide benefits to the broader community. This tool incorporates remote monitoring through Google Firebase, hinging on IoT principles, and facilitates monitoring of voltage, current, and power, all managed through the INA219 sensor programmed on Arduino Uno and Node MCU ESP8266. Akib *et al.,* [19] offer a forward-looking perspective on microhydro power generation and its associated monitoring system. Meanwhile, Suhaili *et al.,* [20] effectively implement IoT technology to assess the energy efficiency of a Hybrid Energy System, specifically in the context of supplying electricity to a guard house. Their IoT system encompasses sensors and software for real-time recording and analysis of electricity supply from the system. Al-Humairi *et al.,* [21] introduce a portable microhydro power generation system featuring floating turbine mechanisms, augmented by an IoT-based online monitoring system. This monitoring system is seamlessly integrated with the Blynk application to facilitate real-time power monitoring. Finally, Has *et al.,* [22] advanced control techniques for Field Voltage Control (FVC) and Excitation Limiting Control (ELC) with the aim of enhancing time response. FVC is managed through a Fuzzy-Proportional Integral (Fuzzy-PI) controller to ameliorate time response, while ELC is optimized through an Adaptive Neuro Fuzzy Inference System-Proportional Integral Differentia (ANFIS-PID) controller to mitigate the impact of load variation on Total Harmonic Distortion (THD) levels. The research gap lies in the need for broader investigations that examine the transferability of these findings to other geographic locations and agricultural settings. Additionally, the scalability of the microhydro power generation system and IoT technology integration should be explored to determine if these solutions can be applied to larger or more diverse agricultural operations.

The research problem addressed in this study revolves around the need to optimize the utilization of microhydro power generation systems in the context of chicken egg farming establishments located in regions like Padamulya Village, Ciamis, West Java, Indonesia. Specifically, the study aims to investigate and overcome challenges related to efficient energy harnessing from water bodies within fish ponds, as well as the real-time monitoring and data processing of key electrical parameters in conjunction with Internet of Things (IoT) technology. This research seeks to answer how to best deploy and integrate microhydro power systems for sustainable energy generation within aquacultural environments, while ensuring seamless connectivity and reliable data processing, thus advancing eco-friendly and technologically advanced agricultural practices.

In this paper, we harnessed the potential of a water energy source in conjunction with a 24V DC generator to efficiently convert the kinetic energy of water into electrical power. Additionally, the integration of software and hardware was achieved through the utilization of the Arduino Uno and NodeMCU ESP8266 module. This integrated system facilitates the real-time monitoring of current, voltage, and energy parameters, all of which are conveniently displayed on the IoT Blynk platform.

2. Methodology

2.1 Site Selection and Setup

The research commenced with the meticulous selection of an appropriate site, situated within Padamulya Village, Ciamis, West Java, Indonesia. This site was strategically chosen to house the microhydro power generation system, owing to its proximity to water bodies within fish ponds and the concurrent presence of a chicken egg farming establishment. The accessibility of these resources played a pivotal role in the project's feasibility.

2.2 Micro-Hydro Power Generation System Design

The cornerstone of our methodology was the design and realization of a microhydro power generation system. This system was specifically tailored to harness the kinetic energy latent within the water bodies of the fish ponds. A 24V DC generator was employed to efficiently convert this kinetic energy into electrical power. Figure 1 illustrates the design of a microhydro power generator, which was created using Inventor software. This tool is responsible for rotating the turbine shaft to generate mechanical energy, which subsequently drives the generator to produce electricity. Additionally, the power plant is equipped with tools for monitoring current, electric voltage during battery charging, and sensors for AC output.

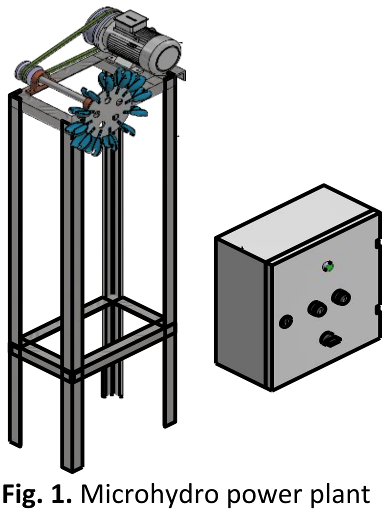

Fig. 1. Microhydro power plant design using Inventor software

2.3 Integration of Hardware and Software

The next crucial phase involved the seamless integration of hardware and software components. An Arduino Uno microcontroller and a NodeMCU ESP8266 module were meticulously selected to serve as the technological backbone of the system. These components were chosen for their prowess in processing voltage and current data streams with precision and efficiency.

In this study, we employed a trio of primary sensors within the monitoring system, specifically the ZMPT101B (voltage sensor), ACS712 (current sensor), and PZEM-004T (sensor capable of monitoring output AC, power, and energy parameters). Furthermore, the hardware infrastructure was fortified with an array of essential components, encompassing relays, charge controllers, low voltage disconnect modules, inverters, DC generators, Pelton turbines, NodeMCU ESP8266 modules, as well as 12V and 15A batteries, thereby constituting a robust and comprehensive instrumentation suite for our investigative purposes. The electronic schematic for a microhydro power plant using fritzing software can be seen in Figure 2.

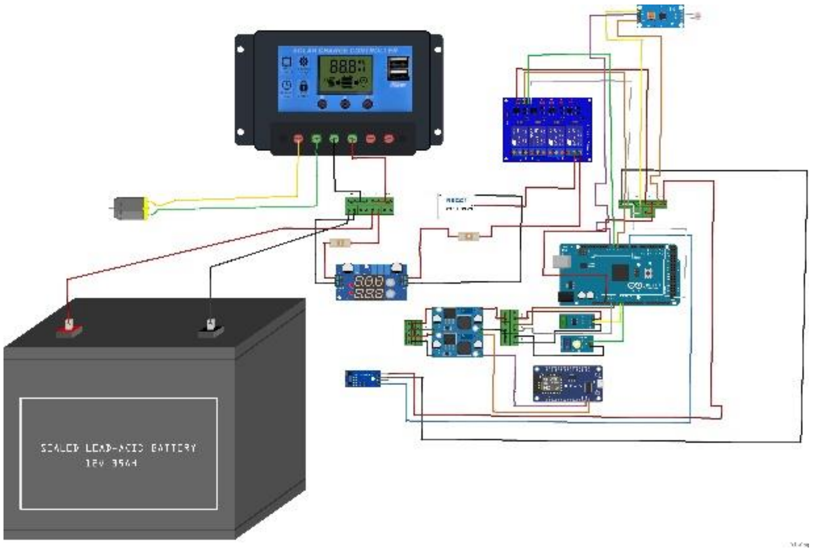

Fig. 2. Electronic schematic for a microhydro power plant using fritzing software

2.4 Internet of Things (IoT) Connectivity

The integration of the Arduino Uno and NodeMCU ESP8266 module facilitated connectivity to the Internet of Things (IoT) ecosystem. This step was pivotal in establishing a real-time monitoring and data processing infrastructure. The IoT connectivity was realized through a symbiotic relationship with the Blynk platform, a renowned IoT framework. Within the microhydro power plant apparatus, the real-time monitoring of current and voltage for battery charging is facilitated through the integration of the Blynk platform, meticulously configured to receive sensor data. Figure 3 vividly depicts the graphical representation of the current monitoring interface, alongside the voltage parameters employed for battery charging and the measurement of AC power output.

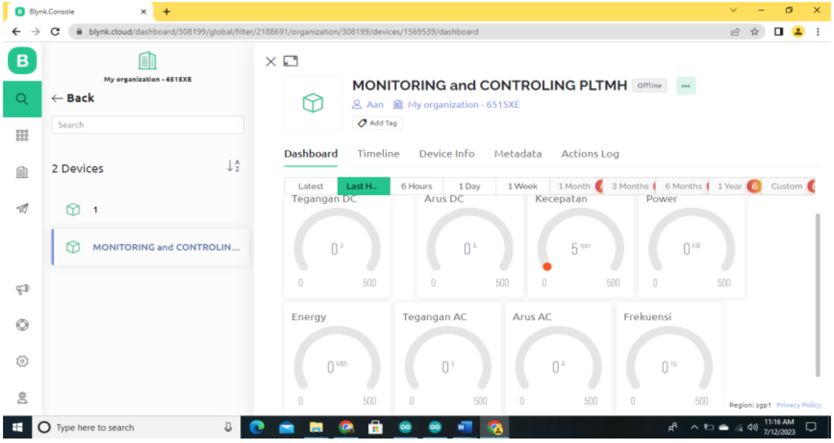

Fig. 3. Blynk platform display

2.5 Data Analysis and Visualization

With the system in place, data collection and analysis became the focal point of the research. Voltage and current data streams were continuously monitored and recorded in real-time. These data streams were essential for assessing the electrical output of the microhydro power generation system. The culmination of the research endeavour saw the successful visualization and dissemination of critical parameters. This included real-time displays of electrical output, current, and voltage on the Blynk platform. These visualizations served to assess the system's performance and efficiency.

3. Results and Discussion

A microhydro power plant, also known as a small-scale hydroelectric power plant or mini-hydro power plant, is a renewable energy system that generates electricity from the energy of flowing water [23-28]. Unlike large-scale hydroelectric power plants, which typically require a significant dam and reservoir system, microhydro power plants are designed for smaller bodies of water and lower flow rates. In this work, the frame base is made of angle iron with a pole height of 105 cm, a width of 30.5 cm and a thickness of angle iron of 1.4 mm. The frame base is used to support the main components of a microhydro power plant as shown in Figure 4.

Fig. 4. Microhydro power plant

In addition to this, the microhydro power generator hardware, which is based on the Arduino Uno microcontroller, serves the purpose of providing voltage derived from a battery. This battery, in turn, is charged through a generator. The hardware components encompass a range of essential elements, including generators, Low Voltage Disconnect (LVD) modules, charge controllers, accumulators/batteries, Arduino Uno microcontroller, NodeMCU, 4-channel relay modules, voltage sensors, current sensors, and PZEM-004T sensors, as illustrated in Figure 5.

Fig. 5. Hardware control box of the microhydro power generator

Furthermore, with the help of Blynk, we can develop a mobile or web application microhydro power plant in real-time. These parameters might include voltage levels, current, battery status, and generator performance. Also, we can display this data on a user-friendly dashboard for easy access. Also, Blynk can be configured to log historical data, which is useful for analysing trends and track of the power plant performs over time. In addition, Blynk can send notifications or alerts when specific conditions are met or when there are anomalies in our system. If the battery voltage drops below a certain threshold or if there is a sudden increase in current, we can receive an alert on our smartphone. The monitoring results using IoT in the microhydro power plant can be seen in Figure 6.

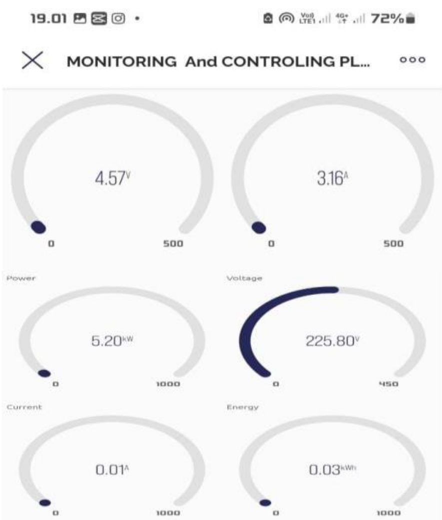

Fig. 6. The monitoring results using IoT of the microhydro power plant in real-time

Table 1 represents a different set of measurements taken at different times or under different conditions during the battery charging process. For example, the first row shows that when the current was 0.02 amperes and the voltage was 5.00 volts, the energy delivered to the battery was 0.100 watts. This result provides a record of the electrical characteristics observed during the battery charging tests for the micro-hydro power plant. It can be used for analysis, evaluation, and comparison of the system's performance under various conditions. The measured current and voltage are unstable due to unstable water speed, thus affecting the resulting current and voltage.

Table 1
Test results of voltage and current sensors on battery charging for microhydro power plants using ZMPT101B sensor and ACS712 sensor

No	Current (A)	Voltage (V)	Energy (W)
1	0.02	5.00	0.100
2	0.01	4.87	0.0487
3	0.02	5.11	0.1022
4	0.02	5.17	0.1034
5	0.02	5.28	0.1056
6	0.02	5.33	0.1066
7	0.01	5.12	0.0512
8	0.02	5.11	0.1028
9	0.01	4.86	0.0468
10	0.01	5.13	0.0513

4. Conclusions

This paper has introduced a pioneering paradigm that harnesses the untapped potential of a microhydro power generation system, utilizing energy extracted from water bodies within fish ponds to power technological systems at a chicken egg farming establishment in Padamulya Village, Ciamis, West Java, Indonesia. The successful implementation of this innovative framework was achieved through the integration of an Arduino Uno microcontroller and a NodeMCU ESP8266 module. These components played a pivotal role in processing voltage and current data streams efficiently while connecting seamlessly to the Internet of Things (IoT) ecosystem, thanks to their integration with the Blynk platform.

The culmination of our research demonstrates the achievement of several key objectives. Firstly, it signifies the successful deployment of a microhydro power generation infrastructure, effectively harnessing the latent hydrokinetic energy potential inherent within the aquacultural environment. Additionally, our findings highlight the seamless and robust operation of the IoT-enabled ecosystem for real-time monitoring and data processing. This has led to the successful visualization and dissemination of critical parameters related to electrical output, current, and voltage.

The synthesis of these elements and their concurrent execution represents a significant milestone in the convergence of sustainable energy generation and advanced technological interfacing. This convergence marks a noteworthy stride toward the realization of eco-friendly and technologically advanced agricultural practices. By efficiently utilizing renewable energy sources, such as microhydro power, and leveraging IoT technologies, we are not only contributing to more sustainable and environmentally conscious farming practices but also paving the way for innovative solutions in the broader agricultural sector.

In summary, the successful fusion of microhydro power generation and IoT-enabled monitoring systems showcased in this study exemplifies a promising path toward more efficient, sustainable, and environmentally friendly agricultural practices. This research serves as a valuable foundation for further exploration and adoption of similar approaches in diverse agricultural settings, ultimately contributing to a greener and more technologically advanced future for the agricultural industry.

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