Implementation of Microcontroller-Based Water Discharge Quality Monitoring System in Micro Hydro Power Generating System

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ABSTRACT

Micro hydro power plants are one of the alternative renewable energy sources that utilize water flow to generate electricity. Stable water discharge quality is very important to maintain optimal performance of the micro hydro power generation system. This study aims to develop and implement a microcontroller-based water discharge quality monitoring system that can monitor water discharge in real-time. This system uses a water flow sensor to measure the water discharge entering the turbine and utilizes a microcontroller to process the data obtained. The measured data will be displayed on the user interface and can be accessed for continuous evaluation of system conditions. With this monitoring system, it is expected to improve the efficiency and sustainability of micro hydro power plant operations, as well as facilitate decision making related to water resource management. The test results show that the developed monitoring system can function well in providing accurate information on water discharge, and can be used as a tool in managing micro hydro power generation systems.

Keywords: Monitoring System, Water Discharge Quality, Microcontroller, Sensor, Micro Hydro.

INTRODUCTION

The use of new and renewable energy (EBT) is growing rapidly along with the increasing need for environmentally friendly and sustainable energy sources. One type of renewable energy that is increasingly used is the micro-hydro power plant (PLTMH). Micro-hydro power plants have a number of advantages, including minimal environmental impact and the use of renewable natural resources, namely water flow. These advantages make micro-hydro a potential solution to meet electricity needs, especially in areas that have not been reached by conventional electricity networks.

Berastagi City, located in a mountainous area with abundant water potential, has a great opportunity to develop micro-hydro power plants. In addition to providing the main benefit of electricity availability for the community, this power plant can also play a role in educating the community about the importance of utilizing renewable energy. Economically, micro-hydro power plants offer lower construction and maintenance costs compared to conventional power plants, making them more easily accepted and adopted by the local community.

Technically, PLTMH works by utilizing water flow, discharge, and water pressure to produce mechanical energy, which is then converted into electrical energy through turbines and generators. However, micro-hydro power plants also face challenges, especially in terms of monitoring and routine maintenance of important parameters such as voltage, electric current, and water discharge. Manual monitoring that is generally carried out currently requires time, energy, and risks causing delays in handling technical problems. To overcome these problems, a more efficient and effective monitoring system is needed through the use of technological developments, one of which is by implementing the Internet of Things (IoT) concept. IoT allows physical devices such as microcontrollers to connect to the internet and send and receive data in real-time. With the application of IoT to PLTMH, data related to voltage, electric current, and water discharge can be monitored automatically and accessed remotely via a web-based platform, allowing for a faster response to problems that occur.

This study aims to design and implement a microcontroller-based water quality monitoring system at the PLTMH in Berastagi City. This system is expected to improve the operational efficiency of the power plant by providing real-time data that can be accessed from anywhere and anytime, thus facilitating remote monitoring and supporting the sustainability and optimal performance of the PLTMH.

Indonesia's diverse geographical conditions allow for the construction of small-scale Hydroelectric Power Plants (PLTA) such as PLTMH. To establish PLTMH, information on river flow potential is vital in the planning stage, especially water discharge data that must be measured continuously throughout the year to obtain accurate results. Because river locations are often difficult to access routinely, an automatic and portable data collection system is needed. As a solution, an automatic data collection system (datalogger) can be designed by utilizing a microcontroller as a control tool (Abiyasa, 2017). The river water discharge is measured using a flowmeter sensor and a water level sensor connected to the microcontroller. The data obtained will be processed by the microcontroller, then sent to an online server via a WiFi connection and a 3G/4G cellular network. For energy sources, this system uses solar panels that charge the microcontroller's supporting battery. With this system, data collection on river water discharge in remote locations can be carried out effectively and continuously. This discharge data is an important factor in determining the right capacity of the PLTMH, so that the electricity generated can optimally meet the needs of the local community.

LITERATURE REVIEW

A. New and Renewable Energy (EBT)

New and Renewable Energy (NRE) is an energy source that comes from sustainable natural processes, such as sunlight, wind, rain, ocean currents, geothermal, and biomass. According to the International Renewable Energy Agency (IRENA, 2021), NRE plays an important role in reducing dependence on fossil fuels and reducing carbon dioxide emissions. One form of NRE implementation is through micro-hydro power plants (PLTMH), which utilize water flow energy as the main source of electricity generation.

B. Micro Hydro Power Plant (PLTMH)

Microhydro Power Plant (PLTMH) is a small-scale electricity generation system that uses water power with a capacity of less than 100 kW (Setiawan & Purwanto, 2019). This system is very suitable for rural and remote areas, where conventional electricity networks are not yet available. PLTMH offers advantages in the form of low construction and operational costs, minimal environmental impact, and the ability to optimally utilize local potential (Handoko, 2017). The key factor for the success of PLTMH is the continuity and quality of the water discharge that drives the turbine.

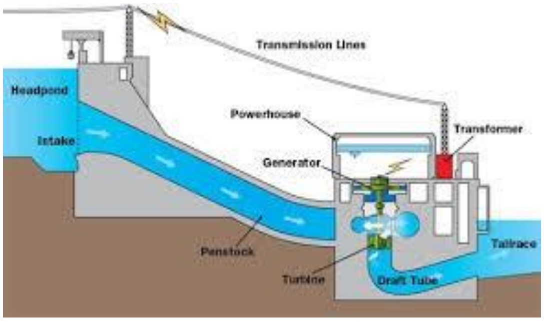

Figure 1. Scheme of PLTMH

C. Water Discharge Monitoring System

Water discharge is an important parameter in determining the potential energy that can be produced by PLTMH. Unstable discharge can disrupt turbine performance and reduce electricity production (Abiyasa, 2017). Manual monitoring of water discharge is considered inefficient, especially in hard-to-reach locations. Therefore, an automatic sensor-based monitoring system is needed that is able to measure and record data continuously.

a) In the literature, several methods of measuring water discharge include:
b) Flowmeter Sensor: Measures the speed of water flow in pipes or open channels (Abiyasa, 2017).
c) Water Level Sensor: Uses ultrasonic or water pressure sensors to determine the water level, which is then converted into flow rate.

D. Microcontrollers in Monitoring Systems

A microcontroller is a small electronic device that can be programmed to control hardware. In a water discharge monitoring system, a microcontroller functions as the main unit to receive signals from sensors, process data, and send results to storage media or servers via an internet connection (Ibrahim, 2020). Several popular microcontrollers used in IoT systems, such as Arduino, ESP32, and Raspberry Pi, offer high flexibility, low power consumption, and integration capabilities with various types of sensors (Ibrahim, 2020).

E. Internet of Things (IoT) in Real-Time Monitoring

Internet of Things (IoT) refers to the concept of connecting physical devices to the internet to collect and exchange data in real-time. According to Gubbi et al. (2013), IoT can improve the efficiency of monitoring systems through remote data access, automatic notification when anomalies occur, and cloud-based data storage for long-term analysis. The application of IoT in micro-hydro power plants allows online monitoring of water discharge, electric voltage, and other operational parameters, so that operators can intervene quickly if a disruption occurs (Gubbi et al., 2013).

RESEARCH METHODS

A. Implementation of Hardware Design

The hardware design aims to build a datalogger system capable of monitoring water discharge parameters and electricity quality at the PLTMH. The design steps include:

1. Creating a System Block Diagram
   Create a block diagram to illustrate the relationship between the main components, such as water discharge sensors, voltage-current sensors, microcontrollers, communication modules (WiFi/3G/4G), solar panels, and data storage servers.

2. Creating Schematic Circuit Diagrams
   Create detailed electronic schematics, including connections between sensors, microcontrollers, power sources, and communication modules.
3. Electronic Component Assembly
   Assemble all components according to the schematic diagram, which includes:
   a. Flowmeter sensor for measuring water discharge.
   b. Water level sensor (ultrasonic).
   c. Voltage sensor and electric current sensor.
   d. Microcontroller (Arduino/ESP32).
   e. Communication module (WiFi module or 3G/4G modem).
   f. Solar panels, batteries, and charge controllers.
4. Electronic Component Function Testing
   Perform unit testing on each component to ensure it performs according to factory specifications before being integrated into the main system.
5. Integration of Components into Datalogger Systems
   All components are integrated to form a portable, Internet of Things (IoT)-based water discharge and electricity quality monitoring system.

B. Implementation of Firmware Design

Firmware is developed to control and regulate the operation of hardware. The stages include:

1. Microcontroller Workflow Diagram Creation
   Design a work process flowchart starting from reading sensor data, data processing, to sending data to the server.
2. Microcontroller Programming
   Coding using C/C++ programming language through Arduino IDE. Programs created include:
   a. Sensor initialization.
   b. Periodic reading of sensor data.
   c. Data processing (filtering or conversion).
   d. Sending data to cloud-based servers.
3. Program Testing and Firmware Integration
   Once coding is complete, testing is performed to ensure the firmware can control the hardware correctly and data is successfully sent to the server.

C. Implementation of Software Design

The software is built to display data in real-time on the user's device. Activities include:

1. Creating a Data Delivery Flowchart
   Create a data process flow diagram, starting from sensors, microcontrollers, cloud storage servers, to monitoring applications.
2. Blynk Application Programming
   Using the Blynk platform to create a smartphone-based monitoring interface, which allows users to monitor:
   a. River water discharge.
   b. Voltage and electric current of micro hydro power plant.
   c. System operational status.

3. Program Testing and Integration with Datalogger
   Test the application and ensure that the data sent by the datalogger can be displayed in real-time on the Blynk dashboard.

D. Datalogger and Portable Power Supply Integration

To ensure the energy independence of the datalogger system in remote locations, portable power source integration is carried out. These activities include:

1. Installation of Solar Panels, Batteries, and Charge Controllers
   a. Solar panels are used as the main energy source.
   b. The battery stores energy for use at night.
   c. The charge controller regulates charging and prevents overcharging.
2. Installation of Voltage and Current Sensors
   Integrate sensors to monitor the performance of solar panels and batteries, ensuring the system gets a stable power supply.
3. Solar Panel Output Testing
   Measure the output voltage and current of solar panels under various weather conditions to ensure power availability.
4. Datalogger Installation and Testing
   Installing dataloggers at simulation locations, testing the function of reading water discharge, voltage, electric current, and sending data to the server via cellular network or WiFi.

RESULTS AND DISCUSSION

A. Sensor Node Creation

The creation of sensor nodes begins with designing and assembling a series of sensors used to measure water level and water flow rate. The sensors used in this system consist of a water level sensor HC-SR04 and a flowmeter sensor YFS201. The HC-SR04 sensor works based on the principle of ultrasonic wave reflection to measure the distance between the sensor and the water surface, while the YFS201 produces a digital pulse that is proportional to the rate of water flow passing through it (Kautsar, 2015).

Both sensors are connected to the ESP8266-based controller via a cable connection according to the designed schematic diagram. The YFS201 sensor gets a 5 Volt voltage supply from the ESP8266 and the digital pulse output from this sensor is connected to the digital pin D7 on the controller. The pulses generated are calculated by the microcontroller to determine the water flow rate.

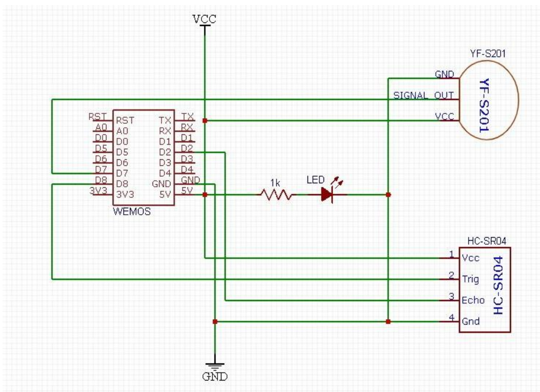

Figure 2. Sensor Node Schematic Diagram

For the HC-SR04 sensor, the connection is made through two main pins, namely Trigger and Echo. The Trigger pin is connected to the digital pin D8 and functions to send ultrasonic waves, while the Echo pin is connected to the digital pin D2 and functions to receive reflected waves from the water surface. The way it works is that the microcontroller sends a signal through the Trigger pin to trigger the sending of waves, then measures the time it takes for the waves to return to the Echo pin. This reflection time is then converted into a distance or water height value by the firmware embedded in the ESP8266.

Since the ESP8266 operates at a logic voltage of 3.3V, while the sensors operate at 5V, it is necessary to adjust the voltage levels, especially on the Echo pin of the HC-SR04, to avoid damage to the controller. This adjustment can be done using a voltage divider resistor or a level shifter. All sensor operations, from initialization, data reading, to signal processing, are regulated through firmware programmed in the microcontroller using the Arduino IDE. Data obtained from the sensor will then be processed and sent to the server or monitoring application via a WiFi network supported by the ESP8266.

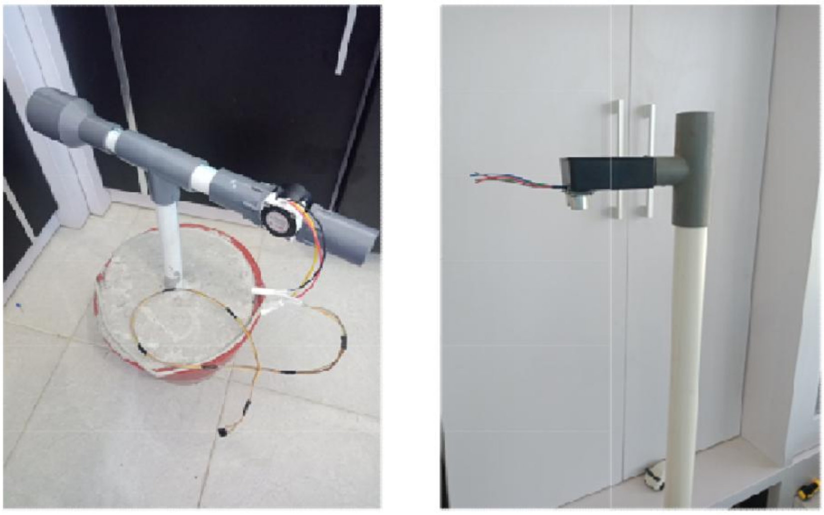

Figure 3. Photo of Sensor Node, a) flowmeter sensor and b) level sensor

The results of the component assembly for the sensor node can be seen in Figure 4.2. On the YFS201 flowmeter sensor, as shown in Figure 4.2 (a), the cable connection is given additional protection in the form of waterproof silicone glue.

The purpose of using this silicone glue is to prevent short circuits due to water exposure, considering that the sensor will be operated in wet environmental conditions. In addition, a pipe system is installed to direct the flow of water into the sensor in a controlled manner, so that the reading of the water discharge becomes more accurate and consistent. To ensure the stability of the sensor in the river flow, the base of the sensor installation is made of concrete. Concrete functions as a weight that keeps the sensor position from shifting due to strong water currents. Likewise, for the HC-SR04 water level sensor, as seen in Figure 4.2 (b), it is installed using a similar method. The HC-SR04 sensor is supported using a pipe as a support pole, with a structural base also made of concrete. This installation aims to keep the sensor position stable and parallel to the water surface being measured, so that the data obtained remains accurate even in a dynamic river environment.

B. Hardware Integration

The next stage in creating the system is to integrate the sensor nodes and communication modules to form a unified online datalogger system. This integration aims to ensure that data collected from various sensors can be automatically sent to the server in real-time, without the need for manual data collection in the field.

The communication module used consists of a router and a modem that supports 3G/4G cellular networks, with data packages provided by the local Internet Service Provider (ISP). The existence of a router plays an important role as a connector between devices because it allows ESP8266-based sensor nodes to connect wirelessly via a WiFi network, so that it no longer requires long cable installations that can be difficult, especially in difficult-to-access river areas. This approach also makes the system more flexible in integrating several sensor nodes at once, because adding a new node only requires a WiFi connection to the existing network. The power source for the entire system comes from a 12 Volt battery, which is connected to a Buck Converter to reduce the voltage to 5 Volts according to the operating needs of the sensor nodes and routers. Thus, electronic components that are sensitive to high voltage can operate safely and stably. The datalogger and router are then turned on using a standard USB power cable, which supplies current from the Buck Converter to each device. This system is designed to be able to operate continuously in varying field conditions, including changes in temperature and humidity, which are common in river environments.

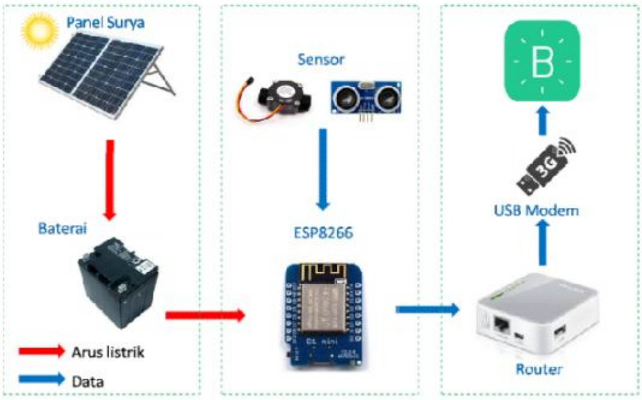

Figure 4. The Sensor Node and Communication Module are powered using a battery via a 5 Volt Buck Converter module.

In Figure 4, the operational flow diagram of the datalogger and communication module can be seen. The sensor node is tasked with measuring discharge and water level data periodically, then sending the data in real-time via a WiFi connection to the router. Furthermore, the data is forwarded by a modem to a cloud-based server that can be accessed from any location via a web-based or mobile monitoring application. With this system, monitoring of water discharge conditions can be done more efficiently, quickly, and accurately, which ultimately supports the optimization of microhydro power plant operations. In addition, this approach also allows for system scalability. This means that if in the future it is necessary to add more sensors or a wider monitoring area, development can be done easily without having to overhaul the existing system. This flexibility is one of the advantages of implementing the Internet of Things (IoT) in microcontroller-based water discharge monitoring.

C. Firmware Programming

To operate a sensor node as an online datalogger, firmware is required to control sensor reading, data processing, and data delivery to the server. Firmware programming is done using the Arduino IDE, which is a popular platform for microcontrollers such as the ESP8266, as shown in Figure 4.4.

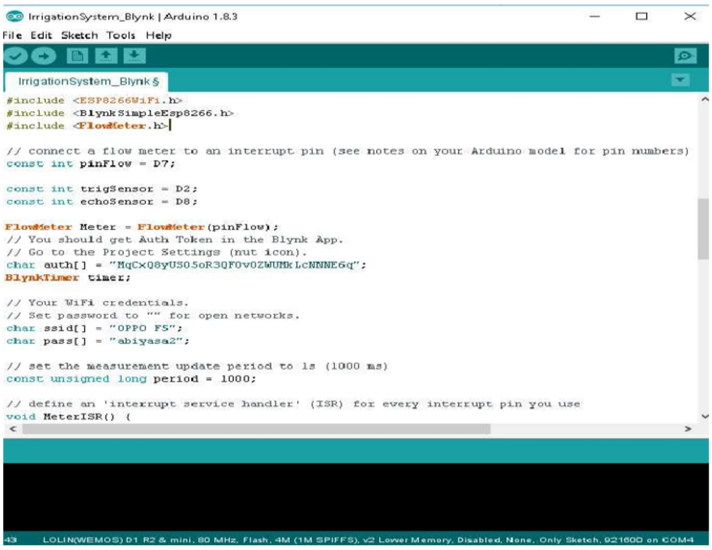

Figure 5. Firmware programming in Arduino IDE

In this program, the ESP8266 reads data from two sensors: a flowmeter sensor (YFS201) and a level sensor (HCSR04). The flowmeter sensor sends digital data directly to the microcontroller, while the HCSR04 sensor measures distance using two pins, Trigger and Echo, to measure the water level.

The data obtained from the sensor is then processed to calculate the water discharge and water level. After that, the data is sent to the server using the ESP8266 WiFi connection. Data transmission is carried out periodically based on the interval specified in the firmware. The firmware also ensures that the data sent is valid and can handle situations if the sensor or network experiences temporary problems. Overall, this firmware allows real-time monitoring of river conditions via the server, even remotely. The source code for this firmware can be seen in the next section of this document.

D. Blynk Server and Application Software

Once the sensor node and communication module have been successfully integrated, the next step is to connect the ESP8266 to the Blynk Server. To do this, the ESP8266 firmware needs to be modified by adding the Blynk Library. This process allows the ESP8266 to connect to the server using an available internet connection. This connection is protected by a unique token code provided by the Blynk server, which serves as authentication and maintains the security of communication between the device and the server.

Here are the steps to connect ESP8266 to Blynk:

1) Creating a Project in the Blynk App: The administrator creates a project in the Blynk app via smartphone, and Blynk will provide a unique token code used to authenticate the ESP8266 device.

2) Adding Token to Firmware: The received token code is entered into the ESP8266 firmware program. Once the token code is added correctly, the ESP8266 will connect to the Blynk app and the connection status will be displayed as "online" in the smartphone app.

3) Data Sending to Server: In the firmware, sensor data will be sent to the Blynk server via virtual channels. Each sensor (YFS201 and HCSR04) will be sent via a different virtual channel, namely V0 for the flowmeter sensor and V1 for the level sensor. These virtual channels identify the data received and sent to the server.

To display the data in the Blynk application on a smartphone, a user interface (UI) is created in the Blynk application. The display can be in the form of numbers or graphs, allowing users to monitor data in real-time. Figure 4.5 shows the interface that can be created in the Blynk application. The Blynk server also provides facilities for storing data in the form of .csv files. These files can be downloaded and further analyzed using spreadsheet software such as Microsoft Excel or Google Sheets. This allows users to analyze the data in more depth and monitor system conditions continuously.

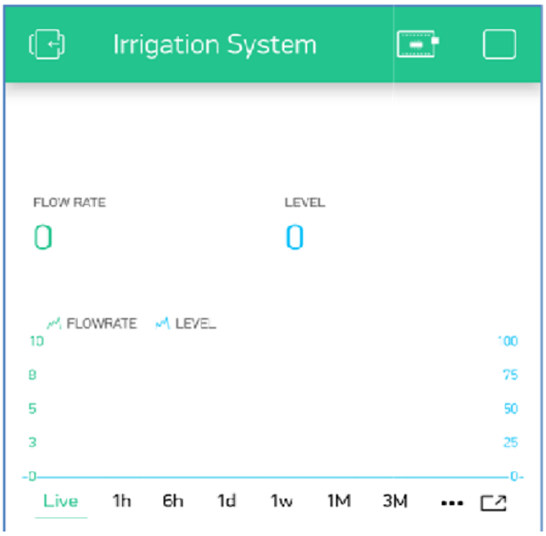

Figure 6. Blynk application interface display on smartphone

E. Portable Power Supply

To support the operation of the tool in the field, the system is equipped with a portable power supply that relies on solar panels and batteries. Solar panels are used to generate electricity from sunlight, which is then stored in batteries to ensure the sustainability of the energy supply to the system, especially in areas that are difficult to reach by conventional electricity networks. This power supply is also equipped with a voltage sensor that monitors the condition of the battery in real time. This sensor is responsible for measuring the level of battery voltage, which is the main indicator of the remaining power condition. By monitoring the battery voltage, users can find out when the battery needs to be recharged or replaced, thus avoiding disruption to the system caused by lack of power. In addition, battery condition data (such as battery voltage) is also sent online via the ESP8266 to the Blynk server. Sending this data allows users or operators to monitor the condition of the battery remotely, without having to come directly to the location of the tool. Thus, battery maintenance and replacement can be done more quickly and efficiently, so that the system continues to function optimally.

This data can also be displayed in the Blynk application on a smartphone, allowing direct monitoring of battery conditions, both in numerical and graphical form. This feature is very important to keep the system running smoothly, especially in hard-to-reach locations.

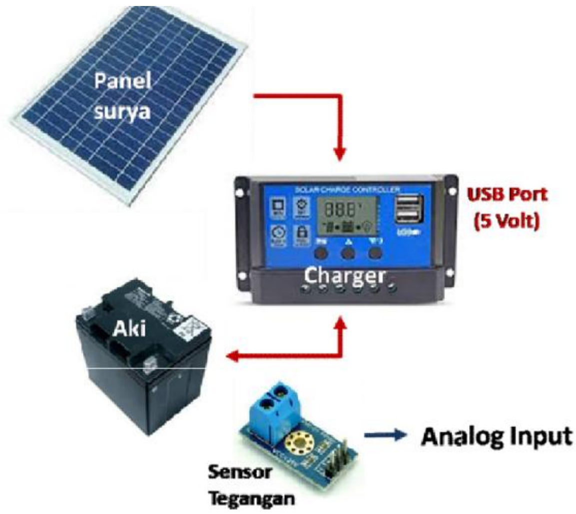

Figure 7. Portable power supply equipped with battery voltage sensor

F. System Testing

The next step is to test whether the sensor data can be received by the online server. The testing process begins by turning on the router which is given a voltage of 5 Volts so that it is ready to operate in the ON condition. Then, the ESP8266 controller is also given a voltage of 5 Volts to turn on the system. The results of the firmware execution can be monitored via the Serial Monitor, which is connected to the COM4 port on the computer, as shown in Figure 5.7. After setting the SSID and Password for the WiFi connection, the message "Connected to Wifi" will appear, followed by the IP address obtained from the router. In this test, the connected IP address is 192.168.43.19.

After the WiFi connection is successful, the ESP8266 controller will try to connect to the Blynk server. The message "Connecting to blynk-cloud.com:8442" indicates that the connection process is in progress. Once the connection is successful, the message "Ready (ping: 80ms)" will appear, indicating that the system is ready to operate. Furthermore, data from the flow and level sensors will begin to be read, and the values will be displayed in the Serial Monitor, as an indication that the online datalogger has successfully sent data to the server. In this test, the message that appears shows the sensor values that have been detected properly, ensuring that the device works as expected.

With the data successfully sent to the server, the information can be accessed using the Blynk API via a smartphone application, as shown in Figure 4.5. In addition, the data can also be downloaded in .csv file format via the application for further analysis. Figure 4.7 shows the Serial Monitor display when the ESP8266 controller is turned on and functioning properly.

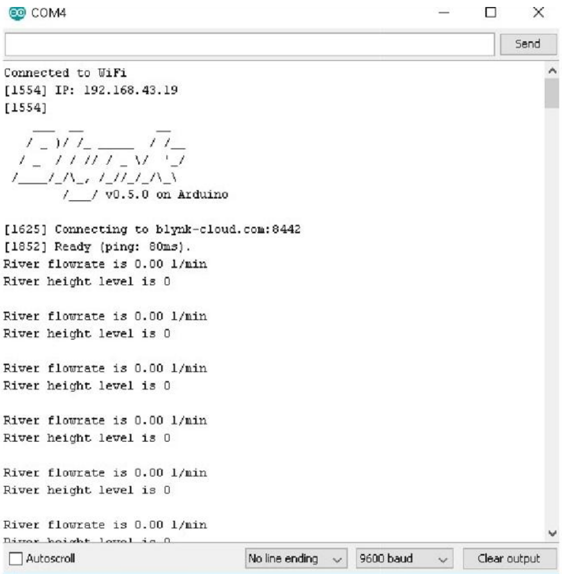

Figure 8. Serial Monitor view when the ESP8266 controller is turned on.

CONCLUSION

The Internet of Things (IoT)-based water level and discharge monitoring system built using HC-SR04 and YFS201 sensors, ESP8266 microcontroller, and Blynk platform has successfully demonstrated its effectiveness in measuring and sending data in real time. The creation of sensor nodes with good hardware integration, including the use of appropriate sensors and voltage adjustment, ensures stable operation in dynamic river environment conditions. Through the testing process, it was proven that this system can send data periodically to a cloud-based server without requiring manual intervention. The use of WiFi connected to a router and cellular modem facilitates sending data to the Blynk application, which can be accessed via a smartphone or computer. In addition, the collected data can be further analyzed by saving the results in .csv file format, supporting a more in-depth analysis of water flow conditions.

The implementation of a portable power supply utilizing solar panels and batteries ensures the sustainability of the equipment's operations in the field, especially in areas not covered by conventional electricity networks. The system is also equipped with real-time battery condition monitoring, which allows for more efficient maintenance and prevents operational disruptions due to power shortages. Overall, the system has succeeded in providing an efficient and flexible solution for monitoring water discharge and levels, which can be used for other applications, such as environmental monitoring, micro-hydro power generation, and natural resource management. The advantages of this system lie in its scalability, ease of integration, and the ability to monitor data in real- time remotely, thus facilitating faster and more accurate decision-making.

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