

Design of Smart Water Meter as Groundwater Consumption Monitor Tool for Villages in Bali-Indonesia

1st Agus Putu Abiyasa

*Department of Electrical Engineering
Universitas Pendidikan Nasional
Denpasar, Indonesia
abiyasa@undiknas.ac.id*

2nd Putu Indah Dianti Putri

*Department of Environmental Engineering
Universitas Pendidikan Nasional
Denpasar, Indonesia
indahdianti@undiknas.ac.id*

3rd Irma Suryanti

*Department of Civil Engineering
Universitas Pendidikan Nasional
Denpasar, Indonesia
irmasuryanti@undiknas.ac.id*

4th I Made Riko

*Institute of Material Research and Engineering
Agency for Science, Technology and Research
Singapore, Singapore
riko@imre.a-star.edu.sg*

Abstract—The exact consumption level of groundwater in many villages in Indonesia is still unknown by the regulator. In this study, we showed a working example of smart water meter that can be used to calculate daily water consumption of household in villages. The smart water meter was built from low cost open source electronic components such as YF-S201 water flow sensor, LCD display and ESP8266 microcontroller. It was also programmed with custom software to collect data from sensor and send the data to online database such as Google Sheet. It was also capable of controlling water pump for automation. The smart water meter has been tested and installed to monitor groundwater consumption of household at Tumbakbayuh village in Bali Province, Indonesia. The result has shown good data collection and it was able to send the data online consistently. From the example household data analysis has shown the average groundwater consumption of 493 liters per day. Our developed smart water meter is scalable and cost efficient to support government program in monitoring and controlling the consumption of groundwater.

Index Terms—Smart water meter, microcontroller, groundwater monitoring, smart villages

I. INTRODUCTION

Globally, the looming challenge of water scarcity, compounded by unregulated water usage, presents imminent threats to the environment and socio-economic stability [1] [2] [3] [4]. In response, the development of smart water metering, driven by the Internet of Things (IoT), offers a transformative solution, enabling real-time monitoring and data-driven insights [5]. Smart water meters, powered by IoT and Big Data Analytics, play a pivotal role in reshaping water resource management by proactively identifying leaks and contributing to sustainable water supply [6]. Notable successes, particularly in Spain, highlight how smart water metering reduces costs, enhances efficiency, and fosters sustainable urban water cycles [7] [8] [9] [10].

Within these advancements lie unexplored opportunities for sustainable water management, notably in the development of low-cost smart water meters [11] [12] [13]. This paradigm shift towards affordability and scalability holds the potential to revolutionize water management systems, particularly when managed by local authorities [14] [15]. Locally developed and cost-effective smart water meters crafted from affordable components signify a transformative approach to water resource management, addressing economic barriers and promoting inclusivity across socio-economic strata. Additionally, the use of locally sourced components tailors the technology to regional needs, facilitating seamless integration and operation within existing water infrastructures. Affordable smart water meters empower local communities, fostering a culture of responsibility and encouraging sustainable water consumption practices at the grassroots level. In essence, the development of smart water meters using locally sourced and low-cost components not only addresses economic concerns but also aligns with principles of sustainability, adaptability, and community engagement.

However, a significant research gap remains, demanding an in-depth exploration into the potential for scaling up the smart water metering technology. This critical examination is essential for understanding how these locally produced meters can be effectively integrated into water management systems and, importantly, how they can be successfully managed by local authorities. Through a comprehensive techno-economic-environmental analysis, this research aims to address this specific gap in knowledge. By delving into the local context, the study seeks to provide valuable insights that are indispensable for local governments. The anticipated findings of this research represent a pivotal opportunity to not only highlight the transformative potential of an affordable IoT-based smart

water metering technology but also to emphasize its scalability. The research promises to shed light on the practical aspects of implementation and ongoing management by local authorities, paving the way for a new era of efficient, cost-effective, and locally-driven water resource management in Indonesia.

II. METHODOLOGY

A. Hardware Design

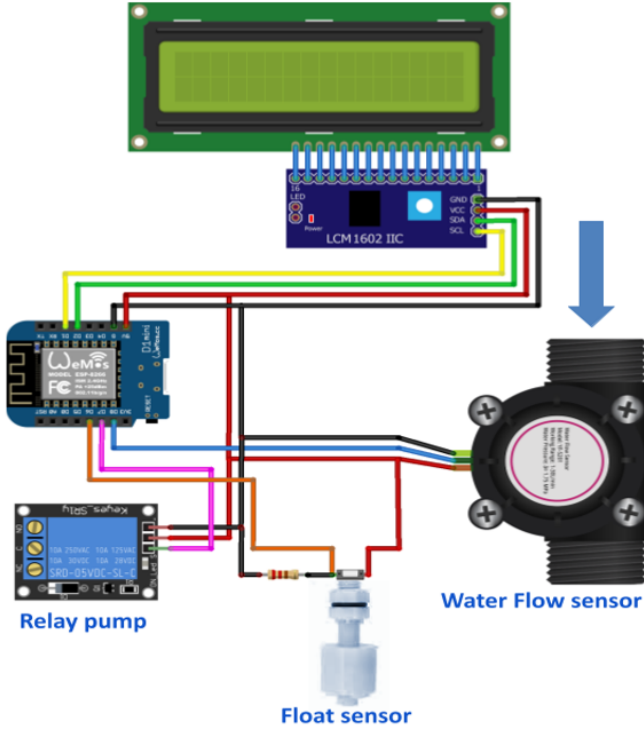


Fig. 1. Wiring Diagram of Smart Water Meter.

For hardware design, the wiring diagram of the smart water meter is shown in Fig. 1. The wiring diagram for the system includes connecting the YF-S201 flowmeter sensor, float switch sensor, relay switch, and LCD display to the ESP8266 microcontroller. The YF-S201 flowmeter sensor is connected to the ESP8266 microcontroller through the GPIO pins. The signal output from the flowmeter sensor is connected to GPIO14 of the ESP8266. The float switch sensor, which provides information about the water level in the tank, is connected to GPIO12. The relay switch is connected to GPIO13 and is used to control the water pump. When the water level in the tank is low, the microcontroller activates the relay switch to turn on the water pump. The LCD display is connected to the microcontroller through the I2C interface. The SDA and SCL lines of the LCD display are connected to GPIO4 and GPIO5, respectively. The I2C protocol allows for digital communication between the ESP8266 WeMos Mini board and the 16x2 LCD display. It uses only two wires, SDA and SCL, for data transfer. The data transfer is initiated by the WeMos Mini board, which sends a start signal to the LCD display. The LCD display then responds with an acknowledge signal,

indicating that it is ready to receive data. The WeMos Mini board can then send data to the LCD display using the I2C protocol. Once the data transfer is complete, the WeMos Mini board sends a stop signal to the LCD display, indicating that the transfer is finished.

B. Software Design

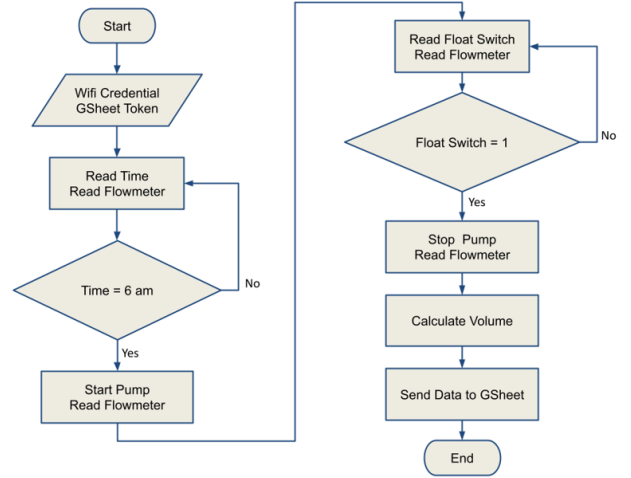


Fig. 2. Flowchart of Smart Water Meter.

To understand the workflow and easy programming for the software of the system, the flowchart for the working of smart water meter is shown in Fig. 2. For programming, Arduino IDE was used in C language programming code. The step by step working of the system is explained as follow. The ESP8266 microcontroller initializes and connects to the Wi-Fi network. It checks the current time, and if it's before 6 a.m., the system waits until the time reaches 6 a.m. before proceeding to the next step. The YF-S201 flowmeter sensor measures the flow rate of the liquid passing through it and sends the data to the ESP8266 microcontroller via its digital output pin. The ESP8266 microcontroller reads the flow rate data and displays it on the LCD display. The float switch sensor detects the level of the liquid in the tank and sends the data to the ESP8266 microcontroller via its digital output pin. The ESP8266 microcontroller reads the level data and determines whether the tank is full or empty.

If the tank is empty, the ESP8266 microcontroller activates the relay switch to turn on the water pump and start filling the tank. At the same time, it records the on-time of the pump. While the tank is being filled, the ESP8266 microcontroller continues to read the flow rate data from the YF-S201 flowmeter sensor and displays it on the LCD display. It also calculates the pumped water volume using the flow rate and time, and records the data for later transmission. Once the tank is full, the float switch sensor detects the high water level and sends the data to the ESP8266 microcontroller. The ESP8266 microcontroller deactivates the relay switch to turn off the water pump and stop filling the tank. It also records the off-time of the pump and displays a message on the LCD display

indicating that the tank is full and the system is in standby mode. The ESP8266 microcontroller sends the on-time, off-time, and pumped water volume data to Google Spreadsheet via the Wi-Fi network. The system continues to monitor the flow rate and level of the liquid in the tank and repeats the above steps as necessary to maintain the desired level. Overall, this system provides an automated way to monitor and control the water level in a tank using the ESP8266 microcontroller, YF-S201 flowmeter sensor, float switch sensor, relay switch, LCD display, and power supply. By programming the system to turn on the water pump at 6 a.m. every day and recording the on-time, off-time, and pumped water volume data, the system provides valuable information for managing water resources and improving water use efficiency.

C. Data Collection and Calibration

The data collection process begins with sensors gathering relevant information, such as water flow rates, from the environment. These sensors, integrated with microcontrollers like the ESP8266, continuously monitor the desired parameters. The ESP8266, equipped with Wi-Fi connectivity capabilities, serves as the bridge between the sensors and the cloud platform. Once the data is collected by the sensors, the ESP8266 processes and formats it for transmission. Using secure communication protocols, such as HTTPS, the ESP8266 establishes a connection with the Google Cloud Platform. Within the Google Cloud Platform, Google Apps Script, a server-side JavaScript platform, is utilized to create a custom script. This script is designed to receive incoming data from the ESP8266 and store it in a designated Google Sheet. The Google Sheet acts as the central repository for all collected data, providing a structured and easily accessible format for storage and analysis. Through this integrated system, data collected by the sensors is seamlessly transmitted to the Google Cloud Platform and recorded in real-time within the Google Sheet. This streamlined process ensures efficient data collection, storage, and management, facilitating further analysis and decision-making based on the recorded data.

Calibration of the YF-S201 flowmeter sensor against a commercial water meter, such as the ITRON Multimag ½ inch, is essential to ensure accurate measurement of water flow. The comparison involves connecting both meters to the same pipeline to measure water flow rates. The process, illustrated in Fig. 3, begins by collecting data from both meters and comparing the readings. If discrepancies are observed between the calculated flow rate and the sensor reading, adjustments to the calibration factor in the sensor's code are necessary. This iterative process involves multiple comparisons and adjustments to fine-tune the calibration and improve accuracy. By repeating these steps as needed, the YF-S201 flowmeter sensor can be calibrated effectively, ensuring reliable and precise measurement of water flow rates.

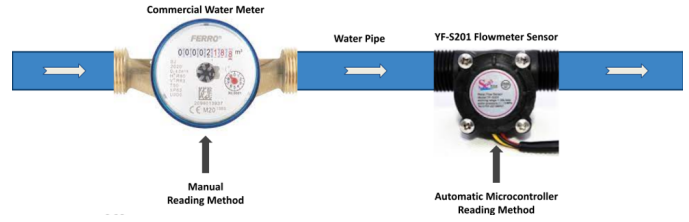


Fig. 3. Data calibration setup.



Fig. 4. Installation of Smart Water Meter.

III. RESULT AND DISCUSSION

Installing the system in the groundwater pump of a household involves several sequential steps as shown in Fig. 4. Initially, a suitable location near the pump must be identified where the system components can be installed and connected to both power and the Wi-Fi network. Following this, the YF-S201 flowmeter sensor is installed in the water pipe connected to the pump, ensuring proper orientation and direction of water flow. Simultaneously, the float switch sensor is installed in the water tank or storage container linked to the pump, allowing accurate detection of water levels.

Subsequently, the sensors are connected to the ESP8266 microcontroller via their digital output pins. The flowmeter sensor is connected to one digital pin, while the float switch sensor is connected to another. Additionally, the LCD display is connected to the ESP8266 microcontroller using its SDA and SCL pins for data transfer. A relay switch is then connected to the ESP8266 microcontroller via one of its digital output pins. Power is supplied to the ESP8266 microcontroller, the LCD display, and the relay switch through a 5V power supply. The ESP8266 microcontroller is connected to the Wi-Fi network by inputting the network name and password into the code. Subsequently, the code is uploaded to the ESP8266 microcontroller using the Arduino IDE software.

In the smart water metering system, water flow is measured using both a commercial flowmeter and a sensor. The

commercial flowmeter, such as the ITRON Multimag ½ inch, provides readings in liters, which serve as the standard for measuring water consumption. These readings offer accurate and reliable data on the volume of water passing through the system. In parallel, the sensor, such as the YF-S201 flowmeter, measures water flow in pulses. Each pulse corresponds to a specific volume of water passing through the sensor. To ensure

TABLE I
SENSOR DATA MEASUREMENT TESTING RESULTS

Manual Reading (x)	Automatic Reading (y)
1	979
2	2466
3	4168
8	11136
17	22640
65	87974
71	97359
73	99517
129	175379

consistency and accuracy, the pulses recorded by the sensor are calibrated against the readings from the commercial flowmeter as shown in Table 1. This calibration process establishes a correlation between the number of pulses detected by the sensor and the actual volume of water measured by the commercial flowmeter. The results of this calibration process are tabulated and compared, allowing for precise adjustments to ensure alignment between the sensor readings and the actual water flow. This table serves as a reference for validating the accuracy of the sensor readings and maintaining consistency in the measurement of water consumption. Through this dual measurement approach, the smart water metering system achieves robust and reliable monitoring of water flow, enabling efficient management of groundwater resources.

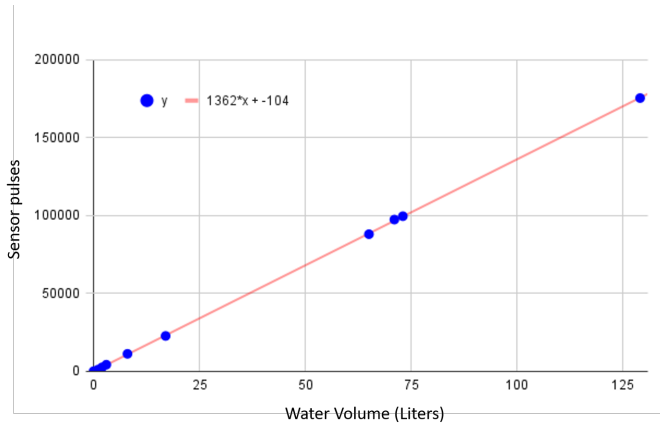


Fig. 5. Calibration Result of Smart Water Meter.

Afterward, the system is thoroughly tested by powering it on and verifying that the LCD display shows accurate readings for flow rate and water level. The float switch is tested by filling the tank and confirming that the relay switch turns off the pump when the water level reaches the top. Finally, the

flowmeter sensor is tested by measuring the time required to fill a bucket with a known volume of water and comparing it to the display reading. The calibration of this process is shown in Fig. 5. A calibration factor was obtained from a linear regression equation:

$$y = 1362x - 104 \quad (1)$$

and was used in the program to calculate the actual volume measured by the flow meter. Once the system is tested and verified, the components are mounted in their final positions near the pump, and regular monitoring is conducted to ensure proper functioning, making adjustments as needed.

Following the successful installation within a household's groundwater pump in Tumbakbayuh village, continuous monitoring and measurement of groundwater consumption become feasible. The system enables the recording of daily usage water volume data, conveniently displayed online as depicted in Fig. 6. This functionality empowers users to monitor their daily water consumption, discerning patterns or alterations in their usage habits. Moreover, the system computes the average daily water consumption from the accumulated data, providing valuable insights for water conservation efforts. Notably, the average daily consumption is recorded at 493 liters. In essence, the system offers a practical and effective means to oversee and regulate household groundwater consumption.

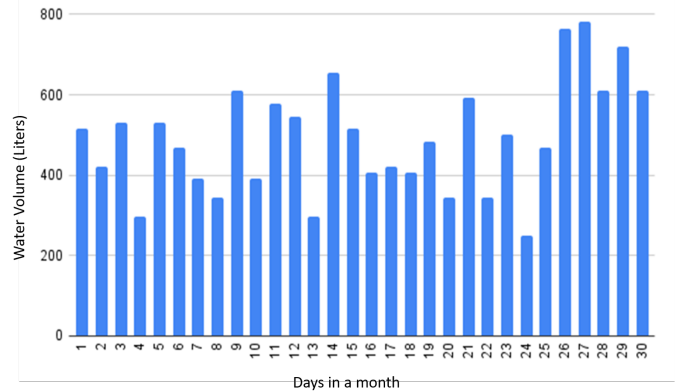


Fig. 6. Water Consumption Measured in a Month.

The scalability of smart water metering systems extends beyond individual households to encompass broader community engagement and collaboration. By establishing partnerships with volunteer households equipped with existing Wi-Fi infrastructure, the implementation of these systems can be scaled up within a region. This cooperative model allows for the installation of smart water meters in multiple households, leveraging the existing infrastructure and fostering a sense of collective responsibility towards groundwater conservation. Through this approach, a network of interconnected smart water metering systems can be established, enabling comprehensive monitoring and management of groundwater usage across a community. Such scalability not only amplifies the impact of water conservation efforts but also promotes

community resilience and sustainability in the face of water scarcity challenges.

IV. CONCLUSION

In conclusion, the designed smart water metering system utilizing ESP8266 and connected to Google Sheets has demonstrated exceptional performance in effectively monitoring and managing groundwater consumption. The seamless integration of IoT technology has facilitated real-time data collection and analysis, enabling households to gain valuable insights into their water usage patterns. The successful implementation of this system in the Tumbakbayuh village highlights its efficacy and reliability in promoting sustainable groundwater management practices. With an average daily consumption of 493 liters per household, the system has underscored the critical role of proactive conservation measures in addressing water scarcity challenges. Moving forward, the widespread adoption of similar smart water metering solutions holds tremendous promise for fostering resilient and environmentally conscious communities.

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