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Study and Design a Low-Power Water Meter

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***Abstract*— At this time, the issue of water scarcity and stress presents a significant and pressing danger to the global population[1]. To conserve water wealth, we must adopt modern controlling and monitoring consumption management techniques. Due to the smart meter, we can automate consumption readings in a distribution network. This work consists of the development of a water meter easy to implement and transmits the volume readings to visualize it in a user interface based on Node-Red. The contribution of this water meter is realizing an intelligent system based on a battery that allows it to prolong its lifespan of it, as long as possible by using a switching circuit between the turbine generator, and the battery that supplies the system in sleep mode. The meter is equipped with a flow detector that wakes up the MCU from sleep mode and also has a flow sensor that allows us to calculate the volume. Through the LoRa module the meter transmits the information to a gateway. To extend the longevity of the battery, we have implemented a circuit that allows seamless switching between the generator and the battery as needed. Additionally, we have incorporated other circuits that effectively disable all system components during sleep mode, minimizing power consumption to the bare minimum. These measures contribute significantly to conserving energy and ensuring optimal battery performance, providing a sustainable and reliable solution for our system.**

Keywords*— *water meter, real-time monitoring, battery, energy harvesting, Node-Red

I. INTRODUCTION

As the world faces increasing water scarcity and the urgent need for efficient water resource management, the integration of recent technology, such as Internet-of-Things (IoT) has emerged as a promising solution[2], [3]. In this context, the advent of water metering systems has revolutionized the provision of real-time monitoring through remote meter reading. Usually, the water meter is located in an area with no on-the-spot electricity supply, which means that further adaptation work has to be carried out at the installation site. This is contrary to the natural provider's desire to achieve the lowest possible installation cost, with minimum work to be carried out on-site, preferably with no wires or external power supplies [4]. Reliance only on the battery is unhelpful, so should adopt an energy harvesting technique. Within water distribution systems, specifically in the vicinity of water meters, various energy sources can be harnessed. These potential energy sources include light, the kinetic energy generated by water flow, temperature differentials, mechanical vibrations, and electromagnetic radiations[5]. Water flow is the most obvious source of energy. Although, several state-of-the-art micro-turbines designed to harvest energy from a water flow have been reported[6]–[9].

II. PROPOSED SYSTEM

Water meter based on Node-Red and STM32 is proposed to monitor the water consumption of a household and make the inhabitants aware of their consumption. The structure of the proposed system is illustrated in Fig. 1, where the data of consumption is measured by a low-cost flow sensor, and the turbine generator is used alternatively to provide power to the system when the flow presents, the role of the water flow detector is used to wake up the microcontroller. The data is transmitted via the LoRa module to the gateway, which sends the data to HiveMQ's MQTT broker, then shows the data on the HMI based on Node-Red.

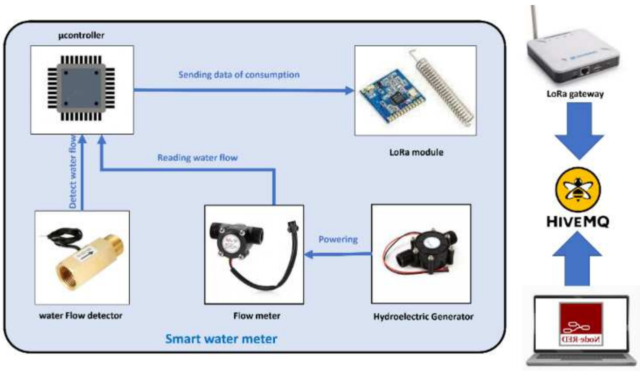

Fig. 1. Block diagram of water meter

III. IMPLEMENTATION

A. Dashboard

The dashboard consists of a web page based on Node-Red. The Node-Red is a flow-based, low-code development tool for visual programming developed originally by IBM for wiring together hardware devices.

Fig. 2 illustrates the main nodes used in this project, where:

- The "mqtt in" node is used to subscribe to the broker and receive messages published to matching topics. The topic used is “test/msg/watermeter”.
- The water meter parameters such as client ID, consumption, flow rate, and battery voltage are depicted using various dashboard formats such as gauges and charts.
- In order to present the water meter parameters received in JSON format in a variety of ways, it is essential to extract each value individually. This is precisely why the function node is employed to extract data from the JSON source

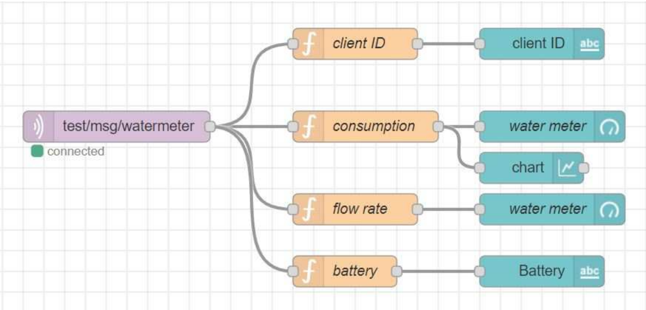

Fig. 2. Node-Red flow

B. Hardware design

1) System component: Fig. 1. illustrates the various constituents of the water meter produced in this paper, with the electronic components of this meter comprising a variety of elements:

- The system was assembled around an STM32L433 microcontroller from STMicroelectronics, serving as the system's central processing unit. We selected the STM32L433 for this project because of its strong computational performance and is designed for ultra-low-power applications.
- The communication part of the water meter is the SX1278 LoRa module (Long Range), the module enables long-range wireless communication to establish reliable connections over extended distances, making it ideal for applications where remote monitoring, tracking, and control. Its low power consumption guarantees battery operation. The SX1278 operates in various unlicensed frequency bands allows it to adapt to different regions and regulatory requirements.
- In our system design, we integrated the YFS201 flow sensor, known for its cost-effectiveness, to measure the rate of water flow. After conducting the flow measurement, the microcontroller employs numerical integration techniques to compute the water consumption over time, as outlined in equation (1)[10]. This integration process allows us to determine the total volume of water consumed within this specified timeframe.

$$\int_a^b f(x)\,dx = \lim_{n\to\infty}\sum_{i=0}^{n} f(x_i)\Delta x \qquad (1)$$

Where

$$\Delta x = \frac{b-a}{n} \qquad (2)$$

- Micro hydroelectric generator is a compact energy-harvesting technology designed to harness energy from water movement. This device finds its niche in scenarios where the electronic system is based on traditional power sources. One of the most significant roles of our water meter is the ability to reduce reliance on batteries during counting consumption. the mini turbine stands as a beacon for sustainable power generation, offering a path towards greater energy efficiency and a reduced dependency on conventional energy storage solutions.
- The water flow detector employed in our system is a crucial component designed to trigger the awakening of the microcontroller from a deep sleep state whenever water flow is detected. This functionality is particularly valuable for conserving power in battery-operated devices or systems, as it allows the microcontroller to remain in a low-power deep sleep mode when not needed and conserves energy resources. The water flow detector starts detecting from 1L/min.

2) Electronic circuit: Minimizing quiescent current is essential in battery-powered applications because it directly impacts the overall battery life. The choice of the passive and the active components for adequate low-power applications is crucial. The 3.3-volt regulator used is HT7333, the key features of the voltage regulator include low dropout voltage and low quiescent current of 3.5µA.

The water flow sensor has a high quiescent current, we made an electronic circuit Fig. 3. to disable it when the system is in sleep mode. A P-channel MOSFET serves as the switch in our setup. To drive the MOSFET effectively, an NPN transistor stage is employed. The microcontroller plays a crucial role in enabling or disabling the flow meter's state by controlling the base of the transistor.

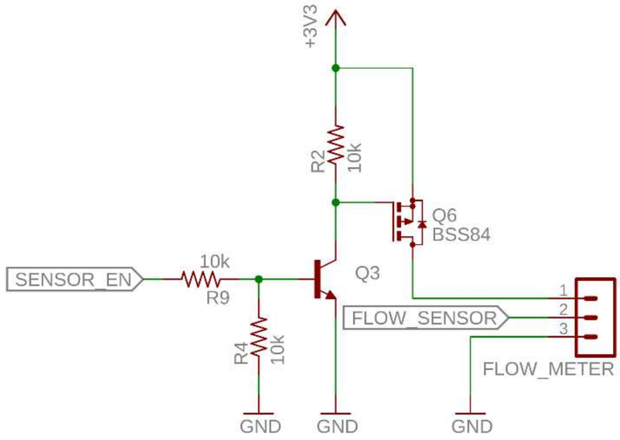

Fig. 3. Electronic circuit for Enable-Disable the sensor

To select the power source of the water meter during the operating and the sleep mode we made the circuit illustrated in the fig. 4.

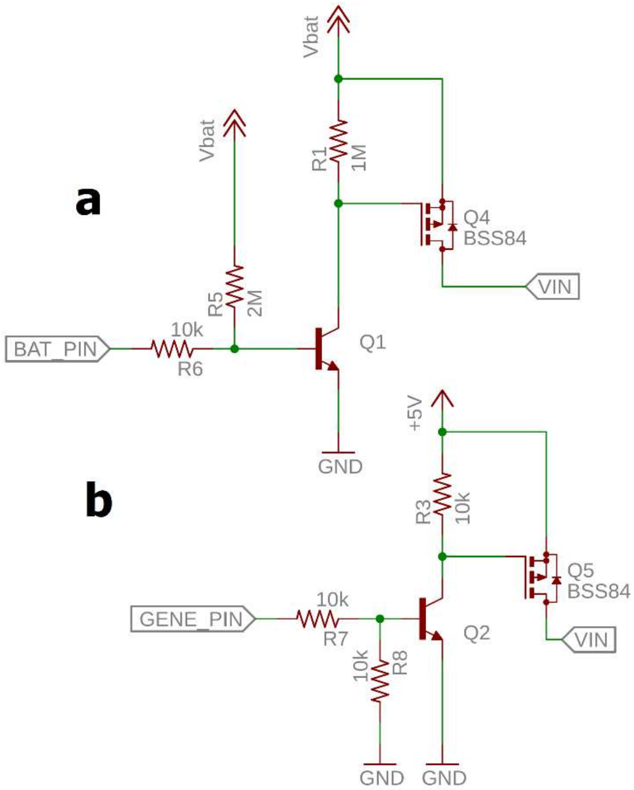

Fig. 4. Battery-generator switching circuit

As we mentioned before, the P-channel MOSFET is used as a switch, it is driven by the NPN transistor stage. Also, the microcontroller controls the power source of the system. Once the battery is plugged into the meter, in the first moment before the microcontroller boot, the pull-up resistor R5 in the circuit (a) automatically excites the NPN transistor that turns on the MOSFET that power the system through the battery, in the same time the pull-down resistor R8 in the circuit (b), disconnect the powering via turbine generator.

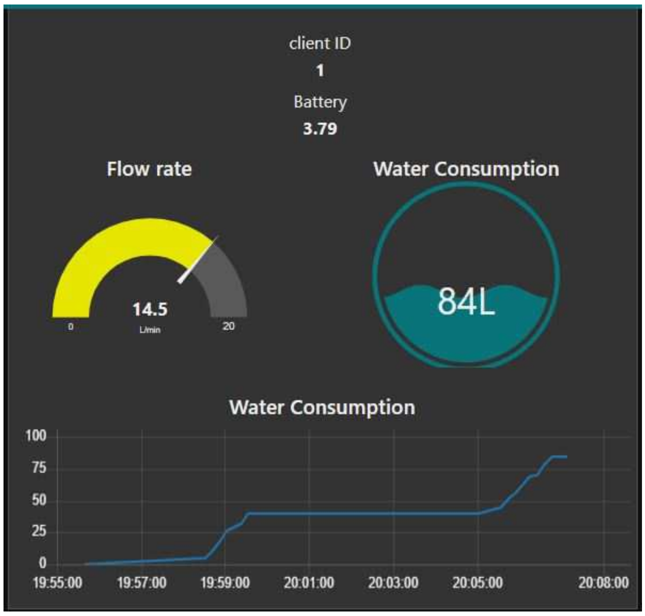

Fig. 7. Dashboard including the flow rate (L/min), consumption (L) and battery voltage.

IV. TEST AND RESULT

In order to validate the efficiency and overall achievement of the proposed system, a series of tests are conducted using a prototype realized which is shown in Fig. 5.

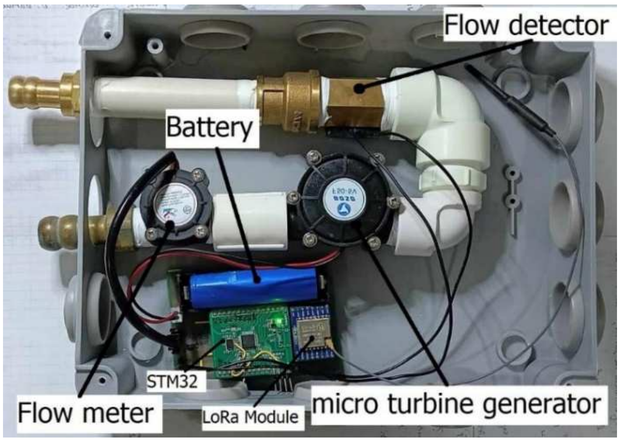

Fig. 5. Water meter prototype

The important thing that must be validated is the power consumption of the water meter and the lifespan of the battery. The following figure Fig. 6 illustrates the current measurements.

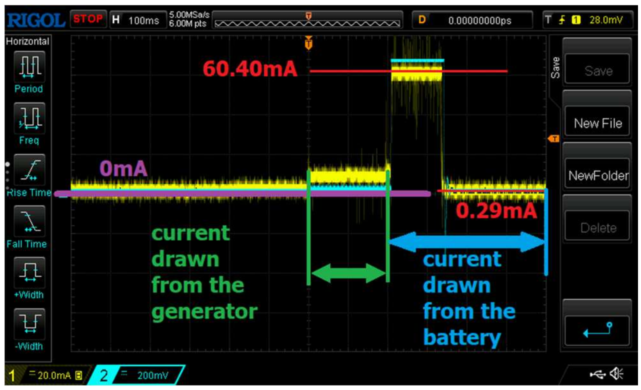

Fig. 6. Current consumption of water meter

During the period marked by the green arrow, the water meter system relied on the generator for power. Conversely, when the water flow stops, which implies that the generator can no longer provide power to the water meter, the system promptly reconnects the battery and initiates the data transmission process, and then it goes to sleep mode.

The peak in consumption occurs only during LoRa module data transmission, drawing a substantial 60.40 mA for a brief 128ms to transmit 20 bytes of data. The system maintains a low power footprint, with a minimal power consumption of just 0.29 mA during deep sleep mode. Given the assumption of water flow detection happening eight times daily, the system's reliance on a 5000mAh capacity battery ensures longevity, providing sufficient power for well over 714 days of continuous operation.

In Fig. 7, we present the meticulously designed Node-Red dashboard, which provides users with a comprehensive real-time monitoring experience. Within this dashboard, users can effortlessly track crucial metrics, including the flow rate in liters per minute (L/min) and consumption in liters. These essential parameters are visualized using gauge and level representations. Moreover, the dashboard offers a historical consumption data chart, enabling users to analyze usage trends over time. Additionally, users have the convenience of monitoring battery voltage, ensuring uninterrupted device functionality. Lastly, for identification and personalization, the consumer ID is displayed within the dashboard interface.

V. CONCLUSION

When there's a need for an automatic reading water meter in an environment without readily available electricity, the selection of an energy-harvesting meter becomes essential. Creating intelligent systems capable of effectively managing energy to maximize battery lifespan is a challenging job.

This paper discusses the implementation of an energy-harvesting water meter, and it is a remarkable achievement for the water meter battery's lifespan of 714 days. What's particularly noteworthy is that this accomplishment has been made possible through the integration of low-cost components.

Our work underscores the potential of energy harvesting as a transformative solution for conserving resources and optimizing the efficiency of IoT devices in various applications.

ACKNOWLEDGMENT

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