Aqua Sink Pro: Enhancing Water Heater Safety and Efficiency with IoT and Real-Time Monitoring: Using Water Flow Sensors

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***Abstract*— The traditional water heaters usually present continues safety hazards and operational faults due to outdated design and due to limited control features. There are listed issues that might affect the water heaters such as electric shocks, heater explosions, inefficient energy and lack of remote-control capabilities which are happening in many houses. To avoid all those issues, Aqua Sink Pro has developed a solution which integrates safety features along with IoT technology to enhance water heating systems. This research evaluates the new water heating system "Aqua Sink Pro" to address the safety concerns which are associated with traditional water heating systems. In addition, it investigates the ability to prevent electrical shocks and heater failure which might cause explosions across various household environments by adding safety features and developing a real-time monitoring capability. Furthermore, the study investigates the device's ability to recognize and reduce dangers via app-based notifications and managing water temperature and remotely control with the goal of improving overall safety and user happiness.**

The system has been tested using the prototype of Aqua Sink Pro. It tested the validation and effectiveness in improving safety, energy efficiency, and user convenience in residential water heating applications. The findings have revealed the potential to transform traditional water heater technology to a smarter and efficient alternative system for modern households.

Index Terms- keyword; Internet of Things, Electrical Water Heaters, Hazards, Water Flow, Smart Cities.

I. INTRODUCTION

Traditional water heaters are common in homes all over the world, but because of their antiquated designs and few control options, they can pose serious hazards to public safety as well as operational uselessness [[1]. Problems like electric shocks and heater explosions are extremely dangerous for both people and property, especially in older models or those with defective wiring [[2]. The lack of user-friendly interfaces in these systems makes it difficult to control water temperature and usage, which wastes energy and raises utility bills [[1]. Furthermore, everyday tasks are made more inconvenient and inefficient by the inability to operate them remotely.

As a result, the Aqua Sink Pro shows up as a creative fix that has the potential to completely transform water heating technology.

By combining cutting-edge safety features and Internet of Things capabilities, Aqua Sink Pro seeks to reduce the dangers of electric shocks and explosions. Users may remotely monitor and modify the water settings using its app-based interface, which guarantees peak performance and energy economy. By automatically identifying dangers and sending out real-time notifications, proactive safety measures help prevent accidents before they happen.

In addition, Aqua Sink Pro promises to save a large amount of energy by optimizing heating operations and turning it on and off based on demand, both of which promote environmental sustainability. Its easy installation and user-friendly interface improve accessibility, which makes it easier for a wide range of household contexts to adopt. The basis for investigating Aqua Sink Pro's revolutionary potential to improve home water heating systems' use, safety, and efficiency is laid forth in this introduction.

A. Problem Statement:

Traditional water heaters pose significant safety risks due to their lack of advanced control and protective features. Common issues include the potential for electric shocks, particularly in households with faulty wiring or older water heater models, which can lead to serious injuries or even deaths.

Additionally, there is a risk of heater explosions due to overheating or malfunctioning components, which can cause substantial property damage and endanger lives. Many existing water heaters also lack user-friendly controls, making it difficult to manage water temperature and usage efficiently. This can result in wasted energy, higher utility bills, and increased wear and tear on the heater, ultimately shortening its lifespan. The inability to control water heaters remotely further exacerbates these issues, leading to inconvenience and inefficient energy use as users must manually adjust settings or turn the heater on and off.

B. Problem Solution:

Aqua Sink Pro offers a comprehensive solution to these critical issues by integrating advanced safety and control

features into a single device.

With its app-based interface, users can easily set and adjust the heater's temperature and schedule, ensuring optimal performance and energy efficiency. The device's smart safety feature continuously monitors the electrical current and automatically cuts off power if it detects any electric shocks in the water, preventing potential injuries and electrical hazards.

Additionally, Aqua Sink Pro collects and analyzes data to identify potential risks and malfunctions, providing real-time alerts and comprehensive protection against water heater failures. By allowing remote control via a smartphone app, users can manage their water heaters from anywhere, enhancing convenience and reducing energy consumption. Aqua Sink Pro transforms water heater use, making it safer, smarter, and more efficient, significantly reducing the risks of electric shocks, heater explosions, and the challenges associated with controlling traditional water heaters.

C. *Research Objectives:*

1. ***Evaluate Safety Efficacy:*** Assess the effectiveness of Aqua Sink Pro's advanced safety features in preventing electric shocks and heater explosions across various household environments. Monitor instances where the device successfully cuts off power in response to detected electrical hazards.
2. ***Enabling Smart Control:*** Implement IoT technology to enable remote control of water heaters via a smartphone app. Focus on providing convenience and ease of management for users through features such as remote temperature adjustments and scheduling.
3. ***Improving Energy Efficiency:*** Design Aqua Sink Pro to reduce water waste and energy consumption. Aim to lower electricity bills and enhance environmental sustainability by optimizing heating efficiency and minimizing standby losses.
4. ***Simplify Use and Installation:*** Develop an easy-to-install device with an intuitive user interface. Ensure that Aqua Sink Pro is accessible and user-friendly, making smart water heating technology straightforward for all users to adopt and operate effectively.

D. *Research Questions:*

1. In what scenarios does Aqua Sink Pro most frequently detect and respond to electrical hazards, and how does this contribute to enhanced safety?
2. How effective is Aqua Sink Pro in preventing electric shocks and heater explosions in various household environments, particularly with the integration of IoT technology?
3. What is the average reduction in energy consumption and cost savings for households using Aqua Sink Pro compared to those without it?
4. What challenges might users face during installation and initial setup of Aqua Sink Pro?

II. LITERATURE REVIEW:

Hundreds of papers have been offered in the literature for the development of water heater safety using various methodologies, considering the regions and their safety regulations [3]. According to [4], water heaters are common in modern households, providing hot water for daily activities.

They use gas, electricity, or solar energy to heat water, which is then employed for showers, space heating, and appliances. However, these devices could cause safety issues, such as electric shocks, heater explosions, and difficulty managing regular water heaters. When a water heater breaks, it can cause damage to the entire house. Various home fires occurred in the Sultanate of Oman each year [2], resulting in health or personal loss. The history of home accidents caused by water heaters, as well as the usage of behavior safety, highlight the importance of designing an electrical system that makes the water heater smart enough to provide safety. As a result, water heater safety to decrease all these hazards has become a necessity to save human lives and protect their health [5].

Researchers have investigated the use of the Internet of Things (IoT) to improve the safety of water heaters and control them from many locations. Recent research has shown that IoT-based monitoring systems can increase the safety of water heaters. Research by [6] has developed monitoring of boiler parameters using wireless communication by avoiding accidents in hazardous places wherever humans are not able to work. The research has monitored the temperature, humidity, fire, and gas and then the values are visualized through mobile apps by using Internet of Things sensors. Visualizing the monitored heaters through mobile apps using the Internet of Things (IoT) will enhance safety in sensitive areas, for example kitchen and bathrooms [7].

The adoption of IoT technology into smart homes has raised new security and privacy concerns. The interactivity of devices and the flow of sensitive data threaten the privacy, authenticity, and integrity of the information collected and transferred [4]. These security flaws can expose smart homes to a variety of attacks, necessitating a thorough assessment of the security state of IoT-enabled homes. Researchers have devised a method that can identify potential security issues and provide a full picture of the security landscape in IoT-based smart homes. Smart homes connect appliances throughout the house to provide safer living conditions and more efficient control [4]. The Internet of Things (IoT) technology plays an important part in achieving this, linking numerous components using physical devices (sensors, actuators, and controllers), allowing for more options to sponsor smart homes [8].

A study has been done in Indonesia [9] to protect the human body from water heater shocks. They depicted what could happen when an electronic shock passes through the human body and how to avoid it. They represented many aspects of safety, such as the importance of proper water heater installation and the types of human mistake that can occur when people use an electrical heater.

III. BACKGROUND

An overview of the key elements of the Internet of Things (IoT) will be provided in this section:

A. *Internet of Things (IoT):*

The term "smart things" refers to a network of physical objects that have sensors, software, and communications capabilities. This network is called the Internet of Things (IoT) [10]. These gadgets are distinguished by their capacity to gather information and share it via the Internet with other gadgets and systems. The rapidly evolving sector of the Internet of Things has the potential to revolutionize a wide range of elements of our lives, from streamlining industry processes to automating household tasks [[11].

B. *Applications of IoT technology:*

Fig. 1 shows some of the most explored applications of the IoT system such as:

Fig. 1. Applications of IoT Systems[1]

- ***Smart Homes***: the automation and remote control of lighting, appliances, security cameras, thermostats, and other elements of the home environment are made possible by Internet of Things (IoT) devices. Convenience, energy efficiency, and security are all improved by this feature [[1]. For instance, smart lighting systems may be managed to save energy, security cameras offer real-time monitoring and alarms, and thermostats can change temperatures based on occupancy patterns. Homeowners' general quality of life and safety are enhanced by smart house IoT technologies [[12].

- ***Healthcare:*** Through wearable medical technology, medication tracking apps, remote patient monitoring, and hospital asset management, the Internet of Things is revolutionizing the healthcare industry. These technologies make it possible to continuously monitor patient health parameters, which makes it easier to identify health problems early and take appropriate action [13]. By extending care outside of conventional hospital settings, remote patient monitoring can improve patient outcomes and lower readmission rates.

  IoT in healthcare also improves hospital operational efficiency by streamlining operations and maximizing asset use.

- ***Industrial Internet (Industry 4.0):*** IoT sensors and devices are incorporated into supply chains and manufacturing equipment in industrial settings to facilitate features like inventory management optimization, real-time production process monitoring, and predictive maintenance [[2]. Industry 4.0's use of IoT boosts output, lowers downtime through preventative maintenance, and increases overall operational effectiveness. Manufacturers may optimize production, reduce waste, and enhance product quality by using data from IoT sensors to inform their decisions [14].

C. *Enhancing Safety through IoT:*

- ***Industrial Safety:*** IoT sensors and devices are essential in industrial settings for keeping an eye on environmental factors and equipment health. These sensors can identify irregularities in machinery, including vibrations or sudden temperature spikes, which may point to possible problems or safety risks [15]. IoT solutions can improve workplace safety by preventing accidents and equipment breakdowns by continuously monitoring these factors in real-time.

- ***Smart Home Security:*** IoT-based smart home security systems monitor homes and alert homeowners to any suspicious activity or breaches using networked devices like cameras, motion sensors, and smart locks [6], [16]. In an emergency, homeowners may take fast action thanks to the remote access and control capabilities of these systems via smartphones or other devices. IoT in smart home security improves monitoring capabilities and allows for quick reaction to possible attacks, giving users peace of mind.

- ***Healthcare Monitoring:*** IoT devices are essential for healthcare monitoring since they gather and send patient data continually, including vital signs, activity levels, and medication adherence [[17]. For instance, elderly patients or those with chronic diseases can be monitored by wearable IoT devices, which can notify caretakers or medical specialists of any deviations from normal parameters. Because it allows for early action in the event of a health emergency or decline, this real-time monitoring improves patient safety [18].

D. *Enhancing Safety of Water Heaters:*

There are several hazards associated with traditional water heaters, the main one being the potential for electric shocks. These dangers result from several factors [18]:

- ***Electrical Faults:*** Electric shocks can result from faulty wiring, improper grounding, or problems with insulation.

- ***Manual Operation:*** Because the heater must be turned on and off by hand, there is a greater chance that it may be

[1] Accessed dated on 27/06/2024 from: https://www.spiceworks.com/tech/iot/articles/top-applications-internet-of-things/

left on accidentally, which increases the danger of overheating and possible electrical risks.

- ***Inaccessibility:*** Conventional heaters are difficult to monitor or manage remotely once installed, which makes it challenging to act f3ast in the event of an issue.

However, using the Aqua Sink Pro, the innovative IoT-enabled smart device, addresses these safety issues, and transforms the water heating experience. Here's how it enhances safety:

1. Advanced Shock Prevention:
    - ***Current Sensor:*** Constantly monitors the electrical current. If an abnormality or potential shock risk is detected, the system triggers an automatic power cut-off via the relay.
    - ***Relay Control:*** Acts as an electromechanical switch that disconnects the electrical circuit instantly in case of detected risks, preventing electric shocks.
2. Real-Time Monitoring and Alerts:
    - ***ESP32 Microcontroller:*** Connects to the Internet, allowing the device to be monitored and controlled remotely via a smartphone application. It sends real-time alerts to the user about any things.
    - ***Water Flow Sensor:*** Detects water movement and ensures that the heater operates only when there is no water flow, which may cause an electrical shortage.
3. Automated Control:
    - ***Remote Control:*** The smart app enables users to turn the heater on and off remotely, adjust the temperature, and schedule operations, significantly reducing electrical consumption due to accidentally leaving the heater on for too long.
    - ***Thermostat temperature sensor:*** it monitors the ambient temperature and ensures that the heater operates within the safe or selected temperature limits.
4. User-Friendly Interface:
    - ***Display inside app****:* Provides clear status updates on the heater's condition, making it easy for users to monitor and ensure everything is functioning safely [9].
    - ***Notifications****:* The system can send notifications to the user's smartphone in case of any issues, allowing for immediate action to be taken even if the user is not physically present [18].

E. How the IoT System Prevents Safety Issues:

The integration of IoT technology in Aqua Sink Pro introduces multiple layers of safety that were not possible with traditional heaters:

- **Proactive problem detection**: Ensures continuous monitoring of heater status and water flow.
- **Automatic Shutoff**: In the event of a detected hazard, the system automatically shuts off power, preventing electric shocks and other potential dangers.
- **Remote Management**: Users can manage their water heater remotely, allowing them to quickly react to any issues by turning the heater off.
- **Smart Alerts**: Immediate alerts to the user's smartphone ensure they are always informed of the heater's status and any necessary actions.

In summary, Aqua Sink Pro revolutionizes water heater safety by combining advanced sensors, automated controls, and real-time monitoring to eliminate the risks associated with traditional water heaters.

IV. AQUA SINK PRO (IOT) ARCHITECTURE:

The main component that makes the connection to the Internet and enables remote control of the device through an application is the ESP32 as shown in Fig. 2. It also includes the code that aids in signaling and controlling other components of the apparatus. The electrical connection is cut off when water flows through the pipe because the water flow sensor signals the current sensor, which then signals the relay.

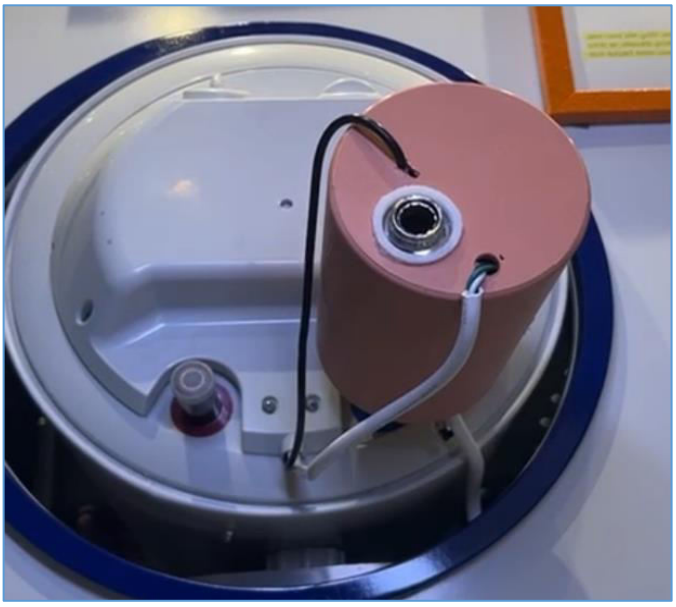

Fig. 2. Aqua Sink Pro (IoT)

The initial design of the device using a Water Flow Sensor and Relay sensor without using the Internet of Things is illustrated in Fig. 3. However, the system has been upgraded and improved to obtain the research objectives. The diagram illustrated in Fig. 4 provides the upgraded configuration of the water heater along with the proposed system of Aqua Sink Pro IoT system. It shows how the water heater safety by combining advanced sensors, automated controls, and real-time monitoring to eliminate the risks associated with traditional water heaters.

Water Flow Sensor sends a signal to the current sensor with a constant voltage when water flow is sensed. The Current Sensor receives the signal from the water flow sensor. Then

sends a constant voltage signal to the ESP-32 module.

Fig. 3. Initial design of Aqua Sink Pro

The Current Sensor receives the signal from the water flow sensor. Then sends a constant voltage signal to the ESP-32 module. ESP-32 is a microcontroller that receives the constant voltage signal from the current sensor. It processes data from the current sensor and water flow monitor. It also receives temperature data from the temperature sensor.

Based on the received data, it sends signals to the relay to control turning on or off the heater. Relay then will receive signals from the ESP-32 module and turns off or turns on the electricity to the heater based on the commands received from the ESP-32 module. The Thermostat Temperature Sensor measures environmental temperature. It sends temperature data to the ESP-32 module. The adapter then converts electricity from alternating current (AC) to direct current (DC) to power the ESP-32 module.

This can be adjusted and controlled by using an app application designed and implemented to test the new prototype system. The application displays heater status data and current temperature. Through the application, the user can adjust settings such as temperature, operating hour or stop hour for the heater, and see the status of the heater.

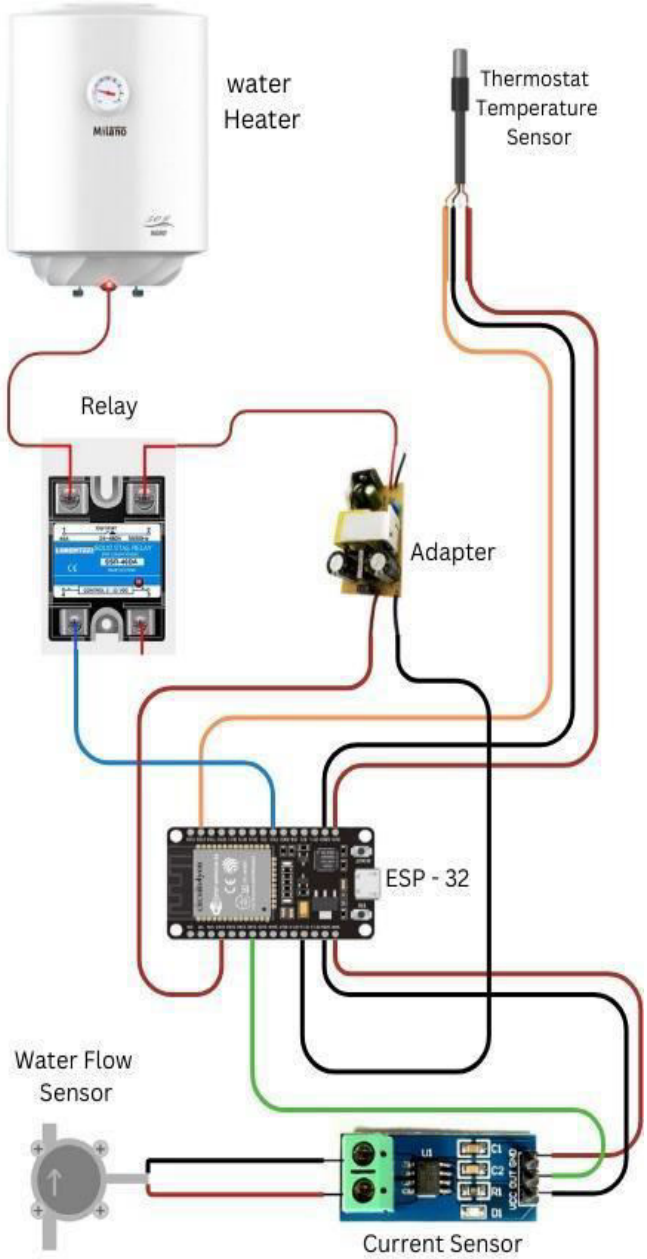

Fig. 4. Electrical connection circuit of measure sensors in Aqua Sink Pro

A. The Aqua Sink Pro's (IoT) Sensors:

1. ***ESP32 Microcontroller:*** It is the basic piece that connects to the Internet and the intermediary that connects the application to the device and contains the codes that contribute to the operation of the device.

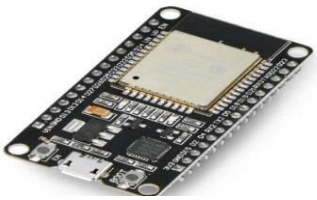

Fig. 5. ESP32 Microcontroller

2. **Water Flow Sensor:** It is a device that detects the movement of water inside the pipe.

Fig. 6. Water Flow Sensor

3. **Thermostat Temperature Sensor**: It is a device that detects the ambient temperature in a room or surrounding area.

Fig. 7. Thermostat Temperature Sensor

4. **Adapter:** convert AC (Alternating Current) electricity to DC (Direct Current).

Fig. 8. Adapter

5. **Relay:** The relay is an electromechanical switch. It serves as a control device for the electrical circuit.

Fig. 9. Relay

6. **Current Sensor:** A device that detects electrical current and generates a constant signal.

Fig. 10. Current Sensor

V. AQUA SINK PRO PRELIMINARY EXPERIMENT:

- ***Overview:***

The preliminary experiment aimed to validate the functionality and safety features of Aqua Sink Pro using simulated conditions with Mouth Blowing Air instead of water. The initial study was designed to test the feasibility, design, and methods of a larger, more definitive experiment.

This approach allowed us to assess how effectively the system detects and manages water flow, ensuring reliable performance in real-world scenarios. The key components tested included the water flow sensor, relay, and current sensor, crucial for the system's operation and safety protocols. The preliminary experiment has gone through different steps until it works successfully and gives positive outputs.

A. First testing (Failed):

The first testing of the preliminary experiment was an assembly of many pieces, and they were connected to each other as shown in Fig. 11. Unfortunately, due to the wrong connections, a short circuit occurred, which led to the burning of the Node MCU piece.

Fig. 11. An assembly of Aqua Sink Pro system

B. Second testing (Pass):

In the second testing, the system has been configured so that all connections should be assembled in proper way, so it doesn't cause same risk which we faced in the first stage. At first, we checked the water heater without any interference from outside and then we noticed that the lighting was on, and this indicates that the heater was running as indicated in Fig. 12.

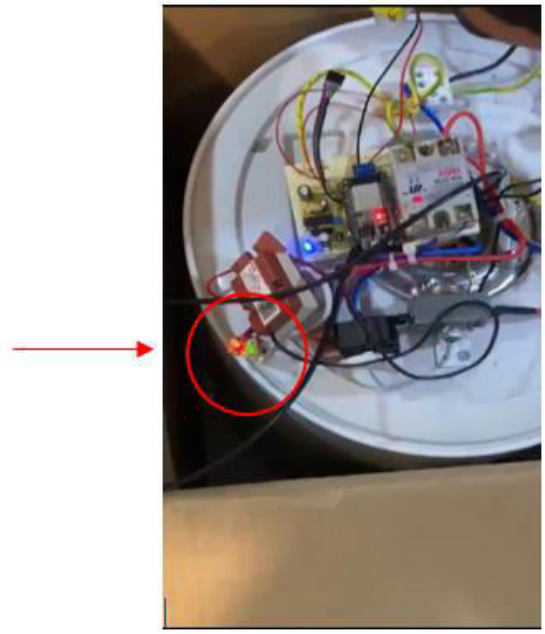

Fig. 12. Light is ON (Heater is Running)

Whereas after we used mouth air blowing, we notice that the lighting is off, and this indicates that the heater has stopped working as illustrated in Fig. 13.

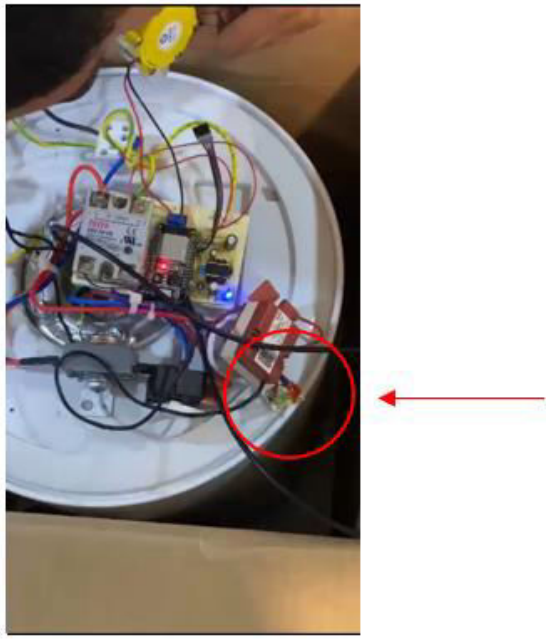

Fig. 13. Light Went Off (Stopped Working)

- ***Integration with Blynk Application:***

Furthermore, we tested Aqua Sink Pro's integration with the Blynk application for remote control functionality as shown in Fig. 14. Through this integration, we successfully demonstrated the system's capability to be turned on and off remotely using the smartphone app.

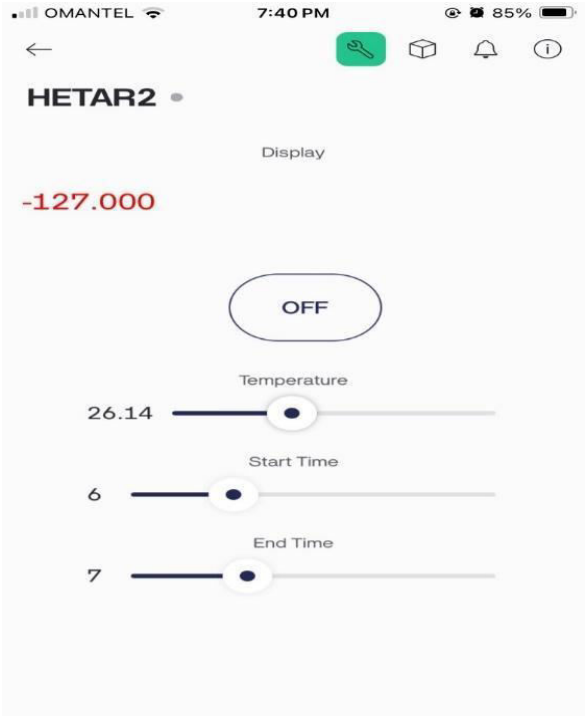

Fig. 14. Blynk Application

This test highlighted Aqua Sink Pro's user-friendly interface and its potential to enhance operational flexibility and convenience for users. By allowing remote management, the Blynk application enables users to control their water heaters from anywhere, optimizing energy usage and enhancing overall user experience.

- ***Conclusion of preliminary Experiment:***

In conclusion, our preliminary experiment validated Aqua Sink Pro's robust performance under simulated conditions using Mouth Blowing Air. The system's ability to accurately detect water flow, control the heater via the relay, and integrate seamlessly with the Blynk application for remote management was demonstrated effectively. These findings underscore Aqua Sink Pro's potential to improve safety, energy efficiency, and user convenience in water heating applications. Future research could build upon these results with extensive field testing to further validate the system's reliability across diverse household environments and usage scenarios.

VI. RESULTS

Our experimental validation using simulated conditions further substantiates Aqua Sink Pro's robust performance, particularly in detecting and managing water flow effectively as listed in Table 1.

Table 1. The Results of the Simulated Environment (Aqua Sink Pro)

Color	Effects	Status	Water Heater
Red/Green	No effects	Light is ON	Heater is Running
Red/Green	Air Blowing	Light Went Off	Stopped Working

Integration with the Blynk application for remote control functionality enhances operational flexibility, illustrating its potential to adapt to diverse user needs and preferences.

The Aqua Sink Pro represents a pivotal advancement in smart water heating technology, addressing safety concerns, improving energy efficiency, and enhancing user experience. Moving forward, continued research and field testing will further validate its reliability across varied household environments, ensuring broader adoption and sustained benefits for users worldwide.

VII. LIMITATIONS & CHALLENGES:

For our main experiment, we tried to get permission from the Civil Defense and Ambulance Authority to test the Aqua Sync Pro project, but we were unable to proceed because they do not have the protective equipment with this type of project. The biggest challenge for the device is obtaining a place prepared to experiment with such devices.

VIII. FUTURE DEVELOPMENT:

- Reducing the size of the device and modifying its shape.
- Using recycled materials in manufacturing.
- Update the application interface with more specific features which allows to control the system from distance.
- Get permission from the Civil Defense and Ambulance Authority to test the Aqua Sync Pro project in real life water heater as full experiment and get real time results.

IX. CONCLUSION

The Aqua Sink Pro represents a significant advancement in addressing the longstanding safety and efficiency challenges associated with traditional water heaters. Through our research, we have comprehensively evaluated its performance across key metrics, highlighting its transformative impact on residential water heating systems.

Our study confirms that Aqua Sink Pro effectively mitigates safety risks such as electric shocks and heater explosions through its advanced safety features and real-time monitoring capabilities. By automatically cutting off power upon detecting electrical hazards, the device ensures enhanced safety for users, significantly reducing the potential for injuries and property damage.

In terms of energy efficiency, Aqua Sink Pro demonstrates substantial improvements by optimizing water heating processes and minimizing wastage. Our analysis reveals notable reductions in energy consumption and associated cost savings for households, underscoring its role in promoting environmental sustainability while lowering utility bills.

User experience emerges as another critical aspect where Aqua Sink Pro excels. The app-based interface simplifies the management of water temperature and scheduling, offering users greater control and convenience. Moreover, the system's ability to provide real-time alerts and proactive risk identification enhances operational reliability and user confidence.

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