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IoT-Based Smart Water Leakage Detection and Control System for Metro Pipelines

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***Abstract*— The proposed project develops an IoT-based leakage detection and control system for urban water pipelines. Flow sensors are placed at different sections to measure the amount of water passing through the pipe. The measured values are analysed using an Arduino controller. Instead of sending all the data to an online server, the controller compares flow readings between two points directly. If a difference continues for a certain period of time, the system assumes that leakage may have occurred. A small delay mechanism is included to prevent false detection due to temporary variations in water consumption. Water leakage in underground pipelines is a common problem in metropolitan cities. Traditional inspection methods mainly involve manual checking at intervals, which does not allow continuous monitoring. Because of this limitation, a system that can observe pipeline flow continuously and react immediately is required. Test results show that the system can identify leakage conditions quickly and effectively, which makes it suitable for improving water management in metro cities.**

Keywords*— *IoT, Water Leakage, Flow Monitoring, Arduino Controller, Smart Water System, Water Leakage Detection, Smart Water Management, Arduino UNO, Flow Sensor.

I. INTRODUCTION

When we started looking into the issue of water leakage in city pipelines, we realized that it is not always a sudden or dramatic failure. Most of the time, the problem develops slowly. In growing cities, water demand keeps increasing because the population keeps growing. But the underground pipelines that supply this water are often old. Many of them have been working for years under changing pressure conditions. Over time, this constant stress affects their strength. Pipelines buried underground face many environmental factors. The soil around them shifts slightly. Small cracks can form, or joints may become slightly loose. These changes are not visible from the outside. Because the pipelines are hidden under roads buildings, it is very difficult to detect leakage at an early stage. In most cases, leakage becomes noticeable only when water appears on the surface or when people complain about low pressure in their homes. By that time, the leakage may have been happening for a while. Even a small crack can waste a large amount of water if it continues for days. This not only wastes water but can also damage nearby roads or structures. Traditional leakage detection methods are still used in many places.

II. LITERATURE SURVEY

The Water-Saving Control System with Multiple Intelligent Algorithms is built to help people use water more efficiently. It keeps an eye on how water is being used, finds leaks or waste, and makes automatic adjustments to prevent unnecessary usage. By learning from everyday patterns, it helps save water, cut costs, and encourages smarter, more sustainable habits—perfect for homes, offices, and factories [1].

The IoT-Driven Leak Detection in Real Water Networks Using Hydrophones focuses on finding leaks quickly and accurately using smart technology. By combining sensors called hydrophones with A IoT systems, it listens to the sounds in water pipes and detects even small leaks that are hard to notice otherwise. This approach helps save water, reduces repair costs, and keeps the water supply running smoothly, making it practical for cities, industries, and communities alike [2].

The Internet of Things-enabled real-time water quality monitoring system is built to make checking water safety simple and continuous. Instead of waiting for manual testing, the system uses connected sensors to regularly measure important factors like pH level, clarity, and possible impurities. If anything unusual is detected, it sends an alert immediately so action can be taken without delay. This helps make sure the water people use every day is safe, clean, and reliable, whether it's for homes, industries, or public supply [3].

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The Smart Water Supply System with a Quasi-Intelligent Diagnostic Method for Distribution Networks is meant to make handling water supply easier and more efficient. It keeps track of how water moves through the network and notices small changes in flow or pressure that might point to a problem. Instead of waiting for a major breakdown, the system helps identify issues early so they can be fixed quickly. This reduces water wastage [4].

The Hybrid TDR-MI Based Wireless Sensor Network for Underground Water Pipeline Leakage Detection and Localization is created to handle the tough task of identifying leaks that happen beneath the surface. Because these pipelines are hidden underground, leaks can go unnoticed for a long time. This system uses wireless sensors to continuously monitor pressure changes along the pipeline. When something unusual is detected, it carefully checks the data to confirm if there is a leak and helps locate where it is happening [5].

Water leak detection in pipeline networks is becoming more important as cities grow and water demand increases. Even today, many systems struggle with problems like inaccurate sensor readings, delayed detection, data overload, and difficulty in monitoring large underground networks. Traditional methods often rely on a single type of data, which may not give a complete picture [6].

The Frequency-Informed Transformer for Real-Time Water Pipeline Leak Detection is designed to spot leaks quickly and accurately as they happen. It uses advanced frequency-based analysis to understand the signals coming from water pipelines, allowing it to detect even small leaks in real time. By catching problems early, this system helps save water, reduce repair costs, and keep the water supply running smoothly for homes, businesses, and communities [7].

The Machine Learning Model and Strategy for Fast and Accurate Leak Detection in Water Supply Networks is designed to make spotting leaks easier and faster. It watches the water network in real time, identifies unusual patterns, and quickly finds leaks so they can be fixed without delay. By doing this, it saves water, cuts repair costs, and helps ensure a steady, reliable water supply for homes, offices, and communities [8].

This work reviews existing research relevant to leaks in city water pipelines are a problem we usually don't notice until it becomes serious. As our cities grow and people use more water, old pipes struggle to keep up. Even tiny leaks, over time, can waste a lot of water, increase costs, and make repairs more frequent. Climate change only makes things worse, putting extra pressure on pipes that are already weak. In the past, engineers had to walk along streets with listening devices or check pressure and flow readings to find leaks. It was slow, and sometimes leaks were discovered too late [9].

This project is mainly about finding water leaks in pipelines at the right time, without depending completely on manual checking. In many places, leaks are noticed only after a lot of water is already wasted. Regular inspections can take time, and sometimes small leaks go unnoticed until they become serious problems. To overcome this, our system uses IoT sensors that are placed in the pipelines to continuously monitor water flow and pressure [10].

III. METHODOLOGY

The authors are using flow sensors, Arduino UNO, relay module, water pump, buzzer, LCD and an IoT module, which are shown in Fig.1. The flow sensors are fixed at different places in the pipeline. These sensors measure how much water is flowing in each section. The Arduino reads these values continuously. If the flow at one point does not match the other point, the Arduino checks whether the difference is large. If it is large and continues for some time, then the system assumes leakage. After that, the relay turns off the pump to stop further water loss. At the same time, the buzzer gives an alert sound.

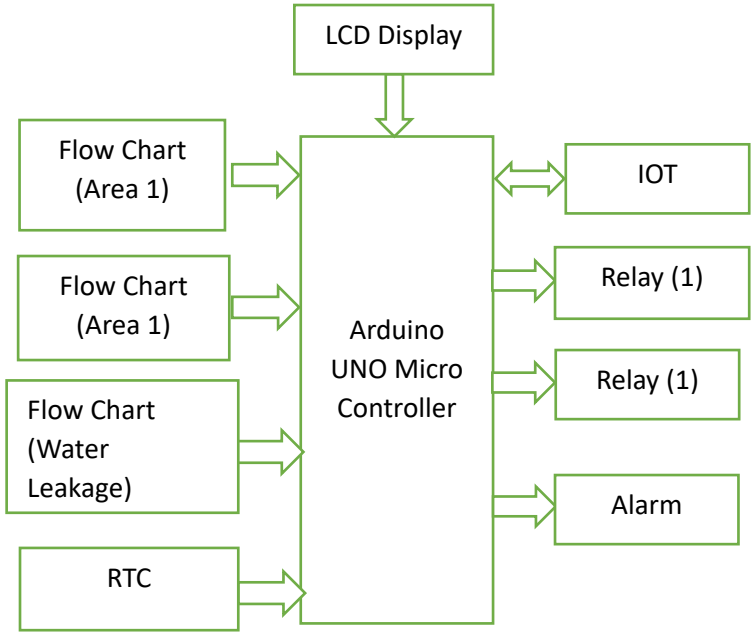

Fig. 1. Block Diagram of the proposed IoT-based water leakage detection and control system.

The IoT module sends the information to a monitoring system so the user can see the status.
The system is arranged in a simple way. Each sensor gives input to the Arduino. The decision is taken inside the Arduino itself, so it does not fully depend on the internet. Because of this, the response will be faster even if the network is slow. The IoT module is used only for sending data and showing the system condition remotely. Users can check flow values and leakage status from another place. This makes monitoring easier for large pipeline areas.

IV. HARDWARE IMPLEMENTATION

The author uses different hardware components that work together to detect water leakage and control the pipeline. The system is designed to work automatically without much human effort. The Arduino UNO, Flow Sensor, Relay and

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Pump, IoT Module, LCD and alarm. Below is a detailed discussion of each component and its role in the system.

A. Arduino UNO

The Arduino UNO works behind the scenes to make sure everything functions properly. It keeps an eye on the data coming from the sensors fixed along the metro pipeline, especially the flow and pressure sensors. When the readings go beyond the normal range, the Arduino understands that something is not right and treats it as a possible leak. Without any delay, it helps in sending notifications and can also control the valve to prevent more water from being wasted. Simply put, the Arduino UNO acts like the thinking part of the system, helping it react quickly and work efficiently.

B. Flow Sensors

In this smart water leakage detection system, the flow sensor is the part that keeps checking how smoothly the water is moving inside the metro pipeline. It continuously measures the speed and amount of water passing through and shares that information with the controller. If there is any sudden drop or unexpected change in the flow, it gives a hint that there might be a leakage somewhere. Because of this, the system can quickly notice the issue and take action before too much water gets wasted.

C. Relay and Pump

In this project, the pump's main job is simply to keep water moving through the metro pipelines so the supply doesn't get interrupted. It pushes the water forward and makes sure it flows at a steady rate. The relay helps by acting like a basic on-off switch that the system controls automatically. When everything is normal, the pump runs quietly in the background. If a leak is noticed, the system immediately uses the relay to switch the pump off. This way, the water flow is stopped at the right time, helping to avoid waste and keep the pipeline safe.

D. LCD and Alarm

In this smart metro pipeline system, the LCD and alarm help people quickly understand what is going on. The LCD screen displays simple messages about the water flow, whether everything is normal or if a leak has been detected. It makes monitoring easy without needing any technical knowledge. The alarm supports this by giving a clear sound alert whenever there is a problem. So even if no one is watching the screen, the alert sound immediately grabs attention.

E. IoT Module

The Internet of things (IoT) is the network of physical devices, vehicles, home appliances, and other items embedded with electronics, software, sensors, actuators, and connectivity which enables these things to connect, collect and exchange data. IoT involves extending Internet connectivity beyond standard devices, such as desktops, laptops, smartphones and tablets, to any range of traditionally *dumb* or non-internet-enabled physical devices and everyday objects. Embedded with technology, these devices can communicate and interact over the Internet, and they can be remotely monitored and controlled.

V. SIMULATION

The author shows the fig.2, the smart water leakage detection system works as a whole. Flow sensors are placed at different points along the metro pipeline to keep an eye on the water flow all the time.

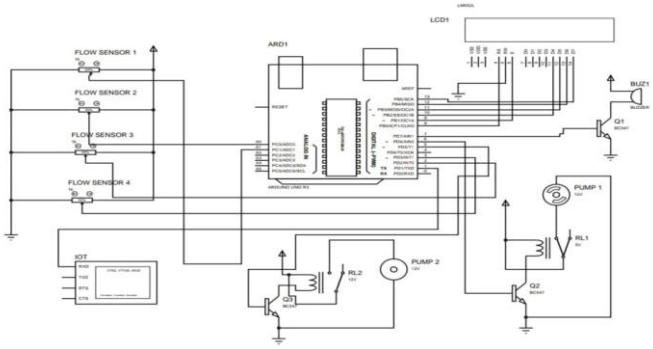

Fig. 2. Simulation Diagram

They send this information to the Arduino UNO, which acts like the brain of the system and immediately notices any unusual changes that could mean there's a leak. The IoT module also lets you check the system from anywhere, anytime.

On the other side, the LCD screen, buzzer, relays, and pumps work together like a team. The LCD shows simple messages about what's happening, so anyone can understand the status of the pipeline at a glance. If a leak is detected, the buzzer rings right away to alert people nearby. At the same time, the Arduino tells the relay to turn off the pump, stopping the water flow instantly. Everything works together to catch leaks early, save water, and keep the pipeline safe.

VI. PROTOTYPE AND DISCUSSION

The IoT-based Smart Water Leakage Detection and Control System for Metro Pipelines is built to make managing city water pipelines easier and smarter. Leaks in pipelines are common and can waste a lot of water if not spotted quickly. This system uses small smart sensors that constantly monitor the flow of water. The moment something unusual happens, like a sudden drop or surge, it immediately alerts the authorities so they can fix the problem fast and prevent bigger damage.

But it doesn't stop at just detecting leaks. The system can also control water flow automatically, closing off the damaged section while keeping the rest of the supply steady. With real-time monitoring and smart control, it saves water, reduces

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repair costs, and ensures that residents always have a reliable supply without interruptions.

VII. CONCLUSION

The IoT-based Smart Water Leakage Detection and Control System for metro pipelines makes managing city water simple and reliable. It keeps an eye on water flow all the time, so leaks are noticed right away, saving water and avoiding expensive repairs. The system can take care of problem areas on its own without disrupting supply to other parts of the city, keeping things running smoothly for everyone.

On top of that, it protects pipelines, reduces the workload for maintenance teams, and helps cities use water more responsibly. With this system, cities can provide a steady water supply, cut down losses, and move toward smarter, sustainable living.

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