SMART WATER LEKAGE DETECTION SYSYTEM

Dr.Senthilpandi S **Shreya Mridula S** **Sriniranjan V** **Suruthi S**

senthilpandi.s@rajalakshmi.edu.in

220701271@rajalakshmi.edu.in,

220701287@rajalakshmi.edu.in,

220701294@rajalakshmi.edu.in

Rajalakshmi Engineering College,
Chennai, Tamil Nadu, India

1.ABSTRACT

Water leakage and illegal siphoning Detection System", is a detection system to manage the rising trend of water leakage and illegal use in distribution networks at the local level. With the application of sensor technologies like high-precision flow meters and pressure transducers, the system is able to efficiently monitor such key hydraulic parameters like uniformity of flow rate, pressure stability, and pressure transient response. Sophisticated data analysis identifies anomalous activity characteristic of siphoning or leaks. Real-time processing optimizes and speeds up detection. The system is installed as a local web application with securely logged data, which provides data integrity, transparency of system operation, and tamper-evident activity logs monitored. The system logs anomaly events to enable infrastructure monitoring and accountability.

Keywords: Smart Water Management, IoT, Leak Detection, Flow Monitoring, Pressure Sensors, Firebase,Secure Website,RealTime alerts.

1.1 INTRODUCTION

Water supply networks are critical as regards to access to clean water for household, farm,
driven by urbanization and population propels the network operation into difficulties, mainly leakage and illegal siphoning, all such problems add up as Non-Revenue Water (NRW) — produced but unbilled water — and undermine the utilities' efficiency and sustainability.

In the Third World, NRW may be over 30–40% because of undetected leaks, corroded and aged pipes, and abuse. Our project demonstrates a smart anomaly detection system using pressure sensors and flow sensors to identify such anomalies. The real-time processing is performed using a microcontroller and streamed to a web application on Firebase offering graphical representation of the water flow and alerts for abnormal patterns. Actionable intelligence is offered by the system to consumers and regulators such that the water supply is clean.

As more people settle in the city, water plants become pressurized and aging older plants with greater theft and tampering being witnessed become an all too likely possibility. Rural and peri-urban areas' regulation and monitoring are uncommon such that regardless of the number of illicit connections made, they never appear, and as a result, supply levels decline with service quality.

Acoustic leak detection and visual inspection are conventional techniques, which are usually plagued by inaccessibility, human error, and wastage of time when applied online. All these weaknesses are overcome in this project through the application of flow sensors, pressure sensors, and ESP32 microcontrollers when measuring water flow dynamic parameters in the network. Sensor readings are computed in real-time and streamed into a main web application built using Firebase upon which notifications and visualizations are initiated and rendered visible to users and authorities.

2. Literature Review

Traditional Methods Leakages have been a bane to water supply systems for centuries. Traditionally,leak detection relied almost solely on visual examination, acoustic listening, and manual testing. These techniques are inherently reactive, time-consuming, and lack the ability to provide real-timeinformation. Acoustic recorders, although still employed, are much less effective in noisy urban settings, and manual tests do not detect small or concealed leaks.

2.1 Sensor-Based Detection Systems

IoT technology-driven innovation—pressure and flow sensors—is the game-changer when it comes to leak detection. Placing the sensors at various strategic points in the water supply network enables one to monitor the condition of the network at any moment in real time.

Pressure and flow deviation from the normal parameters can be indicative of possible leakages or system malfunction. Real-time data enable pre-emptive maintenance, which avoids water wastage and infrastructure loss.

Wu et al. (2018) had also proposed an IoT sensor based real-time leakage detection mechanism to detect pressure oscillation and flow oscillation. These two parameters were reported to a cloud server, and machine learning methodologies were used to detect leakage patterns to enable early intervention and saving of water.

Romero-Ben et al. (2020) improved leak detection by introducing hydraulic simulation and realsensor measurements to predict leak location as a function of estimates versus real-pressure differences. Their model dramatically improved detection efficiency but still remained limited by best deployment cost.

2.2 Applications of Machine Learning

Machine learning (ML) is the technique that is used to achieve automation of water usage anomaly detection when other techniques fail. PC algorithms, which have been trained under supervised learning using the history of past water usage and leaks, are able to recognize patterns of non-conformity from conformity in order to alert one of leaks or abuse.

Where data is under-labeled, one has to use unsupervised learning techniques such as pattern discovery using cluster models or autoencoders or detection of outliers from data. They improve leak detection accuracy as well as adaptability on various deployment platforms.3. Detection of Unauthorized Connections

3.Prevalence and Impact

Illegal water connections, or "water theft," occur most commonly in low-income and high-density communities where water supply is either curtailed or intermittent by official channels. With no regular observation and lenient enforcement from the supply side, illegal connections usually remain undetected, and they cause significant non-revenue water loss and also affect network performance.

3.1 Smart Meter Data Analysis for Unauthorized Use Detection

Advances in smart metering technology enabled monitoring of high-frequency water-use patterns by utilities, which could be used to pinpoint areas of unauthorized use. The monitoring is in line with the use of past billing records as the detection method, but it happens continuously,and identifies real time.

Anomalies including unseasonal peaks in off-peak usage, reverse flow condition, or zero-pattern usage consistently leading to spikes are suspicious signs of illegal tappings or illegal tamperings. Through time-series analysis and anomaly detection methods applied to smart metering data, illegal water consumption can be detected before it occurs even if there is no customer billing data.

This solution provides support for integration with IoT-based alarm systems to alert authorities or cause auto-response (e.g., valve closure) in case of suspicious traffic being detected. This is a data-driven and scalable solution, making it ideal for smart infrastructure-based urban as well as semi-urban cities.

3.2 Real-Time Monitoring and Tamper Detection

Smart water meters with tamper detection features and real-time transmission options are another route for curbing unauthorized use. Such meters trigger alarms upon tampering or if consumption exceeds significantly from the past average. Yet, widespread adoption calls for considerable investment and infrastructure support.

4. Illegal Water Siphoning through Motors

4.1 The Issue of Motor-Based Siphoning

Illicit siphoning, normally by electric or diesel **motors**, is a special problem in water supply systems. The motors are capable of taking huge amounts of water quickly, usually from public pipes, upsetting the flow balance and leading to pressure losses at downstream locations.

This activity is common in agricultural and peri-urban regions where water supply is patchy or inadequately controlled. In addition to unequal access, motor-driven siphoning may lead to pipe bursts, contamination threats, and mechanical deterioration of the delivery infrastructure.

4.2 Detection by Pressure Fluctuations

Mitra et al. (2021) studied sudden pressure fluctuations resulting from illicit motor extraction. They created a detection model that employed past pressure history to defi ne a baseline, followed by detection of abrupt and sharp pressure decreases—characteristics of illegal siphoning.

Chen and Lin (2020) utilized an array of flow sensors and smart valves to monitor abnormal surges in flow. Once they identified siphoning, their system could initiate automatic valve closure to stop further loss. Nonetheless, separation of siphoning from typical high-demand use is still a challenging issue owing to the dynamicity of demand.

5. Tail-End Pressure Monitoring

5.1 Significance of Pressure Monitoring

Pressure monitoring at the end of a water supply main is essential for measuring system-wide health.
Pressure reduction at such points tends to indicate upstream leakage, extraneous usage, or system inefficiencies in the form of pipe aging and design issues.

Giustolisi and Savic (2016) showed the application of hydraulic modeling combined with sensor data to model the predicted pressure at different nodes. By comparing real measurements with simulated ones, network anomalies could be rapidly detected.

5.2 Predictive Analytics and Edge Computing

Shang et al. (2022) presented a predictive model that relied on historical sensor readings and water demand predictions to forecast pressure oscillations. By acting ahead of service degradation, this proactive measure allowed utilities to intervene. Edge computing—locating processing near the source, rather than in the cloud—was employed to minimize latency and enhance system responsiveness.
Edge-based pressure sensors are able to react to anomalies in real time, notifying operators or initiating automated actions such as pressure control or valve opening. These systems are especially valuable in remote and rural areas with poor connectivity.

6. Integrated Smart Water Monitoring Systems

6.1 Unified Platforms for Monitoring

A perfect water distribution monitoring system would combine all the features outlined above—leak detection, unauthorized use monitoring, siphoning prevention, and pressure optimization—into one cohesive platform. This involves coordination of several technologies such as IoT devices, cloud and edge computing, machine learning, and visualization tools.

Li et al. (2019) proposed such a system, a smart water grid that utilized sensors, data loggers, and cloud-based analytics to monitor the entire water network in real time. Not only did their platform detect anomalies but also remote management and control of valves and pumps.

Patel and Jain (2020) further developed this concept by integrating Geographic Information Systems (GIS), through which water authorities could visualize and map consumption, leakage hotspots, and risk areas. This created a spatial awareness that improved strategic decision-making and resource planning.

6.2Challenges of Implementation

Although with promising results, scaling up such combined systems proves to be challenging. These challenges are deployment costs, sensor battery life constraints, data flooding, rural connectivity, etc. Securing data, privacy, and systems resilience against cyber threats is also essential for trust and operation.

6.3Challenges and Research Gaps

Significant research gaps in smart water monitoring are:
Integration: Most of the solutions focus on one specific issue (e.g., leak detection) compared to demonstrating an end-to-end integrated setup.

Accuracy: Real-time anomaly detection from noisy input with dynamic environments remains a challenge.

Scalability: Systems can be readily deployed in a test environment in a controlled manner but demonstrating challenging to deploy citywide or in low-income areas.

Cost and Energy: Low-cost and low-power sensors are needed to cost-effective deployment but remain constrained by technology limits.

Security: Security of remote devices and user data needs to be ensured in a distributed sensor system. monitoring system that leverages the best from IOT,real-time data analysis, and machine learning to identify and detect water leakages by recognizing anomalies in flow and pressure readings,Identify illegal connections by pattern-based consumption analysis.

6.4 Project Objective

The project's aim is to develop and design and entire smart water distribution

6.5 Architecture Diagram

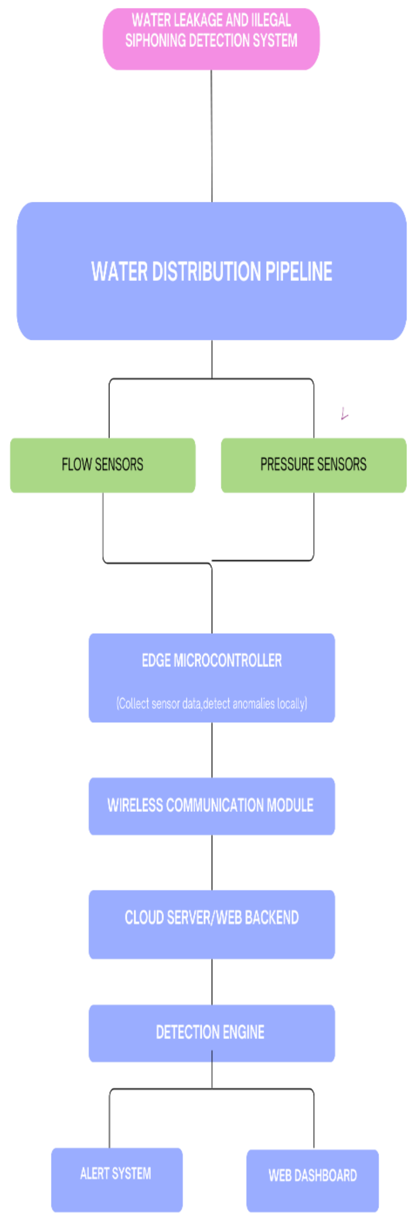


Fig.1.1 Architecture diagram

The illicit water leak detection and siphoning system design is facilitated through IoT-based sensor technology, cloud processing, and web based real-time alerting. The design utilizes some of the most critical steps: sensor data acquisition, preprocessing of data, anomaly detection, and web-based monitoring and alerting.

Mounting pressure and flow sensors on the water supply pipe initiates installation. Sensors are mounted to track instantaneous loss or siphoning action parameters round the clock, which can serve as a gauge for leakage or siphoning activities. Readings from the sensors are captured by microcontrollers (such as ESP32) and wirelessly (Wi-Fi or LoRa) transmitted to a Flask-based central backend server.

Upon receipt, data is preprocessed by removing noise, normalization, and imputation of missing values by cleaning and preprocessing. Key features to be processed are chosen to be processed. Anomaly detection in real-time is achieved by using machine learning algorithms like Random Forest, Support Vector Machines, and Gradient Boosting. Particularly, the greatest application is of Gradient Boosting since it detects at a very high rate.

The model, once trained, is implemented within the Flask server to process sensor data in real time. On identifying such sensing anomalies most likely to be siphoning or leakage, the system alerts through web interface, mail, or SMS.

All model output and sensor data, as well as alert history, are stored in a secure central database. The system supports secure configuration, persistent messaging, real-time alerting, and predictive modeling and thus makes it trustworthy for water authorities and municipalities.and Gradient.

7. Data Flow Summary

Data flow indicates end-to-end process for leak detection in water and unauthorized siphoning based on flow and pressure sensor reading and machine learning algorithm and Flask-based web platform.

The process begins by taking raw sensor readings from flow sensors and pressure sensors at the most appropriate locations in the water distribution pipe. Raw readings are in the form of continuous pressure and flow rates showing the fluctuations in the distribution pipe.

The data obtained is preprocessed with noise removal, removal of outliers, handling missing data, and normalization. Identification of important indicators of siphoning or leakage comes before feature extraction techniques.

The preprocessed data are once split into training data with 80% and test data with 20%. Support Vector Machines (SVM), Random Forest, and Gradient Boosting are trained using machine learning algorithms based on the training data so that normal and abnormal patterns of flow patterns can be identified.confusion matrix and accuracy score. Once the anomaly is identified, the model generates real-time alerts via SMS, email, or web interface.

All alarm alerts, sensor information, and model outputs are stored in a shared database in such a way that traceability, system auditing, and trending history are obtained. The whole system offers reliable, scalable, and secure water monitoring for municipal or smart city application.

8.RESEARCH GAP

Existing water distribution networks do not have sophisticated automation, forecasting, and real-time alarm systems. Legacy systems in most cases depend on manual verification or simple SCADA models without sensor-based, granular monitoring.There is a huge IoT device integration gap for constant flow and pressure monitoring, resulting in undetected leakages and unauthorized water consumption. Further, existing smart solutions are fragmented and do not provide an end-to-end system that combines leak detection, pressure anomaly detection, and cloud-based dashboards for municipal officials or end-users. SMARTFLOW overcomes these deficiencies by combining edge-level sensing, wireless communication, and cloud analytics within one system. The absence of predictive analytics and remote diagnostics in conventional water monitoring reinforces the argument better for our sophisticated real-time systems.

9. MATERIALS AND METHOD

9.1 MODULE DESCRIPTION

Flow Monitoring: Monitoring water volume in real-time.
Pressure Monitoring: Monitoring change in pressure for anomaly detection.
Leak Detection Module: Loss of flow with normal input alert.
Unauthorized Access Detection: Backflow or abnormal activity detection.
Dashboard & Alerts: In real-time displays and sends/pushes/email alerts.
Hardware and Software Needs
Hardware: ESP32, Flow Sensors, Pressure Sensors
Software: Arduino IDE, Firebase, Node-RED, React (for UI, optional)
Cloud: Firebase Realtime Database / ThingSpeak

9.2EXISTING AND PROPOSED ALGORITHM:

Manual measurement of pressure and flow.No or untimely response to misuse or leakages.Locally retained data or absence of data.No real-time alarm system.Low scalability and low automation

9.3 SYSTEM ARCHITECTURE

Modules: ESP32 Microcontroller,Flow Sensor (e.g., YF-S201 or equivalent),Pressure Sensor (e.g., BMP180),Firebase/ThingSpeak for storing data,Mobile/Web dashboard (React, Flutter, or any UI library)

9.4 MODULE DESCRIPTION

Flow Monitoring: Sweeps water in real-time.

Pressure Monitoring: Tests pressure fluctuation for abnormality.

Leak Detection Module: Detects abrupt flow drop with normal input, triggers alarm.

Unauthorized Access Detection: Holds unusual but occasional trend or flow.

Dashboard & Alerts: Shows in real-time with push/email alert.

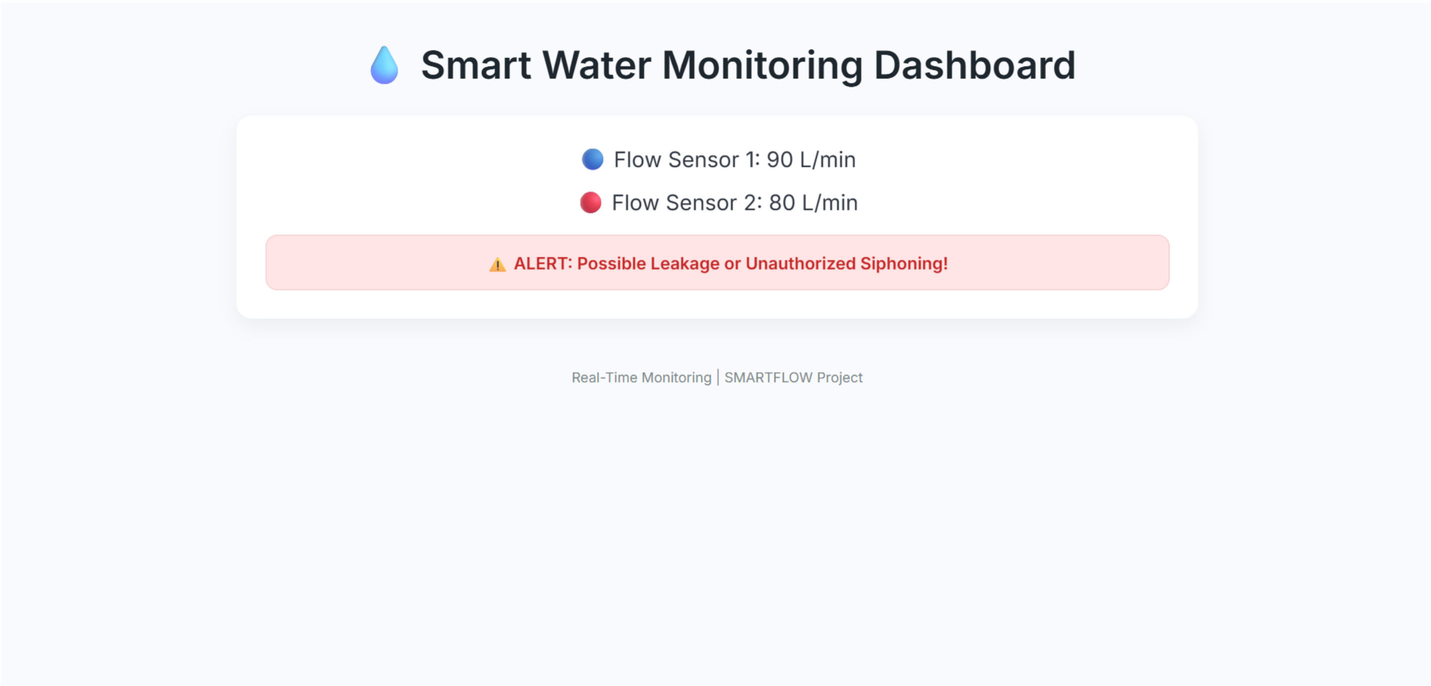
9.5 TECHNOLOGY USED

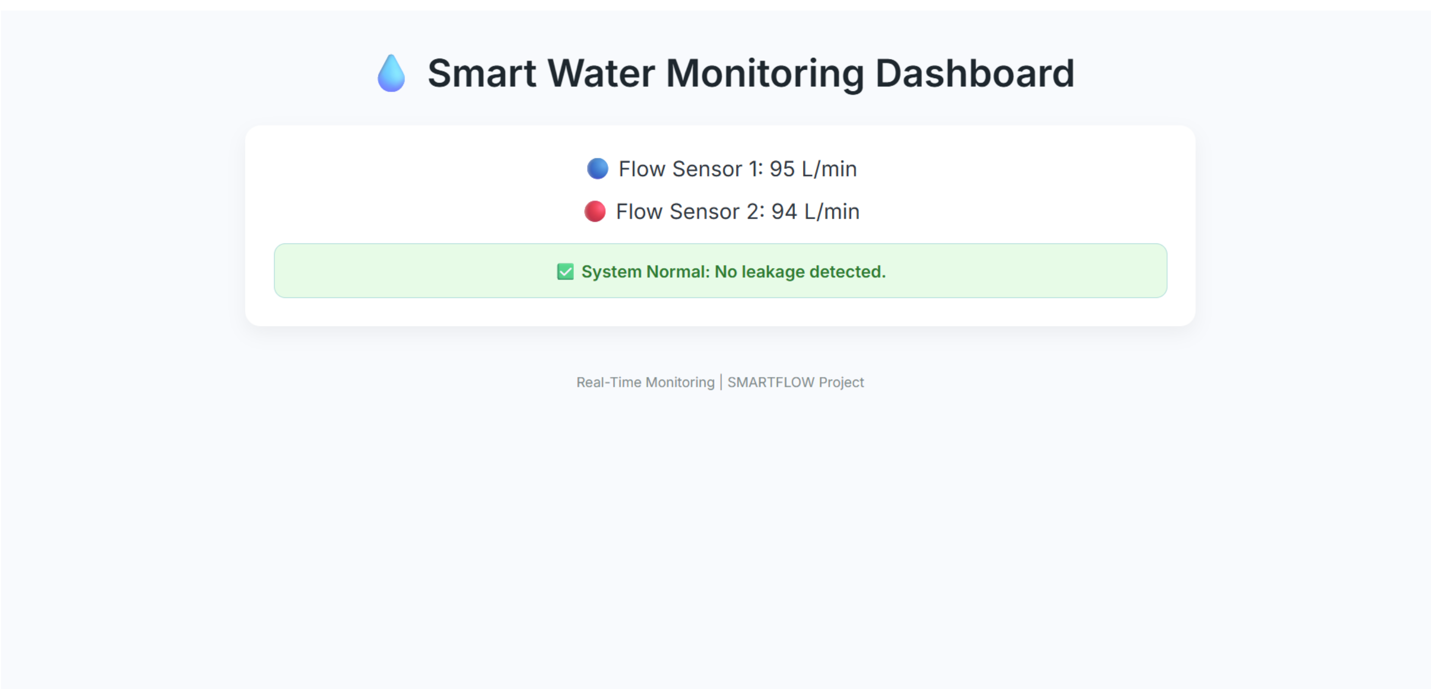
Hardware: ESP32, Flow Sensors, Pressure Sensors

Software: Arduino IDE, Firebase, Node-RED, React (optional UI)

Cloud: Firebase Realtime Database / ThingSpeak

10.RESULTS


💧 Smart Water Monitoring Dashboard
🔵 Flow Sensor 1: 90 L/min
🔴 Flow Sensor 2: 80 L/min
⚠️ ALERT: Possible Leakage or Unauthorized Siphoning!
Real-Time Monitoring | SMARTFLOW Project


💧 Smart Water Monitoring Dashboard
🔵 Flow Sensor 1: 95 L/min
🔴 Flow Sensor 2: 94 L/min
✅ System Normal: No leakage detected.
Real-Time Monitoring | SMARTFLOW Project

11.IMPLEMENTATION

Establishment of the smart water distribution monitoring system combining IoT, sensor networks, real-time data analytics, and machine learning for the identification of water leakage, unauthorized connections, illegal siphoning, and tail-end pressure monitoring in the water distribution network. The system consists of five major modules:sensor deployment, data acquisition, real-time ana-lysis, anomaly detection, and alert/response system.

11.1 Sensor Deployment and IoT Integration

Smart sensors are at the heart of the system.The following sensors are placed strategically within the water supply infrastructure:Flow sensors to capture flow rates at key junctions and terminations.Pressure sensors at selected nodes, particularly at terminations of pipes to record pressure loss.Smart meters located at consumer ends to read water consumption in real-time.All sensors are interfaced with an IoT-compatible microcontroller (e.g., ESP32/Arduino +GSM/Wi Fi modules) to upload the data to the central system over a secure cloud interface or local gateway.

11.2 Data Preprocessing and Acquisition

Sensor reading is read with a fixed rate transmitted to a cloud or central server (e.g., AWS IoT Core or Google Cloud IoT). Data includes:

Flow rates
Pressure readings
Meter readings with time-stamp
Preprocessing functions include:
Filtering out of sensor faults or noise
Handling missing data
Synchronising timestamps for synchrony of data
Normalising data for machine learning

11.3 Data Storage and Real-Time Data Analysis

Back-end is implemented using Python with

web server developed in Flask and SQLite or Firebase for data storage. Real-time processing is Being performed with libraries such as Pandas for Analysis and MQTT or HTTP REST API .
All the real-time data arrive and get logged at all times and also presented on a dashboard in order to observe the system behaviour and history of the trends.

11.4 Alert System and Decision Support

Where irregularities are encountered, the system: Provides instant alerts via SMS, email, or app notification to the maintenance team responsible. Records the incident on the dashboard for auditing and response.Tries optionally automatic controls like:Valve closure close to a leakage point.Pressure normalization actions.Cut-off of use to unlicensed users

11.5 Frontend Interface

Frontend dashboard is created using HTML, CSS .

12.References

1)"Water Supply and Sewerage" by E.W. Steel and Terence J.McGhee

2)" Water Distribution System Handbook" by Larry Mays

3)"Smart Water Technologies and Techniques" by David A. Lloyd Owen

4)"Introduction to Infrastructure: An Introduction to Civil and Environmental Engineering" by Michael R. Penn and Philip J. Parker

5)"Internet of Things: Architecture and Applications" by Rajkumar Buyya, Amir Vahid Dastjerdi

6)"Hydraulic Modeling and GIS" by Pramod Pandey and Santosh Pathak

7)"Data-Driven Modeling for Sustainable Engineering" by Kondo H. Adjallah

8)"Machine Learning: A Probabilistic Perspective" by Kevin P. Murphy

9)"Python Machine Learning" by Sebastian Raschka and Vahid Mirjalili

10)"Water Resources Engineering" by Larry W. Mays

11)"Handbook of Water and Wastewater Systems Protection" by Robert M. Clark and Simon Hakim

12)"Hydraulics of Pipeline Systems" by Bruce E. Larock, Roland W. Jeppson, and Gary Z. Watters

13)"IoT Fundamentals: Networking Technologies, Protocols, and Use Cases for the Internet of Things" by David Hanes et al.

14)"Real-Time Systems Design and Analysis" by Phillip A. Laplante

15)"An Introduction to Water Distribution Systems" by P. H. R. Feddes

16)"Fundamentals of Water System Design" by Robert Pitt

17)"Security and Privacy in Internet of Things (IoTs): Models, Algorithms, and Implementations" by Fei Hu

18)"Smart Cities: Big Data, Civic Hackers, and the Quest for a New Utopia" by Anthony M. Townsend

19)"Water Resources Systems Planning and Management" by Daniel P. Loucks and Eelco van Beek

20)"Applied Hydraulic Transients" by M. Hanif Chaudhry