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Original Article

Internet of Things (IoT)-Based Obstruction Detection and Monitoring System for Remote Mini Hydropower Plant Canals

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Abstract

Mini hydropower plants (MHPPs) in mountainous and remote regions often face low power generation and operational failures due to abnormal water flow conditions and canal blockages. These blockages occur due to heavy rainfall, landslides, and debris. This study aims to design and implement a real-time obstruction detection system using the Internet of Things (IoT) with LoRaWAN (Long-Range Wide Area Network). Solar-powered ultrasonic sensors were installed at 500 m intervals along the canal to measure water levels, and the acquired data were transmitted via LoRa nodes to a centralized gateway for further processing and analysis. Cloud-based analytics with real-time IoT system, including sensors, Arduino Uno, Raspberry Pi, and a LoRaWAN gateway, was used to detect abnormalities. The system was deployed and tested at the Mai Phase-I MHPP (4 × 500 kW), which is a shadow zone of cellular network. Seasonal Autoregressive Integrated Moving Average (SARIMA) predictive models were applied using Python to historical and synthetic power generation data to forecast performance trends. Experimental results showed that the system generated alerts for normal, overflow, and no-flow conditions, enabling timely obstruction detection and improving operational efficiency. The findings demonstrate that the proposed system is low-cost, low-power, enhances monitoring efficiency, and provides a scalable solution for improving MHPP operations in remote areas without cellular connectivity. The system enhances operational reliability and supports improved power generation efficiency in MHPPs.

Categories: Cloud Management and Monitoring, IoT Applications and Use Cases, IoT Integration with Emerging Technologies

Keywords: detection, the things network, sensor, cloud, water level, internet of things, lorawan, sarima, thingspeak, mhpp

Introduction

Mini hydropower plants (MHPPs) serve as a vital renewable energy resource for remote mountainous regions such as Arunachal Pradesh, India. However, the efficiency of MHPPs is frequently compromised due to canal blockages caused by landslides, debris deposition, floods, and intense rainfall, resulting in power generation losses. Thus, continuous monitoring of canal conditions is crucial; however, manual inspection remains ineffective in rugged regions with limited connectivity.

In this study, an Internet of Things (IoT)-based obstruction detection system utilizing Long-Range Wide Area Network (LoRaWAN) technology, ultrasonic sensing, solar power supply, detection conditions (normal, overflow and no-flow), and predictive analysis (Seasonal Autoregressive Integrated Moving Average [SARIMA] model) was specifically designed for remote MHPP canals. The proposed system enables real-time water-level monitoring, early warnings of flow disruptions, and remote accessibility with low power consumption and long-range communication capabilities. The system was deployed and tested in Mai Phase-I MHPP (4 × 500 kW). Field implementation demonstrates reliable data transmission and timely detection of obstruction-induced level fluctuations, supporting proactive maintenance decisions and minimizing downtime.

The findings demonstrate that the system substantially improves operational reliability, safety, and operational efficiency of MHPPs in isolated hydropower regions with rugged terrain. The approach establishes a scalable framework for smart monitoring in decentralized hydropower installations and can be extended to multiple MHPPs infrastructures.

Related work

Several researchers have explored water level measurement and IoT-based monitoring systems for different domains. However, the application of such technologies in obstruction detection for remote mini hydropower canals remains underexplored.

Sensor Technologies for Water Level Monitoring

Mohammed et al. [1] proposed a non-contact water level monitoring system using an ultrasonic sensor and microcontroller, suitable for small tanks but limited in open canal applications due to external interferences. Loizou and Koutroulis [2] reviewed various liquid level sensors and recommended capacitive sensors for their balance of cost, accuracy, and portability in large-scale systems. Cretaux et al. [3] utilized satellite altimetry for water level monitoring in large reservoirs, offering high accuracy but limited applicability to narrow MHPP canals due to resolution and cost constraints. Kumar et al. [4] also highlighted capacitive sensors' industrial utility, though range limitations persist.

Remote Sensing and Canal Monitoring

Shamrat et al. [5] demonstrated that IoT-based embedded detection and alarm systems enhance safety, a concept which can be applied to obstruction detection in hydropower canals. Duane Nellis [6] employed Thermal Infrared imagery to detect canal leakages effectively in the 8-14 μm range, though its use in obstruction detection is indirect without complementary sensors. Nirupam et al. [7] developed a self-calibrating, low-cost model measuring up to 225 cm with ±2% error, but it lacked remote monitoring features essential for canals.

IoT and Real-Time Water Monitoring

Shyju and Mathew [8] implemented an IoT-based predictive system for dam monitoring, enhancing real-time data acquisition and flood mitigation. This underscores the potential of IoT in remote canal environments. Codeluppi et al. [9] validated LoRaWAN-based IoT systems for smart agriculture, highlighting real-time monitoring and energy efficiency, key for remote canal applications. Hong et al. [10] show that interferometric synthetic aperture radar (InSAR) enables precise long-term monitoring of water levels, which can be used in IoT-based canal obstruction detection.

LoRaWAN and Long-Range Data Transmission

Zhanga et al. [11] showed that synthetic aperture radar backscattering effectively detects water-level changes, which offers insights relevant to IoT-based canal obstruction monitoring. Chen et al. [12] proposed edge computing for IoT-based smart grids to overcome cloud limitations, enabling low-latency and energy-efficient real-time monitoring. Siddula et al. [13] proposed an IoT-enabled water level management system for centralized dam control, which, if scaled down, holds potential for decentralized obstruction monitoring in MHPP canal networks.

Broader Applications and Emerging Trends

Kabalci et al. [14] introduced the Energy Internet concept, integrating smart grids and IoT platforms, paving the way for fully automated hydropower monitoring systems. Vitadhani et al. [15] simulated a LoRaWAN-based flood warning system, emphasizing that optimal gateway placement is critical for effective network deployment in hydropower canal monitoring. These findings are vital in planning network infrastructure for hydropower canal monitoring.

The related works present various advancements in water level monitoring, IoT applications, and sustainable sensing systems. However, a significant research gap exists in the specific context of detecting obstructions in remote mini hydropower canals using IoT, particularly with real-time alerts, low-power communication, and robust field deployment in challenging terrains. This study seeks to address this gap by integrating ultrasonic sensors, Arduino Uno, and a Raspberry Pi-based LoRaWAN gateway to monitor canal water levels and transmit data to the cloud through the ThingSpeak platform.

Materials And Methods

The proposed work outlines the methodology adopted for developing a detection system to monitor water canals of MHPPs in Arunachal Pradesh. The primary objective is to design and deploy an IoT-based hardware system using LoRaWAN technology for real-time detection of canal obstructions through water level monitoring. The overall methodology is shown in Figure *1*.

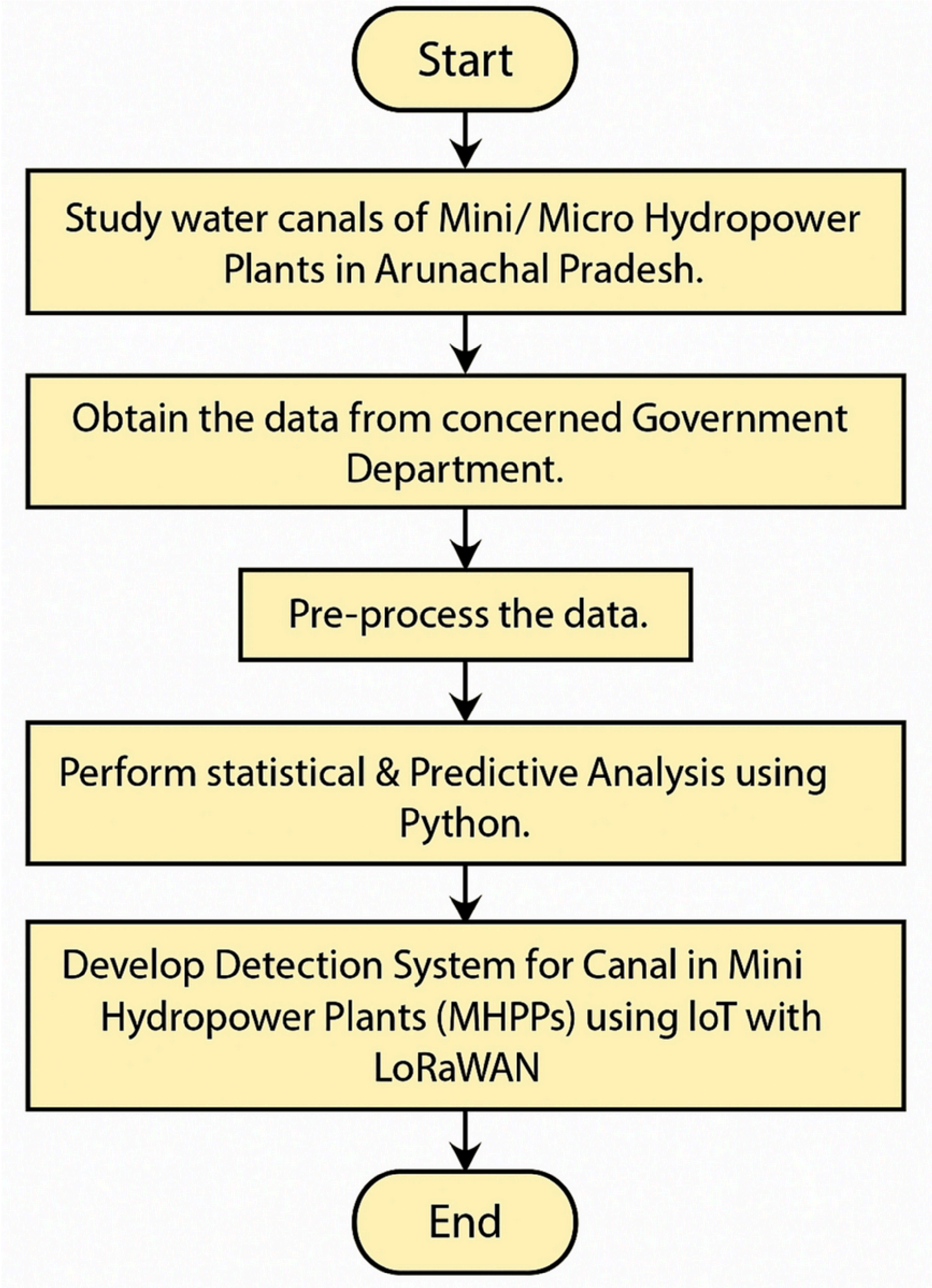
Start
Study water canals of Mini/ Micro Hydropower Plants in Arunachal Pradesh.
Obtain the data from concerned Government Department.
Pre-process the data.
Perform statistical & Predictive Analysis using Python.
Develop Detection System for Canal in Mini Hydropower Plants (MHPPs) using IoT with LoRaWAN
End

FIGURE 1: Flow chart of methodology

Water canal

A study of various water canals used in these plants provides valuable insights into their design, construction, and operation [16-17]. It also provides information on layout, materials, and dimensions. The average canal dimensions were found to be 1.5 m × 1.5 m (breadth × height), and the average canal length was 2 km.

Data collection and preprocessing

Power generation data from over 60 hydropower plants were officially obtained from the Department of Hydropower Development (DHPD), Government of Arunachal Pradesh, covering the period from 2011 to 2023. However, the dataset contained several gaps and inconsistencies, which were carefully analyzed during the study.

During the preprocessing phase, it was found that many hydropower plants were not generating power in line with their installed capacities. Several were non-operational or shut down due to factors such as low water discharge, landslides, or technical issues. After thorough screening, data from 46 hydropower plants, spanning the years 2013-14 to 2022-23, were considered suitable for statistical and predictive analysis [18].

Statistical analysis

Based on the statistical analysis, it was found that during the rainy months (May to September), power generation is very low in more than 80% of the 46 MHPPs. The generation data of two MHPPs located in the same region are plotted, as shown in Figure *2*.

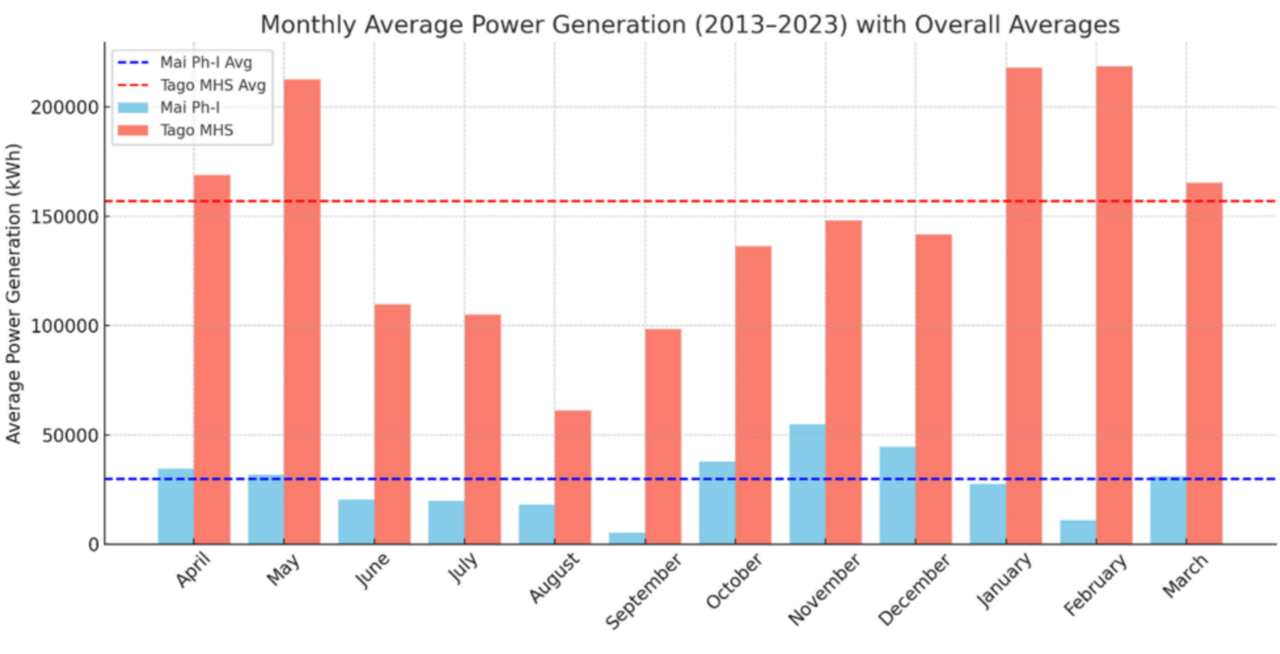

FIGURE 2: Monthly average power generation of Mai Ph-I and Tago mini hydropower plants

The bar graph shows the monthly average power generation (2013-2023) for Mai Ph-I and Tago MHS, with dotted lines representing the overall averages of 29,775 kWh for Mai Ph-I and 156,941 kWh for Tago MHS. The graph indicates that both MHPPs generate not only lower net power but also below-average power during the months of June, July, August, and September, which correspond to the rainy season in Arunachal Pradesh.

Predictive analysis

Time series forecasting using the Seasonal Autoregressive Integrated Moving Average (SARIMA) model was applied to predict monthly power generation for the year 2024 at the Mai Phase-I MHPP [19]. The analysis utilized both real and synthetic (imputed) data from 2013 to 2023. The real data represent actual power generation records, while the synthetic data replace values falling below the calculated average to evaluate improvements in forecasting accuracy [20].

The SARIMA model, an extension of ARIMA that incorporates seasonality, was used to generate 12-month forecasts for 2024. Predictions based on the imputed dataset will be compared against those from the real dataset for validation purposes. Notably, the Mai Phase-I plant, established in 1977-78, has endured various challenging climatic and geographic conditions, making it a valuable case for predictive modeling.

The python program is used to carry out SARIMA prediction or forecast of Mai Ph-I. The graph of SARIMA prediction or forecast using real power generation data obtained from the concerned government department is shown in Figure *3*.

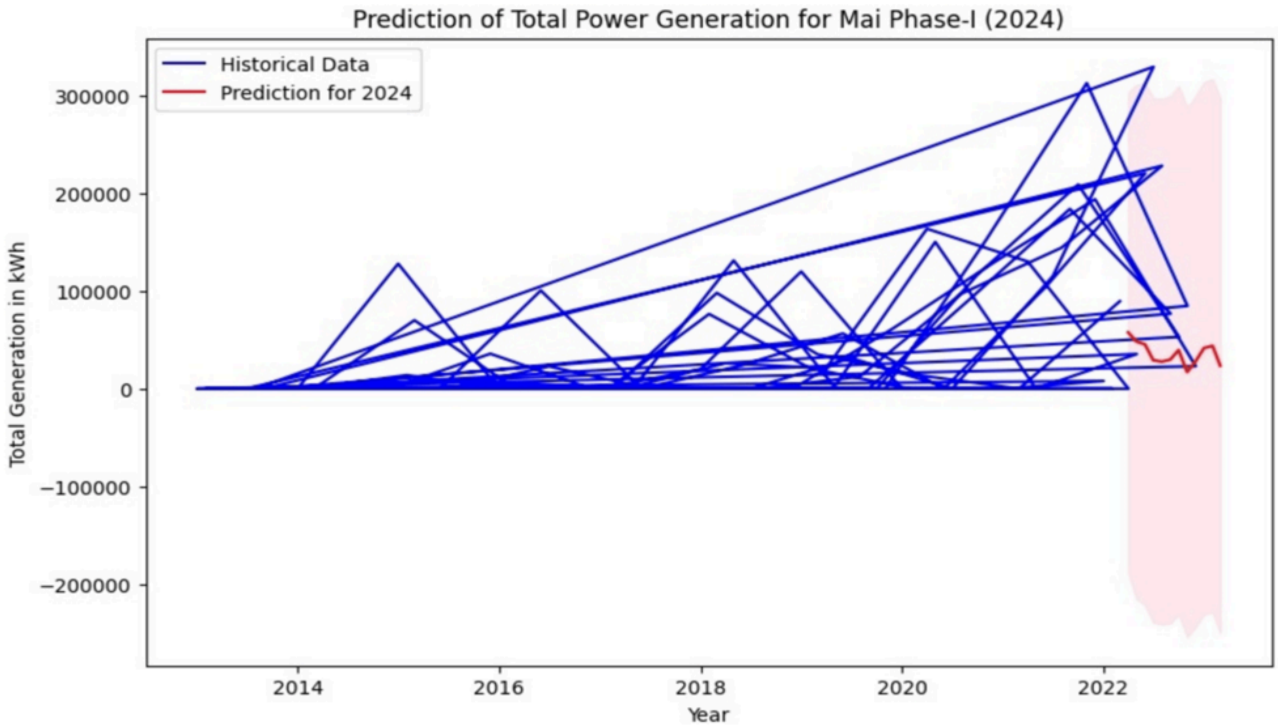

FIGURE 3: SARIMA prediction of total power generation for Mai Ph-I using real data

SARIMA, Seasonal Autoregressive Integrated Moving Average

The forecast is not highly confident, especially in months where uncertainty spikes. This suggests possible rendering issues. As per the real data analysis, this has happened because there are months, i.e., from June to September, each year where power generation has not taken place. These months fall on rainy season of Arunachal Pradesh and cause damages to most of the Hydels in terms of civil structure, electrical installations, and mechanical design [21-22].

Development of canal-obstruction detection system

The detection system for canal in MHPPs using IoT with LoRaWAN is developed using the following steps:

1. Set up and deploy LoRaWAN gateway using Raspberry Pi: A Raspberry Pi is configured to act as a LoRaWAN gateway, which receives data from sensor nodes. The status of LoRaWAN gateway on The Things Network map is shown in Figure *4*.

2. Set up end-node with LoRaWAN: A LoRa-enabled end-node (with a water level sensor) is set up to collect water level data and communicate with the gateway.

3. Data acquisition of water level of canal using sensor: The sensor continuously measures the water level in the canal.

4. Sensor data is sent to the cloud: The collected data is transmitted to a cloud platform via the LoRaWAN network. The system analyses the incoming data to determine whether overflow or abnormal water levels are detected. If no overflow is detected, a green signal or no alert is generated, indicating normal water flow. If overflow is detected, a red signal or alert is triggered and sent to the power station and control room for necessary action. Figure *5* shows the test setup for canal obstruction detection using an ultrasonic sensor.

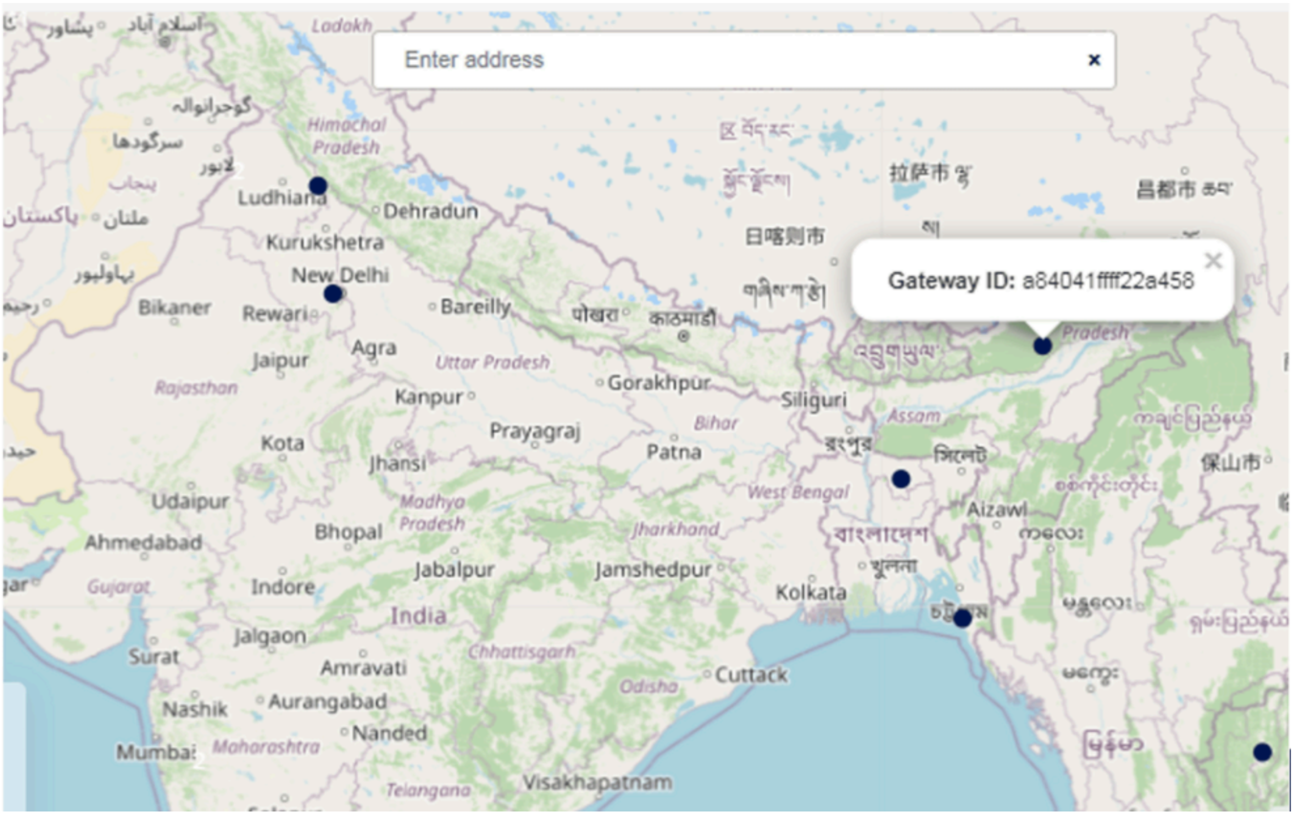

FIGURE 4: The status of LoRaWAN gateway on The Things Network map

LoRaWAN, Long-Range Wide Area Network

FIGURE 5: Hardware test of canal obstruction detection using LoRa

Table 1 shows the hardware and software used in the methodology section.

Sl. No.	Hardware	Software
1	Raspberry Pi	Python
2	Ultrasonic Sensor	ThingSpeak (Software Application)
3	Arduino Uno	The Things Network (Platform)
4	LoRa Shield	
5	LoRaWAN Gateway	
6	Solar Battery	

TABLE 1: Hardware and software

LoRaWAN, Long-Range Wide Area Network

An obstruction detection system was developed using IoT technology with LoRaWAN to monitor canal water levels in real-time [23-24]. This system helps in early detection of abnormal conditions such as overflow, enabling preventive action and ensuring continuous power generation. The detection system was validated through testing under controlled conditions by simulating different water level scenarios.

Results And Discussion

Result analysis of obstruction detection system

The proposed obstruction detection system was carried out to assess its capability for real-time monitoring of canal water levels in MHPPs located in remote areas. The experimental setup is shown in Figure *6*. It was designed to evaluate the accuracy, reliability, and responsiveness of the system under various operating conditions.

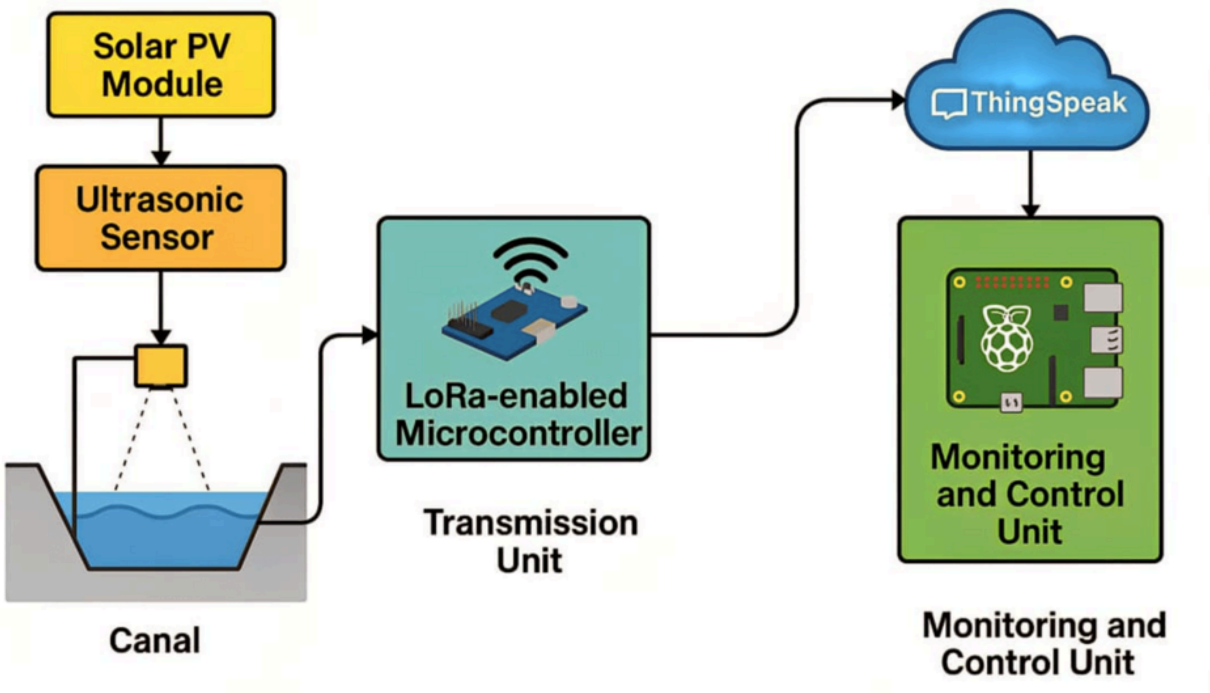

FIGURE 6: The experimental setup showing the working of MHPP-canal detection system

MHPP, Mini Hydropower Plant; PV, Photovoltaic

The developed prototype consists of three functional units: the sensing unit, the transmission unit, and the monitoring and control unit. The sensing unit utilizes an ultrasonic sensor mounted 50 cm above the canal surface to measure the water level at periodic intervals. The acquired data are transmitted to the LoRa-enabled microcontroller, which encodes and sends the readings through a LoRaWAN communication link to a Raspberry Pi-based gateway. The gateway serves as a local concentrator, collecting data from multiple sensor nodes and forwarding them to the cloud platform for storage and analysis.

The communication between end nodes and the gateway was established using LoRaWAN to ensure long-range and low-power data transmission. This makes the system suitable for deployment in regions with no cellular service. The ThingSpeak IoT platform was used for real-time data visualization and analysis. Continuous monitoring of the water level allowed operators to distinguish between different conditions based on the received sensor values. The dynamic data display and automated alerts enabled early detection of canal abnormalities.

To provide power supply in remote location, the entire system was powered by a solar photovoltaic module. Testing was conducted at canal of Mai MHPP located at remote location of Arunachal Pradesh. Controlled experiments were performed by introducing artificial obstructions such as debris accumulation and varying water levels to simulate different conditions such as normal flow, overflow, and no flow or blockage condition. The response and accuracy of detection system were recorded for each scenario.

Figure 7 shows a cross-sectional design of a water canal of MHPP with integrated ultrasonic sensor monitoring.

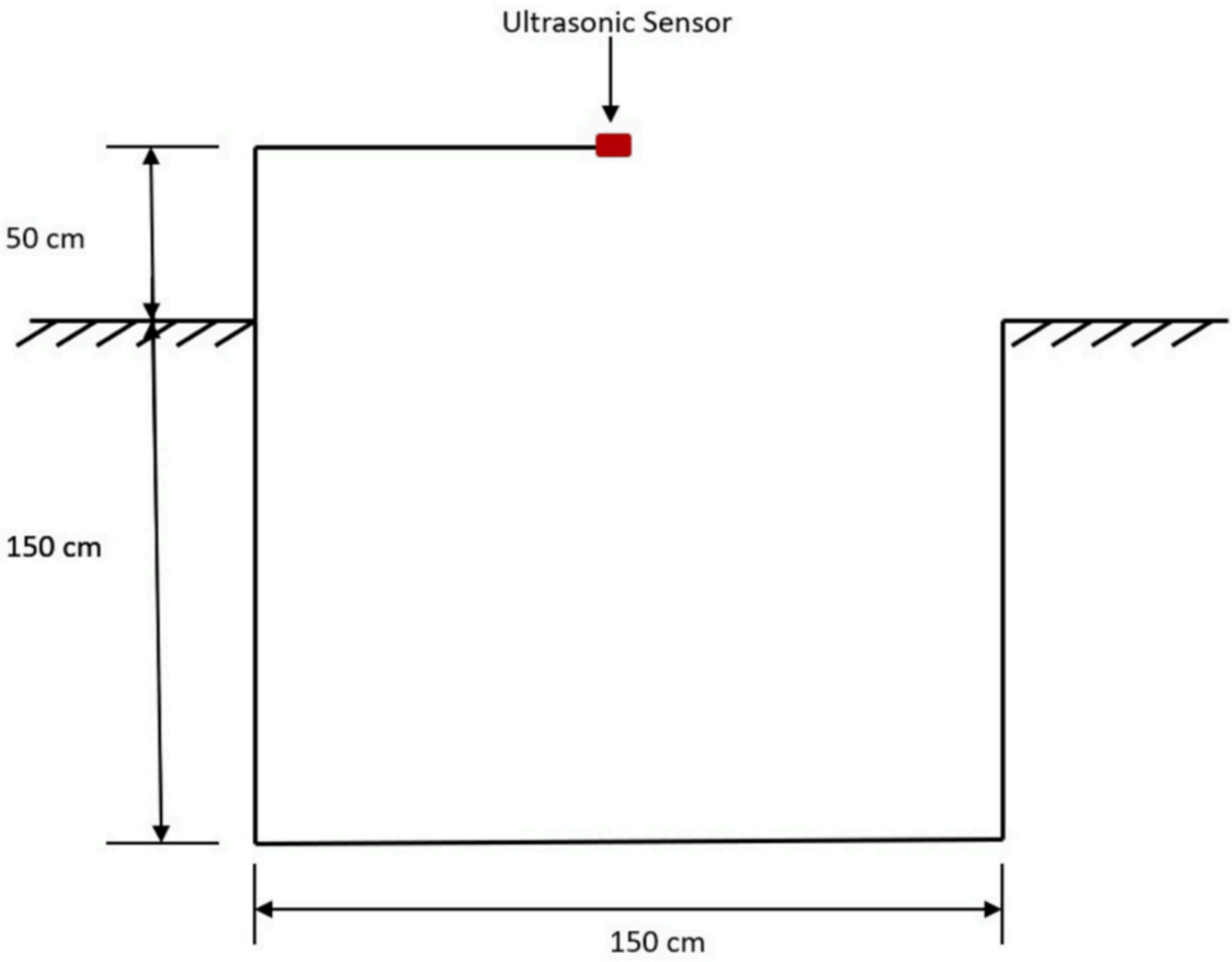

FIGURE 7: Canal design of mini hydropower plants

The canal design specifications are as follows:

1. Shape of Canal: Rectangular cross-section.

2. Internal Dimensions of Canal: Height is 150 cm and breadth (width) is 150 cm.

3. Solar-Powered Ultrasonic Sensor Placement: The sensors are mounted 50 cm above the top edge of the canal, and the distance between the two sensors on the water canal is 500 m.

The ultrasonic sensor is mounted to measure the distance from the sensor to the water surface below, enabling detection of water level changes. The sensor emits ultrasonic pulses downwards. It calculates the distance to the water surface based on the time it takes for the echo to return. When the water rises, the distance detected by the sensor decreases. When water falls (or is absent), the distance increases. Based on this, the system can detect:

Case I: Normal water flow (when the detected distance is less than 170 cm)

Case II: Overflow (when the detected distance is less than 60 cm)

Case III: No flow (when the detected distance is greater than 190 cm, considering the sand or mud settlement in the canal)

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Every 10 minutes, the proposed detection system monitors and updates the water levels in the canals. If the water level exceeds the predefined threshold during this interval, the ThingSpeak platform triggers an alert and sends it to the control room [25]. Upon receiving the alert, the technical staff in the control room promptly initiate the necessary actions to prevent potential hazards along the water canals of the MHPPs [26].

When the value on the ThingSpeak platform is 0 (zero), the light does not glow, i.e., the light is OFF. This indicates that Case I and Case III are applied here. However, when Case III occurs, it may also suggest blockages in the water canals of MHPPs [27]. When the value on the ThingSpeak platform is 1 (one), the light glows red, i.e., the light is ON, as shown in Figure *8*. This indicates that Case II is applied here [28].

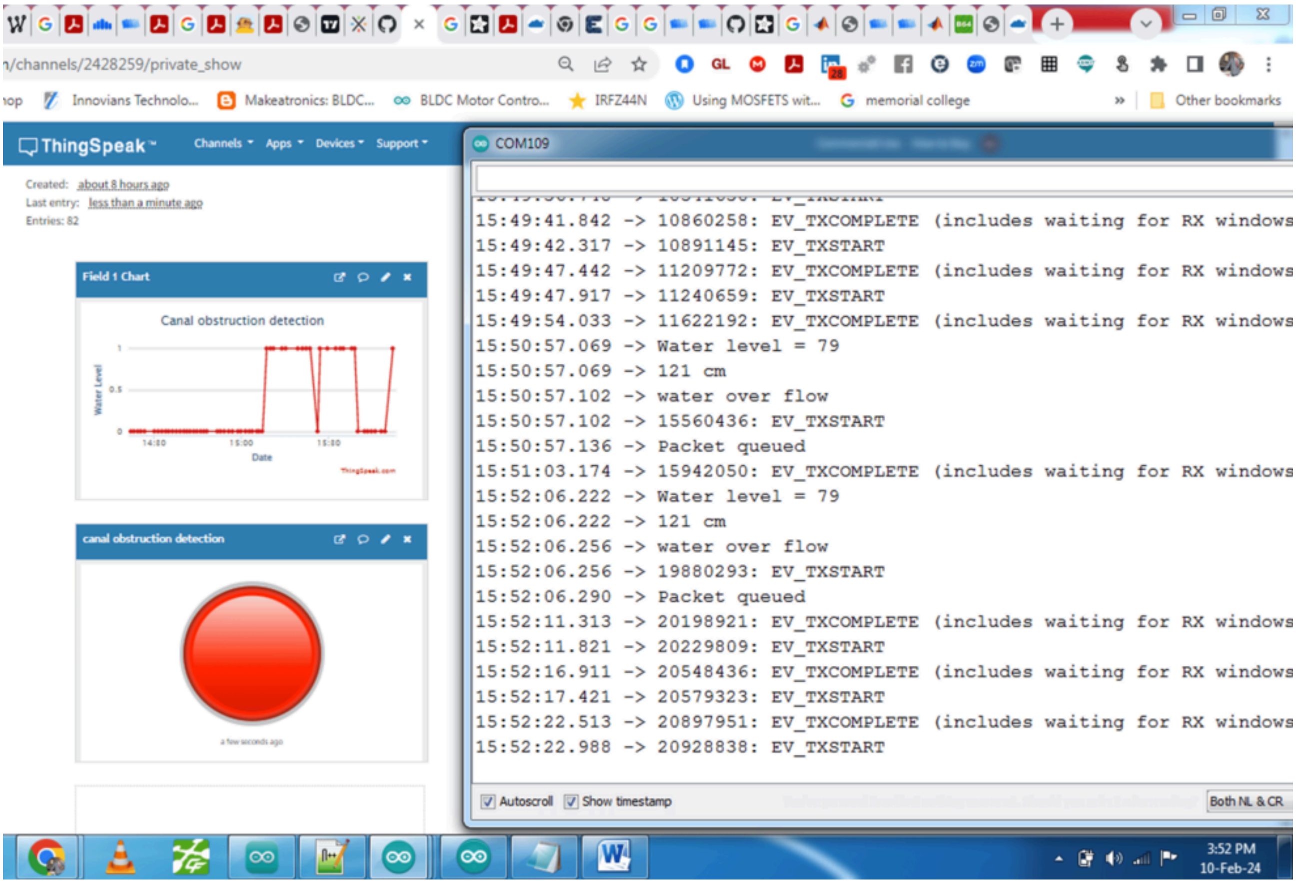

FIGURE 8: Obstruction detected and status updated on cloud

Analysis of SARIMA prediction

The graph of SARIMA prediction or forecast using synthetic (imputed) power generation data is shown in Figure *9*.

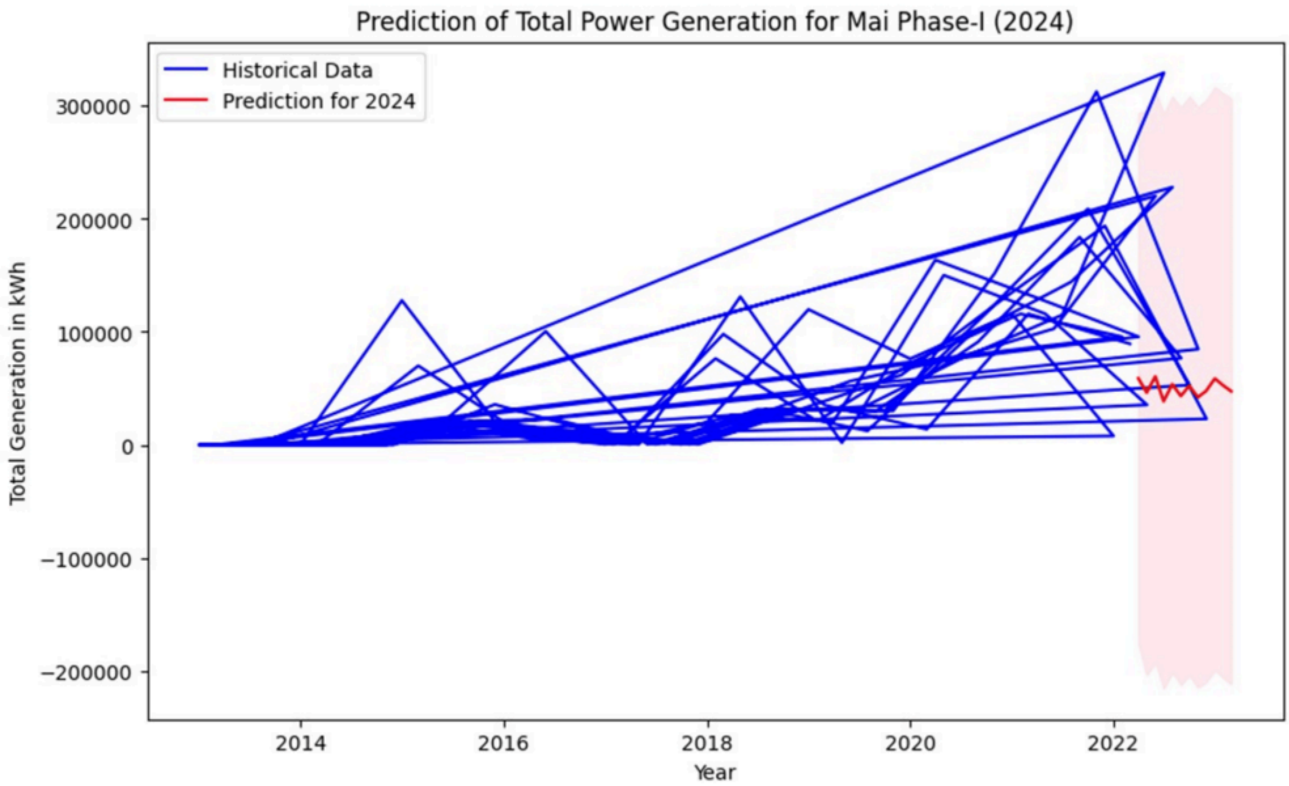

FIGURE 9: Graph of SARIMA prediction using imputed data

SARIMA, Seasonal Autoregressive Integrated Moving Average

The synthetic data (imputed values) represent the calculated average monthly power generation for Mai Phase-I Hydel from 2013 to 2023. This average has been used to replace any monthly power generation values falling below the calculated average, with the objective of assessing potential improvements in forecast accuracy. The same Python program and SARIMA model were employed to predict monthly power generation for 2024 using this modified dataset.

Compared to Figure *3*, the blue historical lines remain somewhat cluttered but appear cleaner. The red forecast line for 2024 is rendered more sharply, offering better clarity. The pink confidence interval remains similar in appearance but is slightly narrower, suggesting increased confidence in the prediction. The 2024 forecast shows a stable monthly generation pattern with minimal variation and no significant upward or downward trend.

This consistent pattern indicates that the implementation of an obstruction detection system in the water canals of MHPPs could enable early detection of water overflow or underflow. Such proactive monitoring would help prevent landslides and other natural disruptions, which are key contributors to reduced or halted power generation in Arunachal Pradesh. Ultimately, this would support MHPPs in achieving power generation closer to their installed capacity [29].

Discussion on experimental analysis

The experimental analysis of the proposed obstruction detection system was carried out to assess its capability for real-time monitoring of canal water levels in MHPPs located in remote areas. The experimental setup is shown in Figure *6*. It was designed to evaluate the accuracy, reliability, and responsiveness of the system under various operating conditions.

The performance of the detection system was evaluated based on three main criteria: accuracy of water level measurement, reliability of data transmission, and response time of detection and alert generation. The experimental results confirmed stable LoRaWAN connectivity, accurate water level detection within ±2 cm, and prompt real-time updates under different flow conditions. The use of solar power further improved the system's feasibility for MHPP in remote locations by ensuring uninterrupted operation without relying on grid power. The comparison of the proposed method with the earlier methods or technology is shown in Table *2*.

Reference	Domain	Method or technology	Communication	Obstruction detection in MHPP canal?	Limitation vs present work
[6]	Canal leakage detection	Thermal Infrared (8–14 μm)	–	No	Costly, airborne sensing
[9]	Smart farming	LoRaWAN nodes for soil/air data	LoRaWAN	No	Agriculture focus; not water-canal conditions
[17]	Low-power telemetry	Solar harvesting + LoRa	LoRaWAN	No	Only telemetry; no anomaly detection
[23]	Landslide monitoring	Sensors + LoRaWAN	LoRaWAN	No	Different hazard; no canal obstruction
[27]	River flood early warning	LoRaWAN gateways for Ciliwung River	LoRaWAN	No	River-scale planning; no canal obstruction detection
Present Work	Remote MHPP canals (weir → forebay)	Multi-point flow-level sensing + IoT	LoRaWAN	Yes	Low cost, purpose-built for remote canals and alerts for obstruction detection.

TABLE 2: Comparison of the proposed method with the earlier methods or technology

IoT, Internet of Things; LoRaWAN, Long-Range Wide Area Network

Overall, the results validate the detection system's potential as a reliable and energy-efficient solution for remote canal obstruction detection and monitoring.

Conclusions

This paper presented the effectiveness of the proposed obstruction detection system for the canals of MHPPs located in remote areas, developed using IoT technology with LoRaWAN communication. The predictive analysis indicates a slightly narrower confidence interval, reflecting improved forecast reliability. Overall, the detection and monitoring system enhances the safety and operational efficiency of MHPPs by enabling remote monitoring, early warning, and rapid response. Its low-power, long-range communication capabilities make it especially suitable for deployment in remote and inaccessible regions like Arunachal Pradesh. This work lays a strong foundation for future improvements and large-scale implementation in similar hydropower applications.

The obstruction detection system holds significant potential for further enhancement and expansion. Future work can focus on the integration of advanced technologies such as machine learning and predictive analytics to forecast canal-water level trends based on historical and real-time data. Incorporating weather data and upstream water flow metrics can improve the accuracy of predictions and enhance proactive decision-making. This detection system, using IoT with LoRaWAN, can be deployed in different MHPPs and data can be stored on the cloud for future analysis. The stored data can be further used to analyze the real-time power generation. Additionally, the system can be scaled and adapted for use in other MHPPs and flood-prone regions, ensuring broader natural disaster mitigation coverage.

Additional Information

Author Contributions

All authors have reviewed the final version to be published and agreed to be accountable for all aspects of the work.

Concept and design: Bengia Taday, Ritula Thakur, Piush Verma

Acquisition, analysis, or interpretation of data: Bengia Taday

Drafting of the manuscript: Bengia Taday

Critical review of the manuscript for important intellectual content: Bengia Taday, Ritula Thakur, Piush Verma

Supervision: Ritula Thakur, Piush Verma

Disclosures

Human subjects: All authors have confirmed that this study did not involve human participants or tissue. **Animal subjects:** All authors have confirmed that this study did not involve animal subjects or tissue. **Conflicts of interest:** In compliance with the ICMJE uniform disclosure form, all authors declare the following: **Payment/services info:** All authors have declared that no financial support was received from any organization for the submitted work. **Financial relationships:** All authors have declared that they have no financial relationships at present or within the previous three years with any organizations that might have an interest in the submitted work. **Other relationships:** All authors have declared that there are no other relationships or activities that could appear to have influenced the submitted work.

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