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Research Article

Internet of Things (IoT) Enabled Water Distribution System for Smart Water Management

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Abstract

Water is a vital resource for life, and its management is a key issue nowadays the water demand is increasing due to global population growth and urbanization. Present technologies for water control are currently facing interoperability problems due to the lack of support for standardization in monitoring and controlling equipment. This problem affects various processes in water management, such as water consumption, water distribution, system identification, and equipment maintenance. Under these conditions, new technologies in the water management infrastructure have been required to enable the distribution of high-quality water to users safely and cost-effectively, from the perspective of efficiently using our world's precious water resource. The Internet of Things (IoT) Based Smart Water Management System is a cutting-edge technology that integrates sensors, communication devices, and data analytics to efficiently monitor and manage water resources. This system enables real-time monitoring of water quality, consumption, and distribution, allowing for proactive maintenance and optimization of water usage. By leveraging IoT technology, this smart water management system offers improved accuracy, reliability, and cost-effectiveness in managing water resources. Based on standards, the system proposal is a smart water management system model combining Internet of Things technology with decision support systems. This system is more efficient in distribution monitoring and control approach for a water utility to reduce water loss. This approach will help utility operators to improve water management systems, especially by exploiting emerging technologies.

Keywords

IoT, Water, Ultra Sonic Sensors, Raspberry Pi

1. Introduction

Water scarcity is a significant global challenge affecting many regions worldwide. According to the United Nations, around 2.2 billion people worldwide lack access to safely managed drinking water services, and about 4.2 billion people live without safely managed sanitation services.

The UN also estimates that by 2050, between 4.8 billion and 5.7 billion people could live in areas where water resources are scarce for at least one month a year, and 3.2 billion to 5.4 billion people could experience severe water scarcity for at least one month per year.

The percentage of water scarcity varies by region, with some areas experiencing more severe shortages than others. For example, regions in the Middle East, North Africa, and parts of Asia face particularly high levels of water stress. In these regions, water scarcity is exacerbated by rapid population growth, inefficient water management practices, and

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climate change impacts.

Water scarcity is a critical issue that requires coordinated efforts at the local, national, and international levels to ensure sustainable water management practices and equitable access to clean and safe water resources for all [1]

In this paper, we propose IoT IoT-enabled smart water management system to resolve the above-mentioned issues in a scaled-down environment.

It gives immense opportunities to study the quality of water, its usage, overflow, and other wastage issues. At the time of taking up the study, it is observed that the wastage of water is almost 50%. This is due to factors like overflow, leakage, and loss in transit. The use of the latest smart technology like IoT-based smart water management systems is expected to reduce the wastage of water and increase the efficiency of water management systems.

These results could be replicated and deployed in systems affecting larger populations. This would not only help in conserving the availability of water resources, it would also enhance the efficiency of water management. The use of the Internet of Things thus could prove to be one of the most important utility-proper systems, especially in making water resources management more efficient [2-5].

The proposed ISWM system implementation provides a cost-effective hardware system and software framework. Automatic detection of overflow through any of the outlets is notified to the user. The major components used to develop this work for monitoring and controlling are Raspberry Pi as a controlling unit, an ultrasonic sensor to measure the water level in the water tank, a motor for pumping water, and a controlling valve for the water closing system [6, 7].

1.1. Problem Statement

Today, most of the water tank users have replaced conventional pumps with electrical pumps. However, they find it very inconvenient for the condition of the water pump because there is no effective water level indication system. As a result, if a mechanical sensor fails, there is plenty of water waste as well as wastage of power consumed by the motor pump. Various types of water pumping systems are available in the market nowadays, but this system along with the traditional system can't overcome the intrusion problem. Measurements have been in the world since the beginning of humans. Every creation since the beginning starts with measurements. The world today has developed complex and un-imaginable technologies to fulfill the ever-demanding of necessities and needs thus creating almost possible control of a system. Measurements have become crucial and higher accuracy is most wanted by now. For example, in an oil refinery plant, overflows of oil can be hazardous, dangerous, and costly. Empty vessels lead to pumps or drain stream processes running dry. Inaccurate measurements in mixture processes can lead to product defects and higher costs. Human supervision is limited for several hours and the accuracy is almost not perfect.

Figure 1. Leakage of water.

To overcome the wastage of water due to water overflow conditions or due to leakage of water we proposed an “IoT Enabled Water Distribution System for Smart Water Management”. Smart Water Management is a water tank automation based on an IoT system. The water tank will be monitored continuously and it will be refilled automatically without any manual intervention. Water filling and consumption information are collected and the minimum amount of water is measured and made available to the user through a user interface. This can be used at homes, offices, colleges, schools, or any public place. This is an easy setup that can be built with less cost and is easy to maintain. It works based on the internet at the site of operation. Data about water consumption from the site is collected from the site and graphs are displayed against the day on the X-axis and water consumption on the Y-axis. These graphs give us a clear view of water used and from that, we can make changes in water consumption to make water usage efficient.

1.2. Internet of Things

The integration of sensors, devices, etc. in the Internet is known as the Internet of Things (IoT). In the Internet of Things concept, the term "thing" can refer either to people, objects (e.g., devices, sensors, machines, etc.), or information. At the present moment, there are various definitions of the "Internet of Things" varying depending on the context, the effects, and the views of the one giving the definition. Thus, from a things-oriented and an Internet-oriented perspective, the Internet of Things is viewed as "a world where things can automatically communicate to computers and each other providing services to the benefit of humankind” [8]. According to [9], who regard the Internet of Things from a semantic-oriented perspective, IoT is "a worldwide network of interconnected objects uniquely addressable, based on standard communication protocols”. However, there are many common points for most of the definitions of the Internet of Things, such as [6]:

1. The ubiquitous nature of connectivity.
2. The global identification of everything,
3. The ability of each thing to send and receive data across the Internet or across the private network they are connected to.

According to the identified research, the internetworking of physical devices, vehicles (also referred to as, buildings, and other items embedded with electronics, software, sensors, actuators, and network connectivity that enable these objects to collect and exchange data. In 2013 the Global Standards Initiative on Internet of Things (IoT-GSI) defined the IoT as "the infrastructure of the information society. The IoT allows objects to be sensed and/or controlled remotely across existing network infrastructure, creating opportunities for more direct integration of the physical world into computer-based systems, and resulting in improved efficiency, accuracy, and economic benefit in addition to reduced human intervention [10-13].

When IoT is augmented with sensors and actuators, the technology becomes an instance of the more general class of cyber-physical systems, which also encompasses technologies such as smart grids, smart homes, intelligent transportation, and smart cities [14, 15]. Each thing is uniquely identifiable through its embedded computing system but can interoperate within the existing Internet infrastructure. Experts estimate that the IoT will consist of almost 50 billion objects by 2020.

In section 2, related work in WMS applications using IoT is discussed. The proposed system architecture and methodology are introduced in section 3. The experimental results are discussed in section 4. Finally, a brief conclusion and future work are given in Section 5.

2. Related Work

The researcher [16] developed a water quality monitoring system using a Zigbee-based wireless sensor network. In proposing system, the sensors are connected to a single circuit which is connected to the Zigbee ZMN2405HP module. The receiver side Zigbee is connected to the PC which shows the GUI of the network circuit. In this system, the high-power Zigbee is used and it can be applied to a small area network, also the base station is necessary for data storage.

The researcher [16] developed a water quality monitoring system to eliminate the cost-consuming jobs of manual monitoring. In this system, the measured data of water quality monitoring sensors are collected by the data kit which gives data to the data processing unit through a GSM modem. In the data processing unit, the data from different sensors are differentiated and it is continuously compared with the ideal parameters of the sensor value. If the water isn't meeting its quality parameter value the alert signal is there which is connected to the buzzer. This system is not reliable for long distances also it will apply to only a single unit of water source.

In this system [17], the water quality sensors collect data, from industrial water and municipal water storage, which are gathered at the sub-station at which the data are processed. This processed data is sent to the main station through Ethernet networks running on TCP/IP and from the main station that data is again differentiated and given to the environment department and public department using the internet. This system has increased data accuracy, reliability, and efficiency, and also it gives effective data management and fully integrated information systems. However, the drawback is that it cannot provide real-time monitoring of water parameters.

The system [18, 19], is used to process the sample and send the relevant data to the monitoring center via the GPRS data transmission. The aim of developing this system is the remote monitoring of water quality parameters and makes it real-time and faster than previous systems used for water quality monitoring, also to control water quality.

In proposing system [20], the wireless water quality sensors send data digitally to the data acquisition kit which collects the data transmitted from all sensors. The received digital data is processed by the data acquisition kit and processed data is sent to the database at which the processed data is compared with the tolerance value of that data. If the water quality parameters cross their threshold value, then the alert message will be sent using the GSM module, otherwise, data will continuously compare with its tolerance value. This process is mainly developed for monitoring the water of ponds or lakes.

The overall limitations of existing systems are

1. Overflow water buzzing system is a water management system that causes vibrations within the copper pipes when the water tank in the attic fills up and causes disturbance to the user due to the drilling sound.
2. Existing systems are costly and the installation procedure is complex which kills time and effort in the process of installation.
3. There should be continuous monitoring and control of the water tank by employing a human to accomplish the task.
4. Highly complex water management systems are difficult to maintain.
5. Damage to a single component leads to severe trouble in identifying the component that is damaged.
6. Additional necessity of human resources to manage and control the water level of the storage tanks.
7. No proper estimation of water being utilized.
8. High rate of power consumption which is not cost effective.

Advantages of the proposed system

A Smart Water Management System based on IoT is an overhead tank automation IoT-based system [21-27]. Where water tank will be monitored continuously and it is refilled automatically without any manual intervention. Water filling and consumption stats are collected and consumption of water is measured and sent to the user. This system requires an internet connection for its operation at the site of work. When the water level of the tank is below the mark of the tank the water is made to inlet via the pipe attached at the inlet of the tank. When the level of the water rises level up to the maximum, the tank can withhold then further the level is sensed by the ultrasonic sensor which gives the information that is being passed to the nearby circuit board which contains the circuit that makes the details of the level of the tank to be made available to the IoT networks which are further connected to the server. Then the water level rises in the tank which leads to the overflow which is avoided by this system this is an easy setup that can be used at homes, offices, colleges, and schools can be built with less cost, and is easy to maintain. The main advantages of the proposed system over the existing systems are:

1. There will be no manual intervention for filling water in ISWMS
2. Users can make changes in water consumption patterns based on their usage.
3. The use of the Internet of Things could prove to be one of the most important utility-proper systems, especially in making water resources management more efficient.
4. Automation of the activities that are involved within the management of water tanks provides efficient utilization of water.
5. Provide a better water management system by designing a user interface that provides information and controlling options.
6. Increases the efficiency of water resource usage by reducing wastage of water in the form of leakage or overflow conditions.
7. Reduces wastage in power consumption and provides efficient throughput.
8. It is a very low-cost device compared to other existing technologies for the automatic management of water tank systems.
9. The maintenance of the system is very easy because there are not many hardware and software components. It can be easily deployed anywhere with an easy installation process and is affordable by all public and private institutions.

3. System Design

The system design of the smart water management system is represented in Figure 2. It illustrates various modules of the water management system which are:

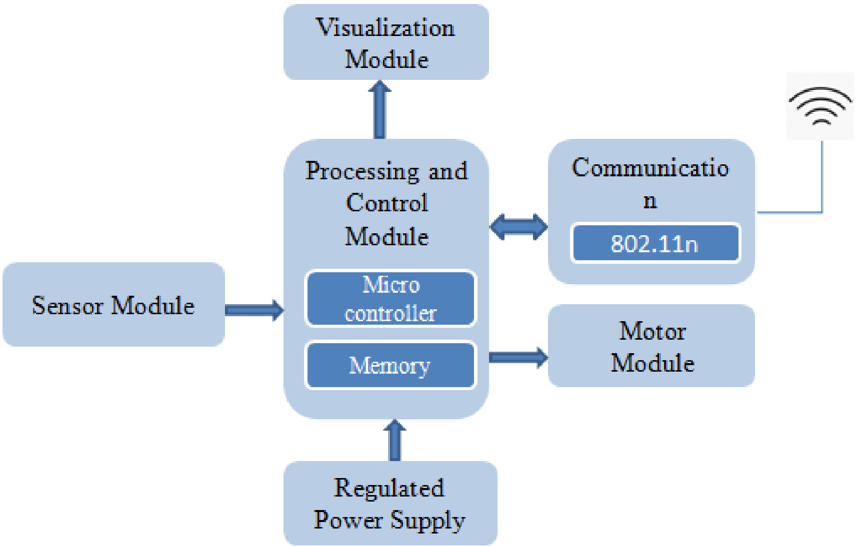

Figure 2. *A typical node design of a Smart Water Management System.*

Processing and controlling module

This module acts as the heart of the water management system as all the controlling and managing activities are carried away by the processing module. Raspberry Pi acts as the processing module in WMS. Its major activities are to collect data and process the received data according to the instructions given by the admin. It is connected to other external devices of the system and controls their actions.

Visualization module

The user interface acts as the visualization module in the water management system, which provides the users with information about the level of water in the tank. The entire statistical data is displayed in the visualization module.

Sensor module

Ultrasonic sensor is used as the sensing module which is responsible for sensing the level of water in the water tank. The typical working of the ultrasonic sensor is it sends waves and these waves get reflected when they collide with an object and are sensed back. This measures the time taken to reflect at a particular speed and calculates the distance using distance = speed/time.

Motor module

The motor is used to regulate the water supply to the water tank. The motor is controlled by the processing module according to the data received from the sensors. If the water level is low and the tank is empty, it powers on the motor and pumps water into the tank. If the water level is high and the tank is full, it off the motor from pumping water into the tank.

Communication module:

Internet and cloud provide the communication between the components of the water management system and act as communication modules. Cloud is mainly responsible for exchanging data between the system components and this data is processed to perform certain activities and analyzed to produce statistical data.

4. System Framework

Things

Hardware components that are used in the water management system are ultrasonic sensors to sense the water level of the tank. According to the level of water that has been detected is controlled by the controlling valve to pump water into the motor. This is regulated by supplying power by power relay.

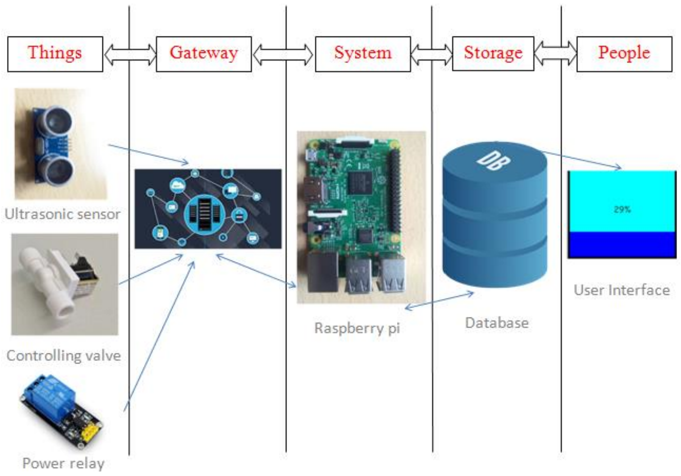

Figure 3. *A framework of water management system.*

Gateway

The Internet of Things acts as the gateway for water management systems which constructs a network through which components will communicate with each other.

System

A system in a software framework is considered to be the processing unit. Raspberry Pi is responsible for processing the data and controlling various components in the water management system by providing distributed processing.

Storage

The database is used to store the data that is generated through components of the water management system. To perform analysis of the data it is retrieved from the database and statistical data is generated by analysis of the recorded samples.

People

Users access the web interface of the water management system that is generated. It consists of a live page, a home page, and a reports page. The live page illustrates the graphical representation of the water level in the tank. The report page illustrates the tabulated and statistical data of the water management system.

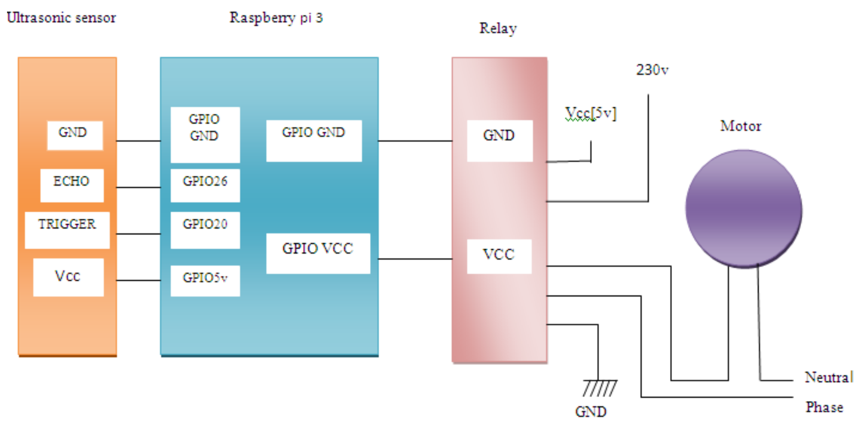

Figure 4. *Overall working model of ISWMS.*

5. Results and Discussion

The proposed system for the management of water is an efficient and time-saving process. This automation of water also reduces the human effort and consequently the cost of the whole process. This system can be implemented at any place with ease and within a reasonable amount of time. The implementation costs for the automation are also affordable. The overall method for the detection and management of water becomes efficient and intelligent. This proposed system would not only function for collecting and updating data automatically and timely, but also it could analyze and use data intelligently. The use of the Internet in this automation makes this system efficient and reliable.

The proposed system consists of a user interface that allows the user to control and monitor the water level in the tank. The user interface consists of a home page, a live page, and a report page. The home page consists of details of the proposed system. The live page consists of details of the tank, date and time, percentage of water filled in the tank, and status of the tank. Below Figure 5 shows the user interface of the proposed system.

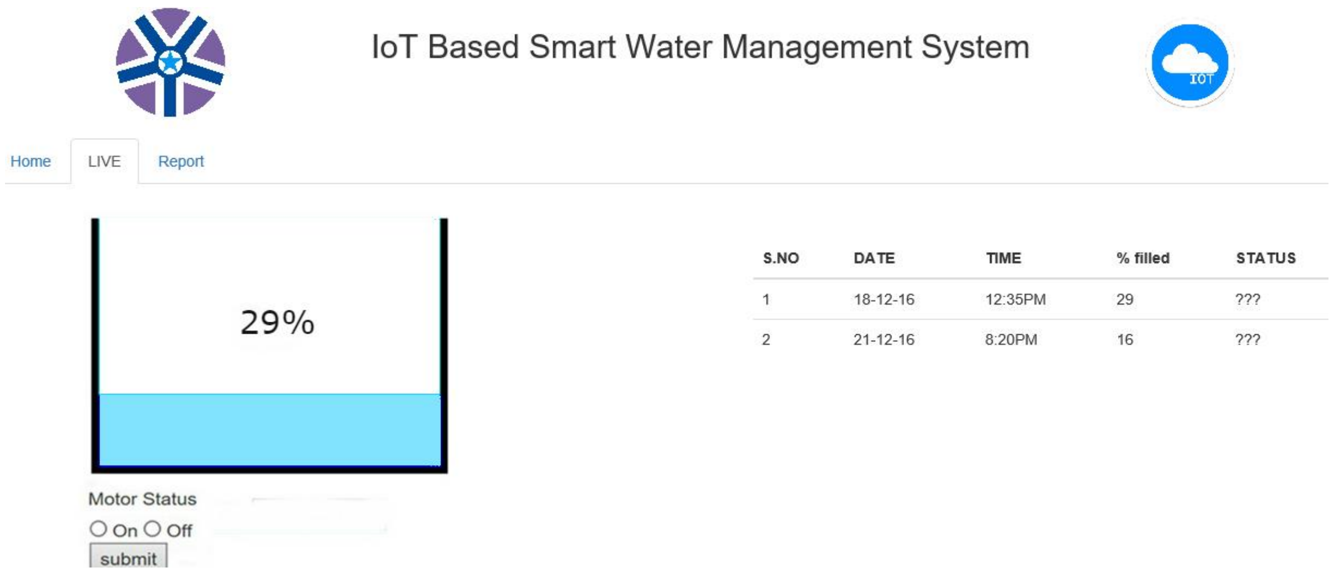

Figure 5*. User Interface Of ISWMS.*

User Interface for Water Level Monitoring

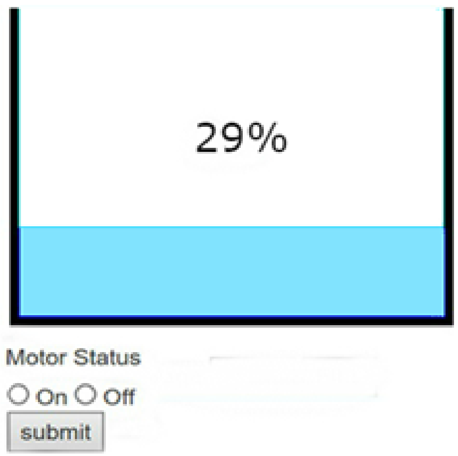

Figure 6*. Water Level Monitoring.*

The proposed system allows visualizing the level of the water in the water tank and can control the motor manually as well automation is also possible in real-time mode. The water level information is provided by the user interface and based on the information the user can control and monitor the water tank. This system not only displays the level of water in the water tank on the user interface but also saves the results with the help of SQLite. The preferred results can be interpreted later. Below Figure 6 shows the water level percentage present inside the tank.

User Interface for Motor Control

With the help of the user interface, the user can control the motor manually as well and automation is also possible i.e., as soon as the water reaches a particular level the user can manually ON or OFF the motor without going near the motor switch, this is possible only with the help of IoT.

Automation is possible under the following conditions; if X is less than 10 then the motor will be turned ON automatically with no human intervention. If X is greater than 90 then the motor will be turned OFF automatically with no human intervention. Below Figure 7 shows the motor status i.e., whether the motor is turned ON/OFF according to the level of the water tank.

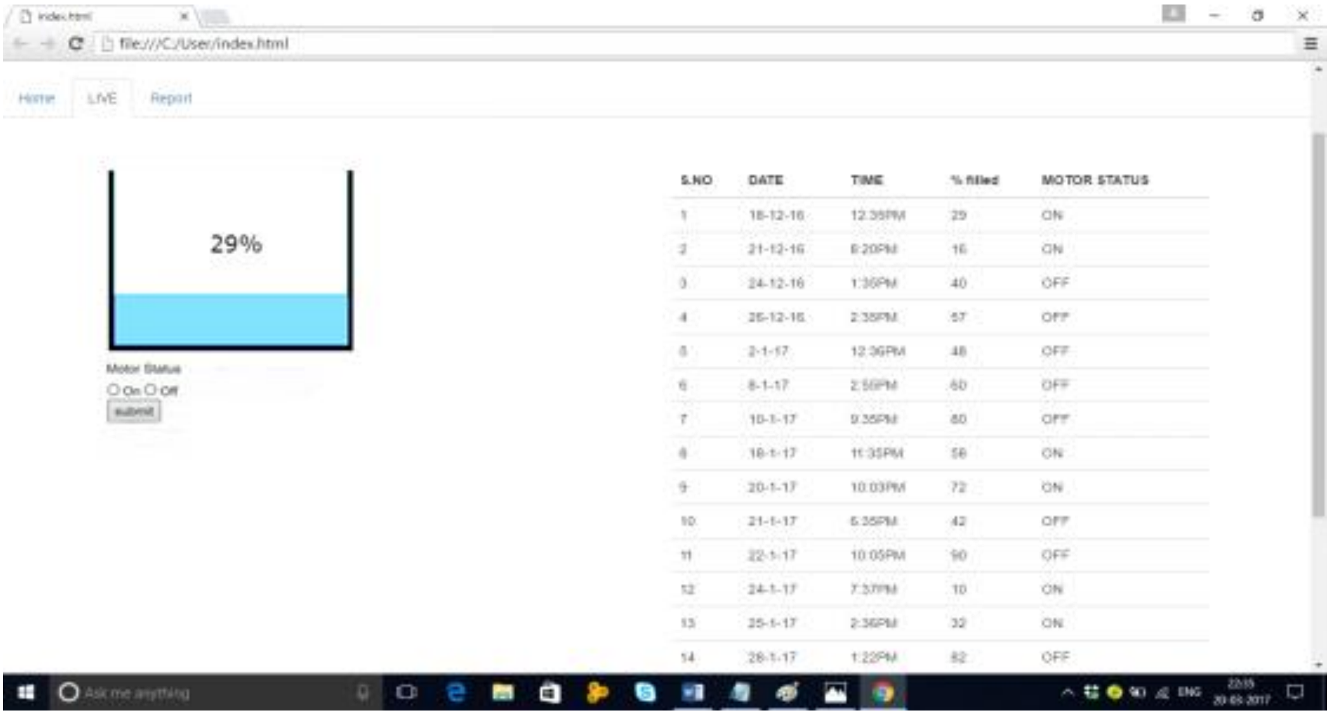

Figure 7. *Motor Control Interface.*

Day-Wise Live Report

A report may be defined as a written account of something that one has observed. The report is analyzed by day-wise, weekly, monthly, yearly, and from date - to date.

Table 1. *Day-wise report.*

S.No	Date	Time	% Filled	Motor Status	Utilization
1	18/12/2016	8:00 AM	90	OFF	0
2	19/12/2016	6:10 AM	10	AUTOMATIC ON	80
3	20/12/2016	5:20 AM	50	OFF	40
4	21/12/2016	9:40 PM	30	ON	20
5	22/12/2016	4:20 PM	60	OFF	30
6	23/12/2016	10:04 AM	20	ON	40
7	24/12/2016	8:05 AM	80	OFF	60
8	25/12/2016	3:10 AM	30	ON	50
9	26/12/2016	8:30 AM	70	OFF	40
10	27/12/2016	11:10 AM	20	ON	50
11	28/12/2016	7:30 AM	70	OFF	20
12	29/12/2016	4:12 PM	30	OFF	40
13	30/12/2016	3:14 AM	10	AUTOMATIC ON	20
14	31/12/2016	10:24 AM	40	ON	50
15	01/01/2017	5:44 AM	30	ON	60
16	02/01/2017	5:05 AM	50	OFF	40

S.No	Date	Time	% Filled	Motor Status	Utilization
17	03/01/2017	8:02 AM	20	ON	30
18	04/01/2017	11:40 AM	90	AUTOMATIC OFF	10
19	05/01/2017	1:06 PM	50	OFF	30
20	06/01/2017	2:00 AM	10	AUTOMATIC ON	90

The above Table 1 shows the day-wise report of the proposed system where the date, time, percent of water filled into the tank, status of the motor all the above information can be known from the user interface.

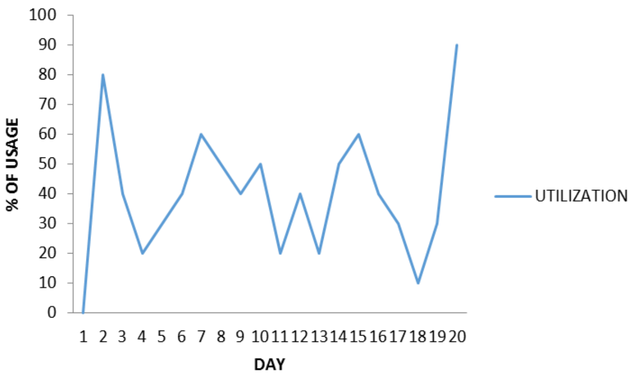

Figure 8. *Graph for day-wise utilization of water.*

The above Figure 8 shows the graphical representation of the day-wise utilization of water for 20 days. In the above graph, we can observe that the utilization of water is 80% on day 1 and then it is 40% on the next day, and so on. Finally, we can observe that more percent of water is utilized on Sundays.

Table 2. *Shows the day-wise utilization of the water.*

Day	Utilization
1	0
2	80
3	40
4	20
5	30
6	40
7	60
8	50
9	40
10	50
11	20
12	40
13	20
14	50
15	60
16	40
17	30
18	10
19	30
20	90

6. Conclusion and Future Work

The Internet of Things (IoT) plays a crucial role in enabling smart water management systems by providing real-time monitoring, data analytics, and automation capabilities. Through the integration of IoT devices, sensors, and communication technologies, water utilities and stakeholders can efficiently manage water resources, detect leaks, optimize water distribution, and enhance overall water quality.

By leveraging IoT solutions, smart water management systems can improve operational efficiency, reduce water wastage, lower maintenance costs, and enhance sustainability efforts. The ability to collect and analyze data from various sources in real time allows for proactive decision-making and predictive maintenance strategies, leading to more effective water resource management.

Furthermore, IoT-enabled smart water management systems promote environmental conservation by promoting water conservation practices, reducing energy consumption, and minimizing the environmental impact of water distribution and treatment processes. These systems also enhance resilience to water-related challenges such as droughts, floods, and water contamination incidents.

The integration of IoT technologies into smart water management systems offers numerous benefits in terms of efficiency, sustainability, and environmental stewardship. As we continue to advance in IoT innovation and adoption, the potential for transforming water management practices and ensuring water security for future generations is promising.

This system is more efficient in distribution monitoring and control approach for a water utility to reduce water loss. This system is tested in the Internet of Things center located at Debre Tabor University which is developed by considering the limitations of the existing system. The observation of the results generated by our proposed system is more efficient than the existing systems. The complete automatic framework for water management systems to save water is our prime research work in the future.

Abbreviations

IoT: Internet of Things
WMS: Water Management System
ISWMS: internet-based smart water management system

Author Contributions

Anduamlak Abebe is the sole author. The author read and approved the final manuscript.

Conflicts of Interest

The authors declare no conflicts of interest.

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