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Smart Pumping System using Energy Efficiency Control Algorithm

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Abstract— Water is one of the most important resources for sustaining life on earth. It is essential for daily activities like cooking, cleaning, and bathing. In residential areas, water supply systems are usually managed by Municipal Corporations or other governing bodies. This project mainly focuses on the IoT based solution for automation of the water tank filling system in our residential area. In this project two Esp8266 MCU connected to the same cloud channel are used, one will be at the Water Source side and other will be at Tank side. The Ultrasonic Sensor connected to the Esp8266 senses the water level in the tank, if the Water level is low the Esp8266 will sent the Motor ON signal to the ThingSpeak IoT Cloud and the Esp8266 at the river or dam side is also connected to the same cloud channel will read that signal and turn the 'Motor ON'. If the tank is full the Esp8266 sends the 'Motor OFF signal' over the cloud and the other microcontroller at the river/dam side will turn OFF the motor. A web interface displaying graphs and indicators is also provided for the user to study and analyze the data from the system.

Keywords- smart pumping, smart control system, energy optimization.

I. INTRODUCTION

The concept behind a smart city is to use technology to improve efficiency in daily life. Water distribution is a crucial job in a smart city. The current water distribution methods are ineffective, so we should automate the complete system using IoT technology to develop the most effective and affordable method for water distribution [1]. As we know that each residential area has its water tank provided by Municipal Corporation, also in the rural area there is one tank provided to one village. The water in these tanks comes from the dam or river. The current water management method requires more time and has limited scheduling flexibility. Liters of water are wasted if there is a leak in the distribution system. We should use technology like IoT, smart sensors, and data processing to solve these issues by utilizing these technologies, we can design a suitable system that allows us to regulate both the timing and schedule of water distribution and the water quality using intelligent sensors[2]. However, the process of filling the water tank is often manual, which can be time consuming and inefficient. There is a need for an automatedsystem that can manage the water supply in a more efficient and reliable manner. There is no such system to automate thisprocess of refilling of the tank. This system approach to automize the manual water distribution operation in ruler andurban area. The real-time data is collected and displayed on website [3]. This paper proposes an automatic water level measurement system using an ultrasonic sensor that canmeasure the water level without direct contact with water, thereby increasing its life span. The paper further discusses the need for smart water systems as alternatives to overcomethe shortcomings of manual metering systems and proposes awireless sensor network of water meters installed in thousands of households that collect periodic measurements reported in real-time over a wireless network to a central database.[5] The role of IoT in the IOT-based Smart Water Pump Switch is to enable communication between the device and the internet, which allows remote monitoring and controlof the water pump [8]. If the distance goes below a certain point, it means that the water level has exceeded the optimumlevel [6]. The device's sensors collect data on the water level in the tank, which is then transmitted to the cloud via the internet. The user can then access this data from anywhere and remotely control the pump, ensuring efficient water management [8]. The unregulated consumption of water alsoleads to wastage and ultimately results in water scarcity. To address these issues, water automation systems can be utilized to reduce human efforts and errors. The water level sensor can also be used in industries to measure the level of chemical liquids in tanks. Overall, the system improves the accuracy of water level measurement and controls the water pump automatically.

II. LITERATURE REVIEW

Kiran M. Dhobale et al. discussed the need for an automated water supply management system with reference to the Smart City [1]. The author proposed an effective and affordable method for water distribution by utilizing the

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Internet of Things technology. Programmer for automating the water distribution procedure is developed by analyzing the data gathered. The maintenance schedules is developed using IoT to guarantee continuous support. The sensors were used to detect the water with the help of rain sensor and by harvesting the rainwater it can be distributed using a supply-on-demand method [1]. Author summarized that the current water management method requires more time and has limited scheduling flexibility. Liters of water gets wasted if there is a leak in the distribution system. The emerging technologies like IoT, smart sensors, and data processing solve these issues and a system was proposed that regulate both the timing and schedule of water distribution and the water quality and quantity using intelligent sensors. The suggested approach makes use of Raspberry Pi to automate the system [2]. Automation of the manual water distribution operation in rural and urban area that monitors the level of water in overhead tanks, flow rate of water, quantity and leakage of water in pipeline system is suggested [3]. The system measures the wastage of water. The real-time data is collected for individual house and displayed on website. The working of this project is that it monitors the amount of water present inside the tank wirelessly using Ultrasonic Sensor interfaced with Arduino. The Flow Meter were used to measure the water consumption. Node MCU serve as Wi-Fi adapter and wireless internet access and it monitors the tank level and flow rate of Water. The Real Time Clock was used to send the digital input of the time to the Arduino based on which the main valve was opened. The float switch was used to sense if the water level in tank fall below the level. Solenoid valves were used to on or off the water supply. The water level In tank was displayed on the LCD display. The leakage of water was also being detected with help of Solenoid valve. The quantity of water consumed by each home was also measured using the solenoid valve. The Data from all sensors were displayed on the Web server of ThingSpeak Iot Cloud.

Continuous and real-time monitoring of water supply based on sensors was suggested [4]. Flow sensor, pH sensor, Soil sensor, and GPS sensor were employed. The Raspberry Pi 3 microcontroller and the ThingSpeak IoT cloud platform was used. All the sensors' Data pushed to the ThingSpeak cloud and the water control was achieved using valves. The solenoid Valves controlled the on and off cycle of the water supply, using Raspberry pi 3 MCU. The Flow sensors measured the flow of water through pipes. MYSQL databases was used to record the information about the amount of water passed through the flow sensor. The pH sensor is used to check the drinkability of water and Soil sensor to identify if there is soil particles in the water. The GPS module tracked the distance of the water source. Authors highlighted the challenges faced with manual water supply system. The study suggests an automated water level measurement method that, by eliminating direct water contact, increases system lifespan. It discusses the shortcomings of manual systems and supports intelligent water systems. The idea includes installing wireless sensors in a lot of homes and using those sensors to provide real-time information to a central database. Arduino, flow and ultrasonic sensors, as well as a GSM module, are among the components. According to the study's findings, this eco-friendly smart meter overcomes the limitations of traditional water meters [5].

Sai Sreekar Siddula et al. created a system that uses Bluetooth modules, ultrasonic sensors, and an Arduino microcontroller to monitor the water level in a container. They attached a water level sensor to the top of the container to measure the distance between the water surface and the container top. If the measured distance is below a threshold, it indicates that the water level has exceeded the optimum level. The system sends water level data to another Arduino microcontroller via Bluetooth module, and the readings appear on a display. When the water level approaches the maximum capacity of the container, a signal is sent to a servo motor that controls agate mechanism. The second microcontroller interprets the input data and activates the servo motor connected to the gate mechanism, allowing water to flow out of the container. As the water level decreases, the second microcontroller stops sending commands to the servo motor, and the gate mechanism closes. The system can also send information about water level readings to a central command center [6]. Design and implementation issues in developing the Microcontroller Based Automated Water Level Sensing and Controlling system was discussed [7]. The PIC16F84A microcontroller is interfaced with the water level sensor. The author programmed the microcontroller using MPLAB. The use of PIC16F84A microcontroller reduces the complexity of the system, making it more manageable and efficient.

IOT-based Smart Water Pump Switch is used to enable communication between the device and the internet, which allows remote monitoring and control of the water pump. The device's sensors collected data on the water level in the tank, which is then transmitted to the cloud via the internet. The user can then access this data from anywhere and remotely control the pump, ensuring efficient water management. Additionally, the device can be integrated with other IoT-enabled devices, such as mobile phones or smart speakers, to provide voice-activated control and alerts. The IoT technology in the IOT-based Smart Water Pump Switch

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enhances its capabilities and makes it a powerful tool for water conservation and management. The aim of this work is to save water and electricity by automatically turning off the pump when the tank is full [8]. Mazharul Islam Nayeem et al. suggested that an Android application can be used to turn thewater pump ON and OFF, resulting in efficient water usage and reduced wastage. There is ample scope for further improvement in this technology, and researchers should prioritize its development. Water automation has various applications in agriculture, industries, households, hotels, and more. Researchers have implemented multiple water automation projects, including android-based water pump controllers, water level detection, billing systems, and leak detection, highlighting its importance in the conservation of water resources [9]. The automatic water pump controller and water level detector system presented in this paper has practical applications in households, industries, and agriculture. It not just reduces water wastage but also saves human effort and time. This system is cost-effective and efficient and has the potential to revolutionize the way water is utilized and conserved in various sectors. A water level indicator system is a useful tool that allows us to monitor the water level in a reservoir. This research paper introduces an automatic water pump controller and water level detector that use a microcontroller chip. The system works by measuring the water level in a tank, displaying it on an LCD display unit, and automatically activating the motor to refill the tank when the water level is low. The microcontroller IC, ATmega 16A, controls the system, and a Reed switch sensor is used to monitor the water level. This water level sensor can also be used in industries to measure the level of chemical liquids in tanks. Overall, the system is designed to improve the accuracy of water level measurement and control the water pump automatically [10].

Intelligent solutions are used to address the worldwide water crisis, which is made worse by a lack of electricity for pumping. Dong and Yang's [11] IoT-driven pumping programs maximize water conservation. IoT and neural networks are combined by Karar et al. [12] for effective irrigation control. Sarmas and co. [13] manage energy for water pumping on islands using ML. Jan and others. IoT-based tank monitoring is provided by [14]. Sangeetha and others. Investigate ML and GIS technology for smart irrigation [15]. Oberascher and others. Integrated water management in smart cities is discussed in [16]. S. L. A. and others. IoT-based sustainable irrigation is described in [17]. Bhardwaj and co. [18] suggest using intelligent irrigation in agricultural. IoT and neural networks combined for irrigation with hardware as Arduino Remote XY interface and electronic sensors in the framework of IoT technology [19]. Data-driven methods for water conservation are optimized with Cloud computing environment to provide a common platform for water conservancy [20] . IoT-driven garden watering is presented by M. S. Nugraha et al. [21]. For resource management, Gupta et al. [22] investigate smart water technology. IoT-based water supply management is introduced by Gonçalves et al. [23]. Solar-powered smart water pump control is created by Karmarker and Shovo [24]. Through technology-driven methods, this research collectively promote effective management of water resources.

III. METHODOLOGY :

Hardware : In this project we have used two Esp8266 MCU, Ultrasonic Distance sensor, Relay and Motor/Pump. The main sensing component in the system is the Ultrasonic Distance sensor. This sensor gives output in form of pulse and that pulse is proportional to the time taken by the Ultrasonic sensor to emit the Ultrasonic wave and receive the reflected wave back. The Equation to calculate the actual distance is asfollows.

$$\text{Distance} = \text{speed} * \text{time} \qquad (1)$$

Eq. (1) Distance formula

$$\text{Distance (cm)} = \text{Sensor Reading} * \frac{0.034}{2} \qquad (2)$$

Eq. (2) Formula to calculate Distance from Ultrasonic sensor

Water Demand Percentage be the calculated water demand as a percentage of the desired range.

$$\text{WDP} = \frac{(\text{CWL} - \text{DMn})}{(\text{DMx} - \text{DMn})} * 100 \qquad (3)$$

Eq. (3) Formula to calculate Water Demand Percentage be the calculated water demand as a percentage of the desired range.

$$MS = Mn + \frac{WDP}{100} * (Mx - Mn) \qquad (4)$$

where

CWL -Current Water Level be the current water level in the tank (measured by the ultrasonic sensor).

DMn -Desired Min Water Level be the minimum water level of the desired range (e.g., 30% full).

DMx -Desired Max Water Level be the maximum water level of the desired range (e.g., 80% full).

WDP -Water Demand Percentage be the calculated water demand as a percentage of the desired range. MS - Mapped Motor Speed , Mn - Min Motor Speed, Mx - Max Motor Speed

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Adjusted Motor Speed = Energy Efficient Control Algorithm (Mapped Motor Speed, Historical Data, Time Of Day, External Factors)

The precise control logic you decide to use is represented by the Energy Efficient Control Algorithm function. The function offers an adjusted motor speed that balances water demand and energy efficiency after receiving the mapping motor speed as input along with pertinent data. The desired motor speed range, energy-efficient control algorithms, and outside variables like historical data and time of day are all components that go into an equation for determining the target motor speed.

To automize the water supply system we are using two Esp8266 microcontrollers which are connected to the same cloud channel provided by ThingSpeak IoT Cloud. Both Microcontrollers are connected to the Cloud through different Wi-Fi routers or Mobile Hotspots. One Esp8266 Microcontroller will be deployed at the Tank side and the other will be at the dam or riverside.

The Ultrasonic Sensor connected to the Esp8266 Microcontroller senses the water level in the tank and that value is sent to the ThingSpeak cloud Field 1 through Esp8266. If the water level in the tank falls below a certain level (distance sensed by Ultrasonic sensor exceeds 100cm) means the 'Tank is Empty', the Esp8266 at the tank side will send the Motor ON signal to the cloud by sending '1' to the Cloud field 2.

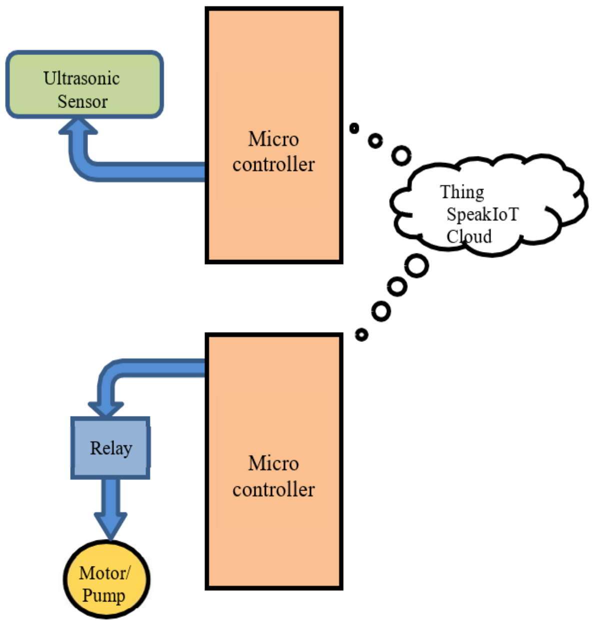

Fig.1 Smart Pumping system

That signal will be received by Esp8266 at the Riverside which is also connected to the same cloud channel. It will read the value '1' from Field 2 and actuate the relay connected to it and the Motor connected to the relay is turned ON automatically and the Green light is indicated. As the water gets filled again the Ultrasonic sensor will sensethe water level in the tank, if the water level increases (distance sensed by Ultrasonic sensor falls below 11 cm) means 'the Tank is Full' the Esp8266 sends an OFF signal bysending a ' 0' value to the Field 2. The Esp8266 at the riverside will read the '0' value from Field 2 sets the relay pinLOW and the Motor is turned OFF and the Red light is indicated. The Microcontrollers are programmed through Arduino IDE. We can also change the threshold values in the program through Arduino IDE and reprogram the Esp8266 Microcontroller.

Feedback loops are used to maintain speed within a small range by continuously measuring the motor's real speed and comparing it to the goal speed. In order to maintain the motor speed as closely as feasible to the desired speed while reducing deviations, the feedback loop modifies it as necessary. Through the use of a feedback loop and variable speed control, energy consumption is optimized.

Algorithm 1 : Energy Efficient Control Algorithm

Input: Distance d
Output: *water demand , motor speed, Energy consumption* data on cloud

1. Initialize Cloud Channel Variable
2. Initialize Ultrasonic Sensor
3. Check WiFi Connection
   If (!WiFi) Repeat steps 3-5
   Else Connect (WiFi)
4. ***Loop***

a. If (WiFi)
  i. Read Distance from Ultrasonic Sensor
  ii. Send Data to Cloud
  A. If (D >= 100)
    1. Send Message "Tank Empty" to Cloud
    2. Start Motor Signal on Reservoir Side
  B. If (D <= 10)
    1. Send Message "Tank Full" to Cloud
    2. Stop Motor Signal on Reservoir Side
  C. If (D > 10) and (D < 100)
    1. Water Demand based on the current water level

$$\mathrm{WDP} = \frac{(\mathrm{CWL} - \mathrm{DMn})}{(\mathrm{DMx} - \mathrm{DMn})} * 100$$

      a. Determine the desired water level range (e.g., 30% to 80% full).
      b. Calculate the current water demand
    2. Calculate Target Motor Speed

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a. Map calculated water demand to motor speed.
b. Adjust the motor's speed

$$MS = Mn + \frac{WDP}{100} * (Mx - Mn)$$

3. Apply Variable Speed Control
   a. Set the motor's speed to the target speed.
   b. Utilize feedback loops
   c. Implement gradual speed adjustments
4. Monitor Energy Consumption
   a. Track the energy consumption
   b. Calculate the energy savings achieved
5. Send Data to Cloud
   a. Send the following data to the cloud
   i. Current water level
   ii. Calculated water demand
   iii. Target motor speed
   iv. Energy consumption data
6. Loop back to the Main Loop

5. **End loop**

The technology works at its most effective level when the motor speed is adjusted in response to real-time demand. Algorithm 1 gives energy efficient system implementation. The feedback loop reduces speed variations and avoids irrational energy spikes. Adjusting speed gradually prevents sudden shifts that could waste energy. As a result, the motor runs as efficiently as possible while still providing the water that is needed.

We have also designed an HTML website which is deployed on Git Hub. It allows the user to view the Water level graphand Motor ON/OFF graph so that the user can study andanalyze the number of times the Water Level changes andalso the number of times the Motor is turned ON and OFF. The water level in cm is also shown on the Website which isupdated every 15 seconds. Also, one green indicator isprovided on the website which glows when the motor is ON.The blue light indicator for Water Level High is displayed onthe webpage which glows when the water level high means the distance sensed by Ultrasonic sensor is below 80cm. Theorange light indicator for Water Level Low is displayed onthe webpage which glows when the water level falls lowmeans the distance sensed by Ultrasonic sensor exceeds80cm. All the data on the webpage is updated in real-time becauseof integration with ThingSpeak cloud at the backend.The website also shows the Source and Destination location with the help of Google Maps integration. We can also change these locations in HTML code.

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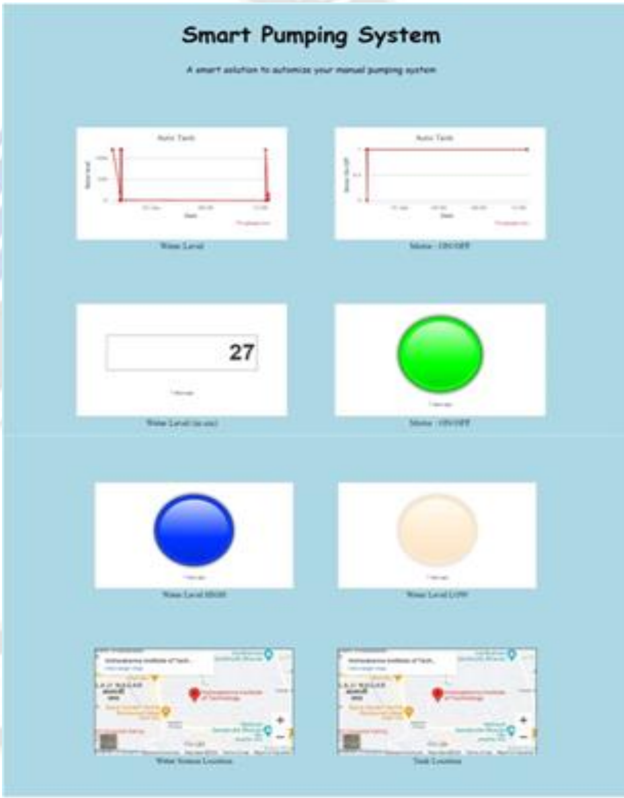

Fig 2. Web Interface

IV. RESULTS AND DISCUSSIONS

The Smart Pumping System was put into use and tested successfully. The Motor/ pump was automatically turned ON whenever the distance sensed by Ultrasonic sensor exceeded100cm and also Turned OFF automatically when the distancesensed by Ultrasonic sensor falls below 11cm. The Webpagealso responds with the change in parameters. The graph is updates with changing water level and

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distance sensed by Ultrasonic sensor. Also the respective indicators glow when the Motor is ON, Water Level High, Water Level Low.

Table 1. Observations recorded

Water Level	Distance sensed by Ultrasonic sensor (cm)	Motor	
		ON	OFF
LOW	110	□	
LOW	80	□	
HIGH	60	□	
HIGH	20	□	
HIGH	10		□

The water level and distance measured by ultrasonic sensor is shown in table 1.

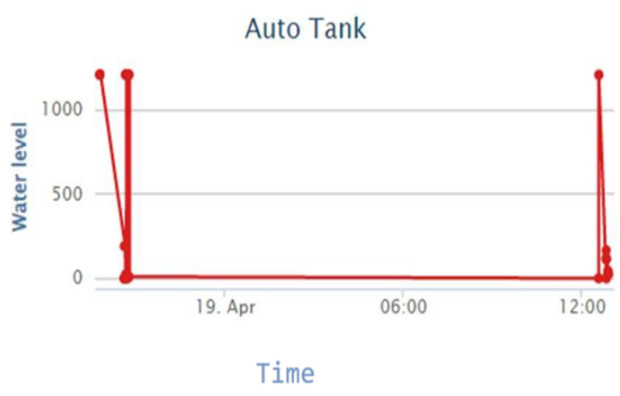

Fig.3. Water level recorded on ThingSpeakChannel

Fig.4. Motor ON OFF signal Recorded

We have recorded the observations and graphs displayed on ThingSpeak Cloud Channel and Web interface. We have recorded the Water level and how many times the Motor gets on and off. The indicators response is also recorded for the different water levels in fig 3 and fig 4.

Min Motor Speed = 100 RPM
Max Motor Speed = 500 RPM

Table 2 Water Demand and required motor speed

Test Case	Water Demand %	Expected Mapped Motor Speed
1	20%	100 RPM
2	80%	400 RPM
3	50%	300 RPM
4	10%	100 RPM
5	90%	500 RPM
6	60%	300 RPM
7	0%	0 RPM
8	100%	500 RPM
9	30%	320 RPM

The different test cases, their accompanying input values, and anticipated results are clearly summarized in this table 2.

V. CONCLUSION

In conclusion, the automated water supply system developed in this project utilizing two ESP8266 microcontrollers and cloud connectivity is an innovative solution that can significantly improve the efficiency and reliability of water supply systems in residential areas. The system utilizes ultrasonic sensors to monitor the water level in the tank and refill it automatically when the water level falls below a certain threshold. The motor at the dam or river side is turnedon through a cloud signal when the water level falls below the threshold, and the motor pumps water into the tank until the water level reaches the required level, after which the systemturns off the motor. The water level and motor status can be monitored through the cloud channel, making it easy to trackthe system's performance. This system can reduce the workload on the governing bodies responsible for managingthese systems and can be a sustainable solution to ensure continuous water supply in residential areas.

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