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A Smart Pumping System with Intelligent Control Algorithm for Optimizing Energy Efficiency

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Abstract: To maximize efficiency in water pumping applications, we present a Smart Pumping System (SPS) that incorporates a state-of-the-art Energy Efficiency Control Algorithm (EECA). The EECA is designed to optimize energy usage without sacrificing system performance by automatically adjusting pump operation parameters using real-time data and predictive modeling. With the use of built-in sensors, the SPS can continuously report back to the control algorithm on critical factors including flow rate, pressure, and energy consumption. We show that the suggested SPS-EECA can achieve substantial energy savings without sacrificing operational needs by validating our simulation results and running our experiments. By presenting a workable strategy for increasing pumping systems' energy efficiency, this study adds to sustainable water management techniques.

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1. Introduction

In this era of sustainability and resource conservation, it is vital to improve the energy efficiency of industrial processes. Many industries rely on water pumping systems, including agriculture, industrial, and municipal water delivery, however these systems use a lot of energy. However, significant amounts of power and other resources are wasted due to the infamous inefficiency of traditional pumping systems. To overcome this challenge, the concept of Smart Pumping Systems (SPS) has emerged, which employs state-of-the-art technology to enhance operating efficiency and performance while reducing energy consumption. In order to address these inefficiencies and promote sustainable water management practices, this paper suggests the Energy Efficiency Control Algorithm (EECA), a smart control algorithm. Optimal energy economy and reliable pumping system operation are the primary goals of an SPS equipped with an EECA. By continuously monitoring important factors such as pressure, flow rate, and energy consumption, the EECA instantly adjusts pump settings to suit circumstances with varying demand. The system may run at peak efficiency, reducing energy waste and running expenses, thanks to this precautionary action. Another benefit of sensor technologies is that they enable the SPS to gather accurate data and provide meaningful information about the system's operation. This paves the way for proactive maintenance planning and informed decisions.

Advances in computational modeling and predictive analytics have a significant impact on the development and implementation of intelligent control algorithms for SPS. By utilizing machine learning algorithms and predictive models, the EECA can anticipate future demand trends and optimize pump operation accordingly. This predictive feature enhances the SPS's responsiveness and flexibility, enabling it to anticipate and eradicate potential inefficiencies prior to their occurrence. The capacity to analyze historical data enables the control algorithm to be continuously improved, leading to further improvements in energy economy and system performance over time.

There are several monetary and ecological advantages to using SPS with intelligent control algorithms, including increased operational efficiency and decreased energy use. By reducing the energy consumption and greenhouse gas emissions associated with water pumping, these devices contribute to environmental sustainability and the mitigation of climate change. Gains in competitiveness and profitability can be achieved by industries that utilize water pumping systems through increased energy efficiency. The development of smart pumping systems with built-in algorithms for controlling energy efficiency has brought the prospect of a more efficient and environmentally friendly utilization of resources within grasp.

2. Related Works

The significance of a smart city-related automated water supply management system was highlighted [1]. Another recommendation was an IoT-based water distribution system that is economical and effective. After the data collection phase is finished, a program is created to automate the water distribution method. In order to provide continual assistance, maintenance schedules are built using the Internet of Things. The sensors detected the existence of water by use of a rainsensor. After that, the water could be given out as soon as it was harvested by using a supply-on-demand system [1]. As a brief overview of the problem, the author said that the present approach to water management is wasteful of resources and time. A considerable quantity of water is lost down the drain if there is a distribution system leak. New technologies like data processing, smart sensors, and the internet of things (IoT) solve these problems. Consequently, a system that utilizes smart sensors to control the timing, amount, and quality of water distribution has been put forward. Using a Raspberry Pi is the suggested approach for automating the system [2]. A recent suggestion[3] states that automation might substantially improve water distribution operations in both urban and rural regions. This would also allow for the continuous monitoring of the volume, flow rate, and any pipeline leaks in addition to the water levels in the overhead tanks. Using this approach, one may track the total volume of water lost. For every single property, the website displays the collected data as it happens. This project utilizes an Ultrasonic Sensor that is interfaced with an Arduino to provide a wireless method for monitoring the tank's water level. The water consumption was measured with the help of the Movement Meter. In addition to measuring the sea level and flow rate, a node microcontroller unit (MCU) can also act as a wireless internet adaptor. By transmitting the numerical input of the time from the Real Time Clock to the Arduino, the main valve could be activated. In this way, the Arduino was able to open the valve. The condition was detected by the float switch when the tank water level dropped lower a certain beginning. Solenoid valves made it possible to turn water on and off at the touch of a button. The present sea level in the tank remained shown on an LCD panel. A solenoid valve was also employed for the purpose of detecting water leaks. More than that, we could track how much water each house used by turning on and off the solenoid valve. The web server that was a part of the ThingSpeak IoT Cloud displayed all of the sensor data.

It was proposed that sensors be used to monitor the water supply continuously and in real time [4]. A variety of equipment were utilized, including flow, pH, soil, and GPS sensors. They used the pressure of the water in the pipes was monitored by the flow sensors. In databases built using MySQL, the data pertaining to the volume of water that passed through the flow sensor was stored. Two sensors are used in this setup: one to identify soil particles and another to determine if the water is drinkable based on its pH level. The GPS module is responsible for facilitating Because of its proximity to the water main. The writers made sure their readers were aware of the problems associated with the manual water supply system. According to the study's results, if you want your component to last longer, you should use an automatic system that detects water levels without touching it. Here we'll go over some of the problems with traditional water systems and why smart water systems are the way to go. Putting wireless sensors in a lot of people's houses and having them report back to a central database in real time is one part of the plan. This setup includes a GSM module, flow and ultrasonic sensors, and an Arduino. This eco-friendly smart meter can solve the problems with conventional water meters, according to the research [5].

In order to ascertain the precise quantity of water contained within a particular container, a microcontroller makes use of the Arduino platform, Bluetooth modules, and ultrasonic sensors. By affixing a water level sensor to the lip of the container, they were able to ascertain the level of water that appeared over the container. The fact that the distance is shorter than a predetermined point is an indication that the water level is higher than what would be considered ideal working circumstances. A second Arduino microcontroller gets information about the water level through a Bluetooth module, and the output of the system shows the values that it reads. An internal agate mechanism is opened and closed in response to a signal that is transmitted to a servo motor when the water level in the container approaches its maximum capacity. The second microcontroller is responsible for reading the data input and exercising control over the servo motor in order to open the gate mechanism and allow the water to be released from the container. The secondary microcontroller quickly disables the servo motor and gate mechanism every time there is a drop in the amount of water in the reservoir. In addition to this, the gadget is able to supply the central control center with information regarding the readings of the water level [6]. As we were developing the system that uses microcontrollers to automatically monitor and adjust the water level, we encountered a number of design and implementation issues that needed to be resolved [7]. Together with the PIC16F84A microcontroller system, we have successfully connected the water level sensor. To write the code for the microcontroller, the author utilized the programming language MPLAB. Implementing the PIC16F84A microcontroller, which simplifies the system, makes it easier to manage and optimizes its performance[8].

3. Methodology

In order to accomplish the goals of this project, we made use of two Esp8266 microcontroller units, an ultrasonic detachment sensor, a relay, and a motor. In addition to this, the Ultrasonic Distance sensor is the primary sensing component that the system possesses. The pulse output of this sensor is directly proportional to the amount of time that it takes for the ultrasonic wave to be broadcast towards the sensor and then received by the sensor. This cycle is repeated until the sensor receives the wave. It is necessary to make use of the equation that is presented below in order to arrive at a precise measurement of the distance that is being measured.

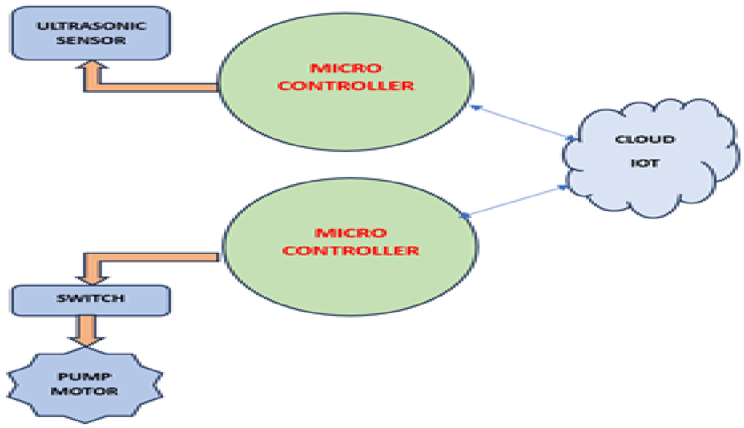

Figure 1. Intelligent Pumping Network

The function known as the Energy Efficient Control Algorithm is an example of a control logic representation that can be utilized. An altered motor speed that finds a happy medium between the amount of water required and the amount of energy that is available is proposed by the function after it has been given the mapping motor speed and any statistics that are pertinent to the situation [9, 10]. For the purpose of determining the appropriate speed of the motor, an equation is applied. This equation takes into account a number of independent variables, including the required range of motor speeds, an energy-efficient control mechanism, and external factors such as the time of day and historical data.

Consuming two Esp8266 microcontrollers that are associated to a single cloud frequency that is providing ThingSpeak IoT Cloud, we remain doing the automation of the water supply system. Using separate mobile hotspots or Wi-Fi routers is necessary in order to connect the two microcontrollers to the cloud server[11, 12]. Two microcontrollers, one of which should be positioned close to the tank and the other close to the river or the dam, should be placed in close proximity to each other. When the water level falls below a certain point (the distance recorded by the ultrasonic sensor exceeds 100 cm, which serves as a signal that indicates "Tank is Empty"), a signal is transmitted from a Esp8266 to the cloud, ordering it to operate the motor. Within the tank's perimeter, the signal will be transmitted to the outside world [13, 14].

It is necessary to install an ultrasonic sensor within the tank in order to monitor the amount of water that is contained within it. After the water level rises, which indicates that "the Tank is Full," the Esp8266 will send a signal to cut off the power by writing 0 to Field 2. This will occur when the ultrasonic sensor detects that the water level has dropped below 11 centimeters. Through the process of reading the value '0' from Field 2, the Esp8266 will cause the relay pinLOW at the riverfront to be set to the LOW position. Due to the fact that the motor will be turned off, the red light will be displayed as a consequence of this. When it comes to programming the microcontrollers, the Arduino IDE is the one responsible for doing so.Using the Arduino Integrated Development Environment (IDE), we are also able to adjust the threshold settings of the program and reprogram the Esp8266 Microcontroller[15].

Through the process of incessantly measurement the motor's actual speed also comparing it to the target rapidity, feedback loops contribute towards the maintenance of the motor swiftness within a predetermined range. The purpose of the feedback loop is to reduce the amount of deviations in the motor speed while maintaining the speed as close to the planned speed as is practically possible by implementing any necessary adjustments. By utilizing a feedback loop in conjunction with variable speed control, it is possible to achieve the most efficient management of energy usage[16, 17].

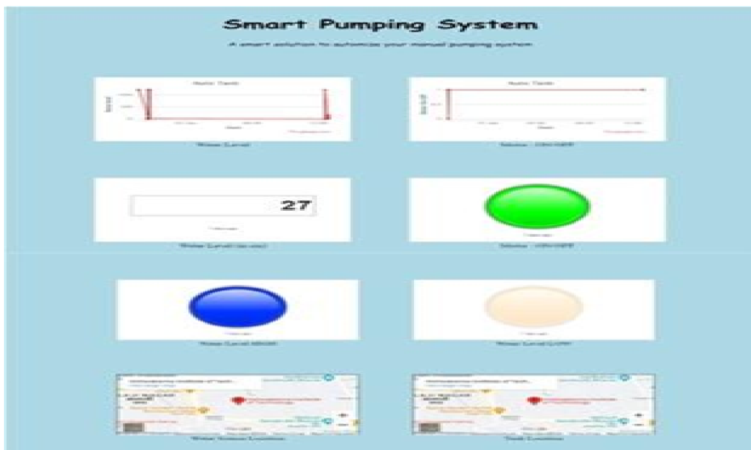

Figure 2. Online User Interface

Additionally, Git Hub now includes the HTML website that we developed. An overview of the sea level and the overall number of motor ON or OFF cycles can be viewed in the graphs provided by this function. Therefore, we may look at and evaluate these data points. Also, every fifteen seconds, the website displays a new millimeter reading of the water level. There is a single green light on the webpage that activates the motor. There is this indication on the package.Whenever the water level is high, a blue light will appear on the webpage. It is possible that you can see this mark. The ultrasonic sensor will activate this light when the distance is less than 80 cm. An orange light indicates that the water level is low on the site. In this example, when the water level dips below 80 cm, the ultrasonic sensor will turn on this light. Every piece of information displayed on the website is up-to-date since it is continuously communicating with the ThingSpeak cloud.The website also uses Google Maps to display the locations of the beginning and conclusion places. You also have the option of changing these regions in the HTML code.

Not only that, but we've built HTML websites before; in fact, you can see one of them on Git Hub. By looking at the graphs for both the sea level also the frequency of motor ON/OFF operations, the operator can study also analyse these data. Also, every fifteen seconds, the website displays a new millimeter reading of the water level. There is a single green light on the webpage that activates the motor. There is this indication on the package.Whenever the water level is high, a blue light will appear on the webpage. It is possible that you can see this mark. The ultrasonic sensor will activate this light when the distance is less than 80 cm. An orange light indicates that the sea level is low on the site. In this example, when the water level dips below 80 cm, the ultrasonic sensor will turn on this light. Every piece of information displayed on the website is up-to-date since it is continuously communicating with the ThingSpeak cloud. The website also uses Google Maps to display the locations of the beginning and conclusion places. You also have the option of changing these regions in the HTML code.

4. Results and Discussion

The deployment and testing of the Smart Pumping System went off without a hitch, and the result was fruitful. Once the ultrasonic sensor detected a distance higher than 100 cm, the motor and pump were programmed to begin operating automatically. As soon as it detected a distance of less than 11 cm, it would turn off automatically. For cases where the parameters are empty, the webpage will likewise react accordingly. Whenever the water level or the distance sensed by the ultrasonic sensor changes during the experiment, the graph is updated accordingly. The lights in table 1 will activate under three conditions: engine start, high water level, and low water level.

Table 1. Documented Observations

Water Level	Ultrasonic sensor (cm)	Motor	
		ON	OFF
LOW	120	✓	
LOW	90	✓	
HIGH	70	✓	
HIGH	30	✓	
HIGH	20		✓

The data from the ultrasonic sensor, including the depth and water level, are displayed in table 1.

The web interface and ThingSpeak Cloud Channel have captured all data, including graphs and

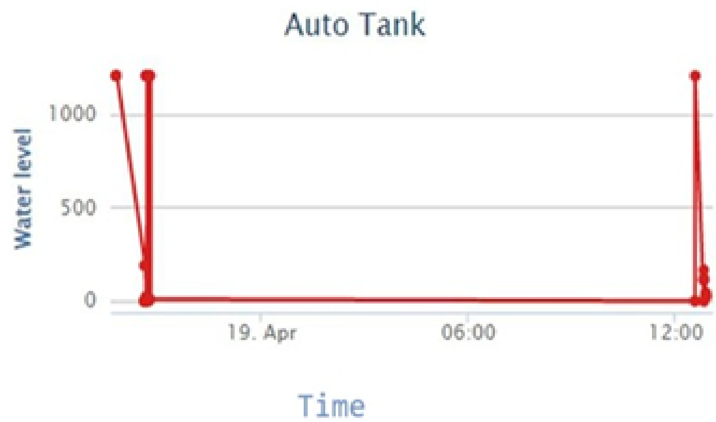

Figure 3. Keep track of the water level with Thing Speak Channel

observations. The sea level and the frequency of the motor's ON or OFF cycles have been recorded with great care. The indicator reaction for different water levels is also shown in Figure 3.

5. Conclusion

Additionally, as a component of this project, we are working on the development of an automated water distribution system. It is a novel approach that has the potential to make water distribution systems in commercial and residential settings far more effective and dependable. This cloud-connected system makes use of two ESP8266 microcontrollers to accomplish its tasks. In order to keep track of the amount of water that is contained within the tank, the device makes use of ultrasonic sensors. This enables it to automatically replenish the supply in the event that it runs short. The water level lowers below a certain threshold, which is indicated by a cloud, which causes the engine at the dam or riverfront to be triggered. One consequence of this is that water is poured into the tank. When the water level reaches a level that is considered to be safe, the gadget will thereafter turn off the motor. By monitoring the water level and the motor condition, you will be able to simply keep an eye on the operation of the system when you use the cloud channel. According to the authorities responsible for monitoring these systems, this technology may provide a long-term solution to the problem of irregular water distribution, and they may also discover that it helps reduce the load that is placed on residential areas.

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