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Smart Water Pump Control System with Remote Access for Improved Energy and Water Resource Management

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ABSTRACT
Water has remained an essential natural resource. Man has explored various means of ensuring the sustainable supply of this important liquid. The use of electric pumps to supply underground water is a major means of water supply. Epileptic power supply in the country has resulted from many families leaving their water pumps ON while away during the day's work. The challenges posed by the cost of electric energy and losses in water resources are of concern. This research designed and deployed a smart water pump control system to ensure improved energy and water resource management. The remote access to the pump operation status through the GSM module helps the building residents to decide when to add other loads to the power system, in order to manage the installation capacity of the power supply system in the building thereby eliminating the need for high rated circuit breakers and cable sizes. This results in reduced cost of initial electrical installation and energy costs. The results obtained from the controlled deployment of the smart water control system showed that the system is capable of minimizing the cost of energy by 34.44%.

Keywords: *water resource, smart pump, energy management. remote access, control system*

1 INTRODUCTION

Water ranks high in the needs of life. Only about 0.3% of water in the world is safe for use. This suggests an eminent shortage of this important natural resource (Kılıç, 2020). Living things are basically constituted of water. Water provides the solution for most biological metabolism in living organisms. As a helpful liquid, water is used by man in most of his daily activities. These activities include but are not limited to cooking, washing, agriculture, and industrial applications. Though water has been taken so simply as a natural liquid, the human body is made of about two-thirds water, and man requires water to live(Chaplin, 2001). Human healthy living has been linked to the availability and use of clean and safe water. Preventive health care has a lot to do with the availability and use of clean water (Huck, 2018).

On the technological front, smart and intelligent pumping has been identified as sustainable means of combating global water shortages arising from population, environmental regulations, process limitations, and associated energy wastage. Smart water pumping is capable of reducing energy wasted in traditional methods of water processing and delivery by 25%(Ahmed, 2013). Islam and Amjad, 2018 opined that water as an essential natural resource should be used with minimal wastage. The research also identified uncontrolled use of water and associated wastage as the major cause of water scarcity. They suggested eliminating human efforts and errors in automation through the use of the Android Application. Politicians, managers, health officials, and others should know that implementing low-cost water supply technologies on a larger scale is a better cost-effective alternative to costlier major water infrastructure projects with the associated complex operation and management problems (Zhonga et al., 2013). (Zhonga et al., 2013) illustrated some innovative water technologies, such as using sunlight to purify water, and domestic use of ceramic water filters known to provide clean and bacteria-free water at a minimal cost of about US$ 3 per family per annum.

World energy demand has continued to rise unabated due to the increasing human population and the quest for industrialization. Effective energy management and its utilization were identified to be as important as the availabilityof energy for sustainable development (Awan, et al., 2014). The authors furtheremphasized that developing smart systems could be a veritable means of ensuring energy demand/supply match. They also stressed that an efficient energy management system is a practical business strategy for sustainable growth. This research is aimed at designing a smart water pump control system that will improve energy management. Available similar systems do not have a way of monitoring the level of water in the well, and as such there are higher possibilities of energy wastage when there is insufficient water in the well.

2 REVIEW OF RELATED LITERATURE

Smart technologies have found useful applications in various human and industrial activities. Water supply is not exempted from this all-embracing technology. Hasan, (2020), designed and implemented an automatic water pump controller and water level detector using a microcontroller. The researchers were able to implement their research at an experimental level. Though there was no effort to relate the operation of the system to the availability of water in the well. Ourwork seeks to bridge this missing link by getting feedback regarding the availability of water in the well in order to isolate other malfunctioning behavior of an underground water supply system. There was also no information regarding the energy management implications of the system in real-life applications. Our present study will endeavor to link thesystem operation with energy management benefits. Water wastage as a causative factor of water scarcity in Pakistan motivated (Jamal, 2016) to develop a logical automatic water control system for domestic applications. His proposed circuit used NE555 timer integrated circuit as a major logic component. The design was implemented at the experimental stage using light-emitting diodes (LEDs) to indicate water levels of 0%,30%,90%, and 100% in the water tank. There was no sufficient information concerning the practical application of the design.

Furthermore, Adil, (2018), proposed a flexible automatic water level controller and indicator to curb water wastage in homes. Thedesign was equipped with a selection switch allowing users to select a preset level to which water can be pumped by the system. They further stressed that the system could be improved upon through the use of Arduino and the internet of things (IoT). Our study will incorporate Arduino and IoT to improve the functionality andreliability of the system. (Okhaifoh, et al., 2016), realized a microcontroller-based water pumping machine using an ultrasonic sensor as a means of relating the water level in the tankto the controller.

Gonzalez, et al., (2016), worked on the automated water pump controller (AWPC). The system applied three water level sensors to monitor the water level in both the underground well and the overhead tank. The pump was madeto switch off as soon as the reservoir reached about 10% of full capacity. This was done with the aim of protecting the pump against unnecessary overwork. This research will build on this principle by conveying well water status as a control signal to avoid damaging the pump. Also, ultra-sonic sensors and Arduino controllers were applied by (Preethi, et al., 2015) to realize a prototype system that is capable of sensing water level and using the signal to trigger the water pump. Getu and Attia, (2016), designed a waterlevel sensor device capable of detecting and controlling the water level in a storage system. The system uses sequential logic implemented flip flops to initiate water pumping at a predetermined threshold and stops pumping when water reaches an upper preset limit.

As a result of the information available from the reviewed literature, this research seeks to bridge the observed research gap between the application of automatic water pumpingsystems and energy management. Energy management has come to stay as a tool for sustainable industrial and economic development. The study will attempt to relate smart water pumping systems with energy conservation considering the effect of increasing energy demand on the economy and availability of energy for other important applications. The research will also add the Internet of Things (IoT) to existing designs toguarantee remote access to the automated system.

3 MATERIALS AND METHODS

The research utilizes both hardware and software components to realize the design. The method explores the simulation and prototype approach.

3.1 MATERIALS

The design uses conductance sensing to measure water level. The sensor assembly consists of four aluminum wires mounted at 25%, 50%, 75%, and 100% volume levels in the tank. The opposite ends of these wires are connected to analog input pins A1, A2, A3, and A4 of the Arduino respectively. The bottom of the tank is mounted with a ground conductor for complete system circuitry. Resistors R4 to R7 are pull-down resistors. The dry ends of the sensor wires are connected to a +5V DC source in parallel with the analog input pins of the Arduino. When water touches a particular probe, an electrical connection is established between that probe and the +5V probe because water has slight conductivity. As a result, current flows through that probe and is converted into a proportional voltage by the pull-down resistor. Arduino reads the voltage drop across each pulldown resistor for the purpose of sensing the level of water in the tank. The same sensing method was used for measuring the level of water in the underground source well.

Digital pin 7 of the Arduino controls the buzzer, and digital pin 8 controls the motor. Transistor Q2 drives the buzzer and resistor R5 limits the base current of Q1. Transistor Q1 drives the relay that switches the pump. Resistor R2 limits the base current of Q2. D1 is a freewheeling diode that protects therelay coil due to the transients associated with inductive load. POT Rv1 is used to adjust the contrast of the liquid crystal display (LCD). resistor R1 biases Q1. Resistor R4 limits the current through the power ON LED. The GSM module facilitates remote access to the user.

3.2 METHODS

A simulation and prototype development approach was adopted. The circuit design was carried out in proteus software. Arduino Integrated Development Environment wasused to write the program codes. The prototype was realized and deployed to obtain energy consumption data. Figure 1 shows the circuit design of the smart water pump control system with remote access.

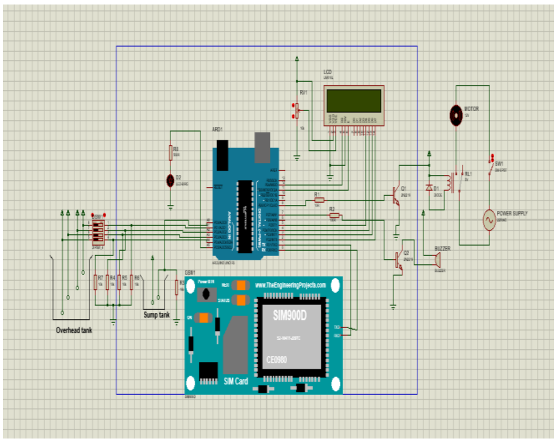

Figure 1: Circuit design of smart water pump control system withremote access

3.3 PROGRAM CODE

The design program code was written in Arduino IDE andassembled using a Proteus circuit design interface. A prototype design was implemented as shown in Figure 2. Thepower consumption of the prototype system was used to estimate the power consumption of a real-life deployment since the water pump used in the prototype is a typical 1.5Hpsingle-phase water pump, hence it was a matter of adjusting the volume and time components of the pump power consumption.

Figure 2: Prototype of smart water pump control systemwith remote access

4 RESULTS AND DISCUSSIONs

The energy consumption for a household with a smart waterpump control system and a household without a smart water pump control system is analyzed in this research work. An active household with or without a smart water pump control system within 10 days of 120 hours of demonstration provides the records of energy consumption as documented. The remote access to the pump operation status through the GSMmodule helps the building residents to decide when to add other loads to the power system, in order to manage the installation capacity of the power supply system in the building thereby eliminating the need for high rated circuit breakers and cable sizes. Table 1 shows household energy consumption with a smart water pump control system, while Table shows the energy consumption for the same household.

Table 1: Household energy consumption record with smart water pump control system

	Lighting/Air conditioning and Refrigeration Load	Water Pump
Number of days	10	10
Power Rating (W)	1310	740
Duration (Hrs)	120	5.5
Total Energy Consumption (WHr)	**157200**	**4070**

From Table 1, the average Daily Energy Consumption with smart water pump control system = $\frac{57200+4070}{10}$ =16127 WHr.

Table 2: Household energy consumption record without smart water pump control system

	Lighting/Air conditioning and Refrigeration Load	Water Pump
Number of days	10	10
Power Rating (W)	1310	740
Duration (Hrs)	120	120
Total Energy Consumption (WHr)	**157200**	**88800**

From Table 2, the average Daily Energy Consumption without smart water pump control system = $\frac{157200+88800}{10}$ = 24600 WHr

Percentage energy saved with smart water pump control system $= \left(\frac{24600-16127}{24600}\right) \times 100 = 34.44\%$. The implication of this result is that a household that installed the smart waterpump control system would save 34.44% of the total energy they could have consumed without the system. This would have a spillover effect on the entire economy as more power would beavailable for other purposes. In addition, there will be guaranteedavailability of water for use with minimal energy cost.

Figure 3 shows the energy consumption of the water pump and other household loads in the 10 ten days period with thesmart pump control system. It can be seen that the power consumption of the pump with the smart pump control system was reduced to 3 percent of the total energy consumed in the building.

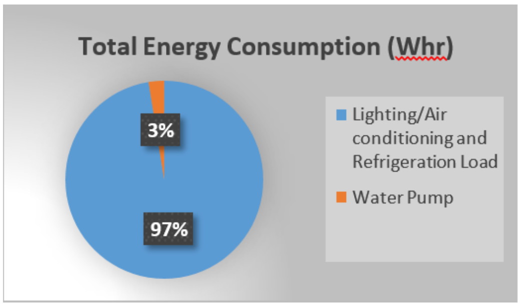

Figure 3: Energy consumption for a household with SmartPump Control System

On the other hand, Figure 4 shows the operation of the pump without the smart pump control system, and this resulted in an increase in the power consumption of the pump to the tune of 36 percent of the energy consumption of the building.

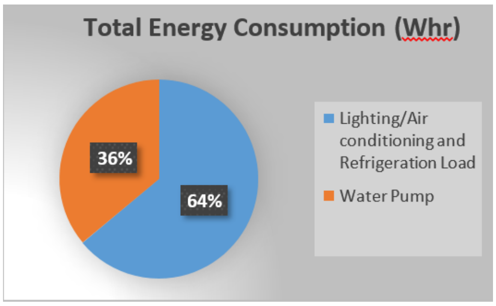

Figure 4: Energy consumption for a household without SmartPump Control System

5 CONCLUSION

The study designed and implemented a smart water pump control system with remote access for improved energy and water resource management. Results obtained from the deployment showed that the system is capable of saving up to34.44% of energy with the associated cost. The application ofthis system will reduce the power consumed in water pumping systems. It also ensures the uninterrupted availability of water for use. The saved power could be used for other useful ventures that require electricity. The remote access to the pump operation status through the GSM module helps the building residents to decide when to add other loads to the power system, in order to manage the installation capacity ofthe power supply system in the building thereby eliminating the need for high rated circuit breakers and cable sizes. This can effectively reduce the cost of initial electrical installations. Further research would explore the system's deployment in a larger setting like industry or community settlements.

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