An Automatic Controller for a Domestic Water Pumping Machine Using CD4001BE Integrated Circuit

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ABSTRACT

These days, the rate of using water pumping machine has increased because of the ease of pumping from the well. However when this water has gotten to the brim, it overflows the brim and spills on the floor causing flooding which leads to erosion and damages to the pumping machine due to over usage. This is the present scenario in most Nigerian homes and it is persistent due to the high cost of acquiring, configuring, connecting and installing a controller on/to the pumping machines. To solve this issue of water wastage and machine damages, this paper presents a cost-effective automatic water pump controller to monitor the water levels and switch ON/OFF the pump motor as necessary. The controller circuit was designed using a common and easily available electronic component named CD4001BE integrated circuit with other electronic components such as transistors, resistors, a relay, transformer, diodes and capacitor mounted on a Veroboard according to the circuit diagram and installed inside a weather resistant casing to oversee the pumping process for the residence. The circuit produces two power output; 12V for the controller circuit and 220V for the pump motor. At the test of the product, the device could automatically control the pump motor as necessary.

Keywords: CD4001BE, Integrated Circuit, pump, automatic controller, water

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1. BACKGROUND OF THE STUDY

Electricity and water are two valuable properties for any country. In Ondo State of Nigeria, the want of electricity and water are the burning question. Load shedding has become a very common problem in our daily lives. The need for a constant and reliable water supply is important for our needs (Harrington, 1989). Water is used for a variety of purposes ranging from bathing and cleaning to drinking and cooking. In the United States and other first world countries, private water developers and private water agencies have constructed thousands of reservoirs to store and distribute water (Water Education Foundation, 2014). To perform any sort of family task, water is necessary. In Nigeria, most probably every house, office and industry use water pump for needed water. But, controlling the water pump that is, switching it on and off is a boring and cumbersome task. Most times, users forget to start water pump at the appropriate time or forget to switch it off. Consequently, there is a huge wastage of water as well as the electricity (Sobuj, 2015).

To avoid wastage and any form of exposure to hazard that may result from overflow of water, the need for an automatic water pump arose (Choe and Wittington, 1996). Automatic controlling involves designing a control system to function with minimal or no human interference. Last few decades several monitoring systems integrated with water level detection have become accepted. Many researchers proposed many similar solutions to that particular problem (Ning and Yu, 2011; Eltaieb and Min, 2014). Nevertheless, there is the need to provide a cost effective automatic controller for water pumping machines for Ondo State residents in Nigeria due to the peculiar level of scarcity of water in some areas of the state including the capital, Akure.

2. RELATED WORKS

Ayoola (2009) Constructed an automatic water level control system to control the water level in the water reservoir which could not turn off the pumping machine. Khalid, Shah, Tariq & Mohsin (2010) developed a microcontroller based automated water level sensing and controlling system which senses the presence of water and indicates it but do not turn it off. Anyanwu, Mbajiorgu & Anoliefo (2012) designed an automatic regulator suitable for water level sensing and control was realized using the MC14066 integrated circuit. It cannot be installed for an already installed reservoir; it has its own customized tank. Erua & Anyasi. (2014) designed a controller that makes use of an over load relay which senses the presence of excess current and disconnects the supply and a mercury flood switch. It cannot be easily repaired when damaged. Sanam, Anuj, Sukirti & Milan (2014) designed a system of an automatic water level controller using Arduino with SMS notification though when the phone is stolen there is no way to control the pump and no means of notification. Alam and Kyle (2016) also designed an automatic controller which prevents siphoning of air in to the pipe though not popular in all areas.

Latte and Done (2017) designed a low cost automatic water level control though it could start running unnecessarily and overheat itself. Aravind & Kumar (2017) developed one that controls the water pump motor by automatically switching it on and off but due to average importation costs, it is not available for average Nigerians. Dinesh (2017) presented a controller system which works with a water-level sensor assembly. Anderson (2018) constructed an automatic water level controller which controls, monitors and maintains the water level in the overhead tank and ensures the continuous flow of water but it is still costly locally. Ejiofor & Oladipo (2018) also designed a controller but Circuit board cannot be repaired when the IC is damaged

2.1 Statement of Problem

People generally switch on their water pump when their water tanks or reservoirs are short of water, that is, when the taps stop running. In like manner, people switch off the water pump not when the tanks are full but when they start overflowing. This results in unnecessary wastages of electricity consumption and water resource thereby leading to money wastage, damage of equipment and property, flooding, and other environmental hazards.

2.2 Objective

The main objective of this study is to develop an automatic controller for a domestic water pumping machine. (A case study of Ondo State, Nigeria)

3. METHODOLOGY

3.1 Design Analysis

The design of the controller system contains the operational flowchart of the device; the schematic block diagram shows the input and output module of the device and the installation model of the device. The circuit was simulated using a Livewire simulation software.

3.2 Block Diagram

The block diagram in figure 1 shows the framework of the device including the input module, control module and the output module of the project. The Input Unit consists of the power supply of 220V. The Control Unit comprises of majorly the Integrated Circuit used for the control system which is CD4001BE and other electronic components. The sensor Unit consists of the two contactors which are to be dipped into the reservoir. It is bidirectional because the power input into the control unit will also power the sensor and the signal gotten from the sensor when the water is filled to the upper level is carried to the signal unit.

Figure 1 The Device Framework

3.3 Design of the Control Circuit:

This majorly consists of the CD4001BE a 14 Dual-In-Line (DIL) IC. The first pin and the second pin are connected together and looped to a 10KΩ resistor which is connected to the fourteenth. The terminal from the fourteenth is connected to another 100Ω resistor in series with a Light Emitting Diode (LED) and in parallel to a 1N4001 diode. One of the output terminals is connected to the collector of a transistor, the emitter of the transistor connected to the seventh pin and looped to the other terminal of the sensor circuit; the base of the transistor is connected to a 1KΩ resistor in series with the fourth pin.

3.4 Design of the Complete System Circuit

Figure 2 shows the complete working circuit. The Power circuit output was connected to the Pump and the Control circuit for the flow of needed voltage level to the pump and the IC. The Sensor output was connected to the input terminals of the control circuit in order to input signal from the circuit. Then the output of the control circuit was connected to the relay and to one of the terminals of the pump.

3.5 Calculations of parameters

Where

Ic is the collector current and can be derived through equation (1)

Ib is the base current and can be derived through equation (2)

$$Ic = \frac{Vcc}{Rc+Re} \quad (1)$$

$$Ic = \frac{12V}{1000+100} = 0.006A$$

$$Ib = \frac{Ic}{\beta} \quad (2)$$

$$Ib = \frac{0.006A}{100} = 0.00006A$$

B = 100 (a reasonable average value for low power signal transistors)

A general rule of thumb is a value of at least 10 times Ib flowing through the resistor R1. Transistor Base/Emitter Voltage, Vbe is fixed at 0.7V (silicon transistor) and this gives the value of Resistor 1 and Resistor 3 as depicted through equations 3 and 4 respectively;

$$R1 = \frac{Vre+Vbe}{10\ X\ Ib} \quad (3)$$

$$R1 = \frac{1+0.7}{10\ X\ 0.00006} = 2.833 = 3K\Omega \text{ (Approx)}$$

$$R3 = \frac{Vcc- Vbe)}{11\ X\ Ib} \quad (4)$$

$$R3 = \frac{12-1.7}{11\ X\ 0.00006A} = 15606.06 = 15K\Omega \text{ (Approx)}$$

However 10KΩ resistor was used since it is the available value that can be gotten and it can still do the same work as the 15KΩ resistor.

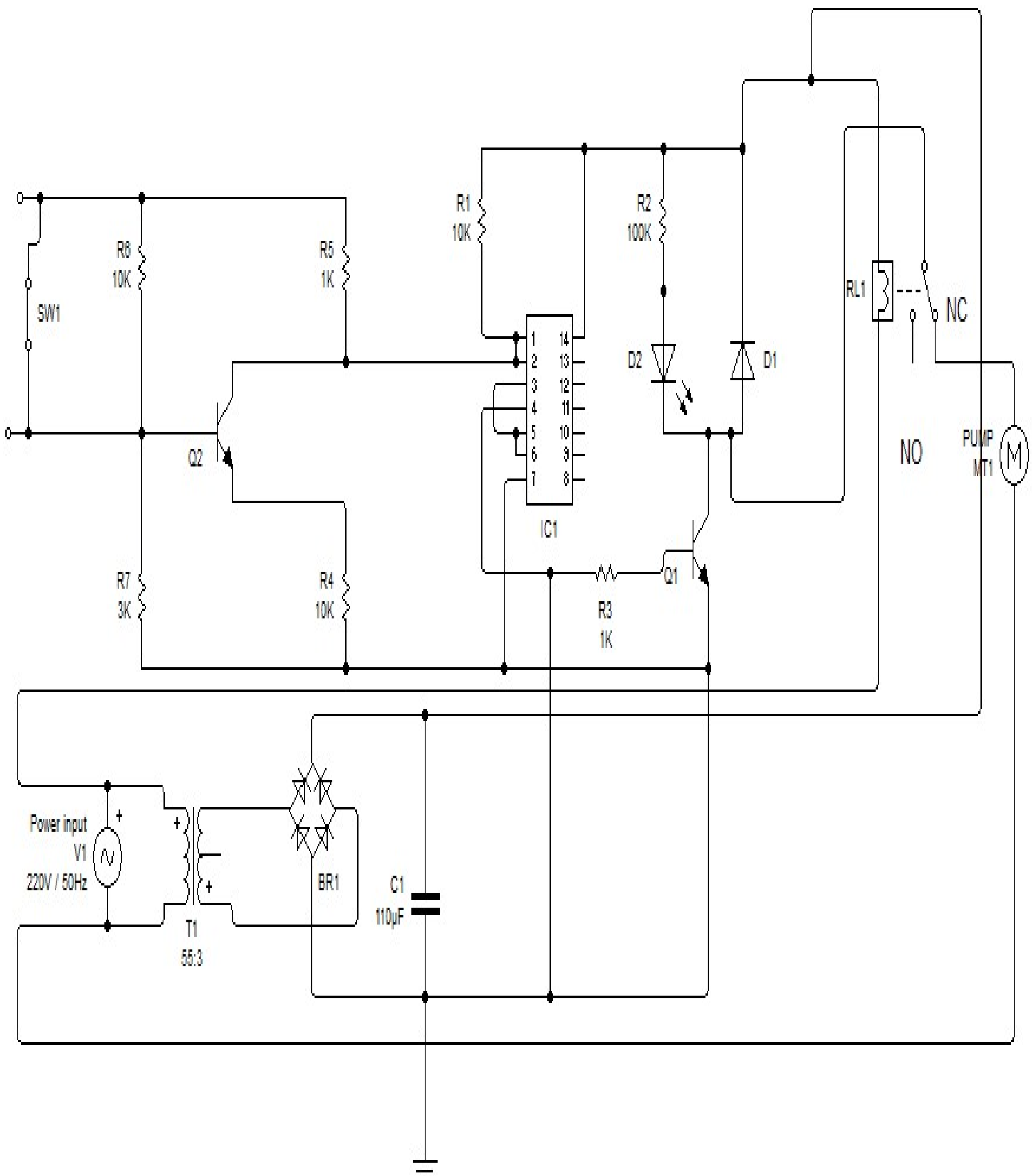

Figure 2: The System Complete circuit

4. CONSTRUCTION PROCEDURE

From the simulated circuit, the circuit was constructed in order to meet the aim and objectives and to operate according to the flowchart.

4.1 Etching

The technique used for the circuit construction on the PCB is etching. Most PCBs are made from a material called FR4, which is a glass-reinforced epoxy composite (basically a sheet of fiberglass) with copper traces on one or both sides for carrying signals. The circuit boards usually start as a fully copper-plated sheet. The outcome of the etching process is found in figure 3 and figure 4.

The etching process is explained below:

I. The schematic diagram of the circuit was sketched;
II. The design was inputted into a PCB design software and printed out 1:1scale so the layouts dimensions were accurate;
III. The layout was transferred to the board by taping the print out over top of the copper clad laminate PCB. By a pushpin was used to stab through the paper where each component lead will penetrate the board. This is to leave dots on the copper where these components go;
IV. The printed sheet was removed and marked on the copper and a 1/32'' bit was used to drill out holes that were marked on the copper;
V. A piece of sandpaper was used to clean the top of the copper plate after drilling. The ink was allowed to dry;
VI. The board was touched up where the marker was faint
VII. Once the second coat of marker was completely dry, the board was soaked in ferric chloride, a corrosive and acidic chemical compound that would chop away all copper on the board that was not protected by the marker's ink for ten minutes;
VIII. After 10 minutes the board was inspected and in the absence of visible copper, it was removed while wearing a latex glove;
IX. The board was patted dry with a disposable rag to remove all ferric chloride from the board;
X. The board was rinsed with acetone that made quick work of the marker ink to reveal the unharmed traces;
XI. A multimeter was used to do a continuity test on the board and verify;
XII. The components were mounted on the board in their correct position and soldered.

The outcome of the etching and mounting done on the PCB is shown in figure 3 and figure 4 respectively.

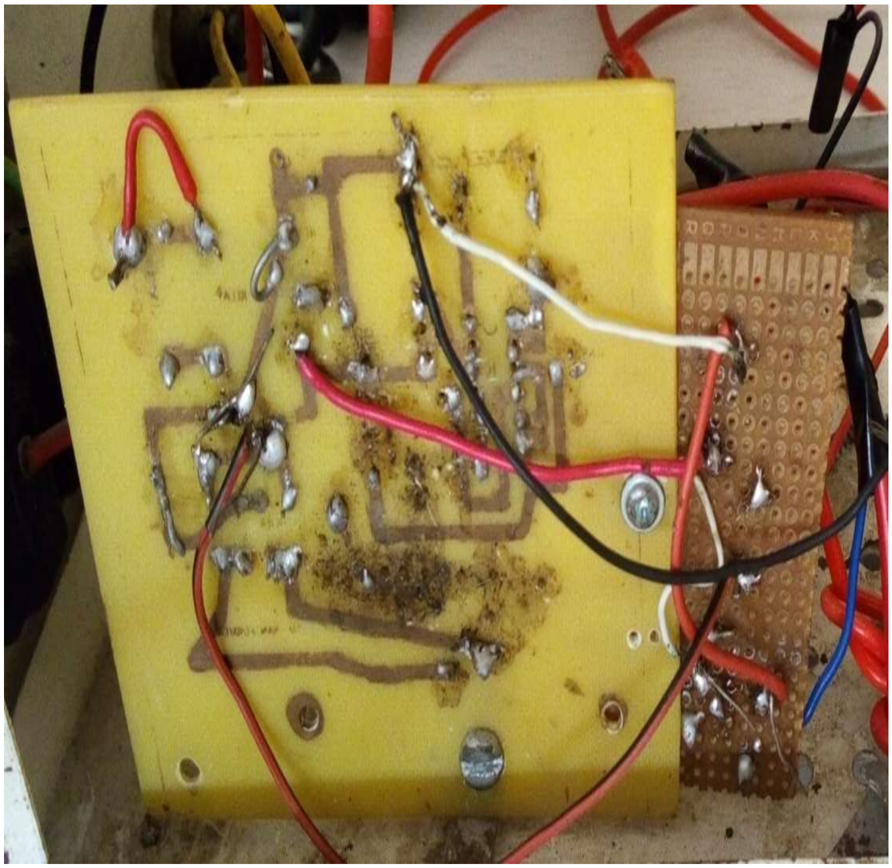

Figure 3: The Etched Circuit Layout on the PCB

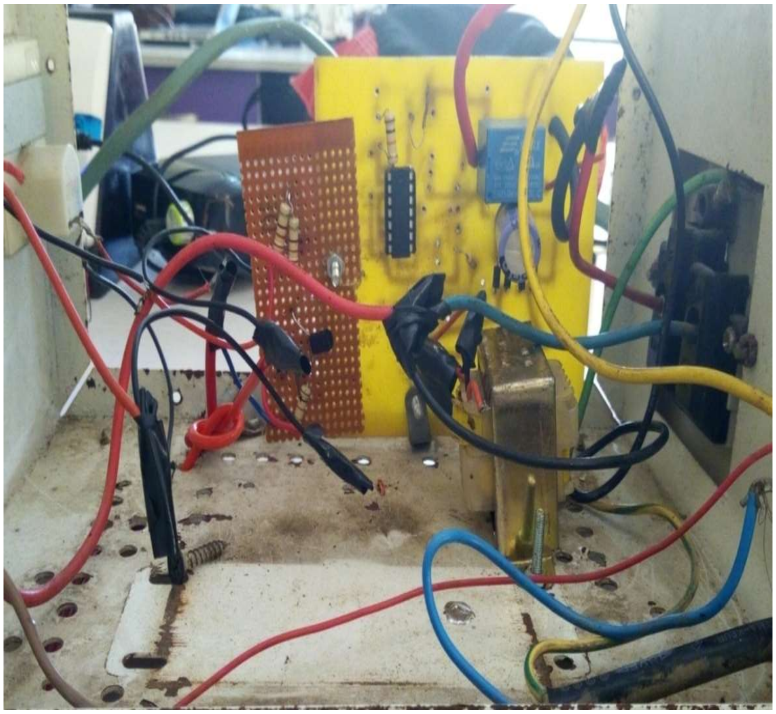

Figure 4: The Mounted components on the PCB

4.2 Prototype Setup

Figure 5 shows the setup for the implementation and testing. A testing lamp was plugged to it to indicate the ON/OFF state of the pump.

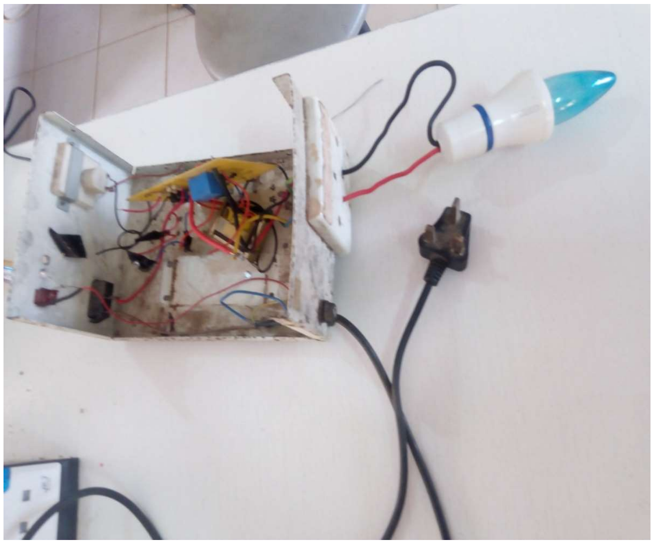

Figure 5: The Prototype setup with the testing lamp

4.3 The Sensors

The sensors are made of aluminum contactors which are sensible to current. One of the contactors is placed at base level of the tank and the other at the bream level of the tank. These sensors are activated by the power supplied to the control unit. When both sensors are in contact with water, there is exchange of ions between the constituents of the water which are hydrogen and oxygen ions and the contactors element, hence there will be flow of charges in the circuit which are passed to the IC and transfer to transistor, then the transistor gives a signal to the relay that there is a presence of excess current which is above the operating current of the pump, then the relay trip off from normally close to normally open.

Figure 6 shows the cost effective contactors used for the device.

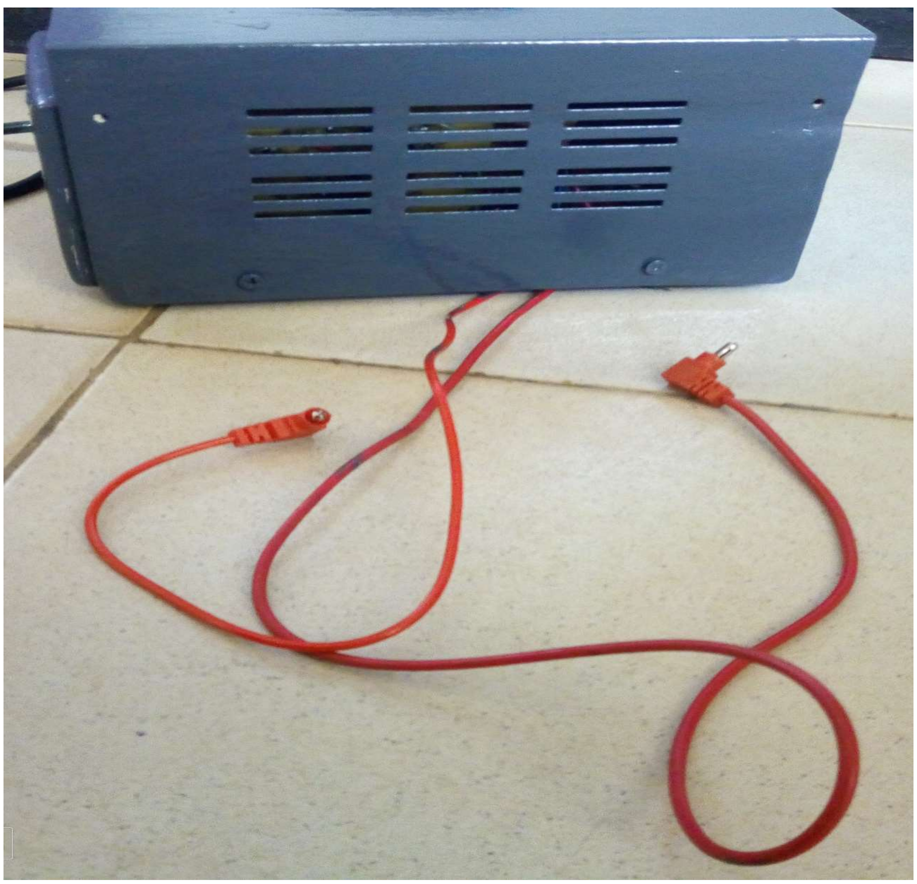

Figure 6: The Sensors

5. PERFORMANCE TEST

Figure 7 shows the testing stage of the work. This involves carrying out a prototype testing on the controller system by getting an empty bucket as the reservoir, a testing lamp as the ON/OFF state indicator of the pumping machine. The testing lamp was connected to the socket outlet of the controller, and the controller plugged to a supply mains, and the two metallic contactors were connected to the two output terminals and one dipped to the bottom level of the bucket and another at the bream level of the bucket.

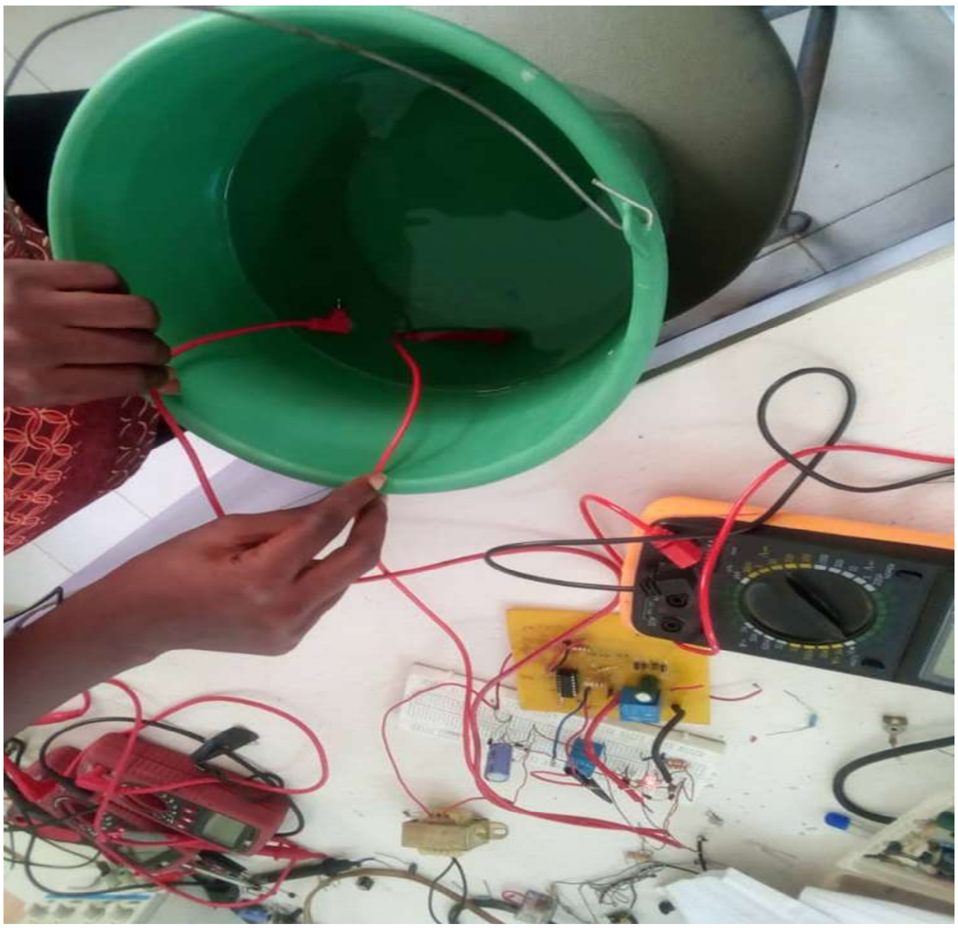

Figure 7: Performance Testing

5.1 Presentation of Results

When the controller was turned ON, the testing lamp turned ON indicating that the reservoir was ON and the bucket is empty. Water was poured inside the bucket until it got to the beam level where the other sensor was then the testing lamp turned OFF which the pumping machine is OFF because the water has gotten to the bream level hence water wastage due to overfilling problem solved. The results and discussions of the test are shown in Table 1.

Table 1: Result and Discussion of the Developed Controller

Power supply State	Lower Contactor	Upper Contactor	Pump state	Discussion
0	0	0	OFF	When there was no power supplied to the system, the pump will not start
1	0	0	ON	When there was power supply and there was no water in the reservoir, the pump turned ON
1	1	0	ON	When the water got to the lower level contactor, it still continued to pump water to the reservoir.
1	1	1	OFF	When the water got to the upper level contactor, the pump turned OFF.

6. CONTRIBUTION TO KNOWLEDGE

From the literature reviewed, there has been research and implementation undertaken with regards to water pumping automation, but there has been few implementation in the area of study (Ondo State, Nigeria), therefore, this work intends to solve the problem of monitoring of pumping process in the chosen area of study thereby affording new insights into little-understood phenomena of known facts that can alter the residents' perception of the world around him.

7. CONCLUSION

The aim of the work to provide an automatic control system for domestic pumping machine to oversee the water pumping process independently when there is power supply was met by the design of the controller circuit and its implementation through testing and getting a positive result. The Domestic water pumping machine automatic controller system will be a great device to have in places where pumping machine are used.

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