



Design and Implementation of Industrial Automatic Liquid Level Sensing and Control System

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ABSTRACT

Most homes, institutions and businesses in sub-Saharan Africa provide water for themselves as pipe-borne water from the public water supply system has become almost non-existent over the years. As a result, virtually every home, institution, and businesses rely on their water supply system popularly called 'bore-hole' fitted with water pumping machines which are either submersible or surface mount machines that extract groundwater and pump same into an overhead water storage tank from which water is delivered to users through a network of pipes. Because the water storage tank is usually overhead and difficult to access, one cannot tell when the water level/volume becomes too low to initiate pumping or when the tank is filled during pumping to avoid spillage which leads to loss of resources, and waste of energy. Thus, designing and constructing a system that continuously monitors the level/volume of water or any other liquid and automatically turns 'ON/ OFF' the water pump as a response to the measured level/volume without human intervention is imperative. This paper presents the design and construction of a Liquid level monitoring and control system that monitors the level of water in a tank, displays the various level via the LEDs on the display unit, and automatically cordons 'ON/OFF' an incorporated water pump whenever the level exceeds/drops below a predefined upper/lower threshold. The incorporation of an inhibitor switch, a feature that is absent in other designs, which enables switching between automatic/manual modes of operation makes this design a novelty.

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INTRODUCTION

Over the years, individuals, companies, site owners, and business owners have relied on the tried and trusted manual method of monitoring the volume/level of the liquid in their storage tanks. Usually, they dip a stick in the tank, read the measured volume/level and note the same. While this method may seem a safe way to monitor the liquid level in a tank, it is labour-intensive, cumbersome, unsafe as one needs to climb to be able to access the tank if it is an overhead tank, and prone to error because of the innate error in human judgement (Ajinkya and Milind, 2017; Priya and Sailusha, 2017)

More so, technology has advanced to an extent where there are more efficient, reliable and smart ways to undertake routine tasks. Rather than waste time and scarce resources monitoring the liquid level of a tank

being filled or knowing when to pump without exhausting the liquid content of the tank, say water, a simple technology solution can be implemented to better undertake that task. An automatic liquid-level monitoring and control system has more advantages over the tried and trusted manual system of employing a dipstick to determine the volume of liquid in a storage tank (Eiyike *et al*, 2018; Delgado *et al*, 2006; Ciubotaru *et al*, 2006). One salient advantage is in terms of precision over the manual method. This saves time, money, and eliminates the spillage of expensive liquid such as specialized chemicals/reagents, and petroleum products to mention but a few.

This work is geared towards implementing a practicable and cost-effective way of automating the process of pumping water from a bore-hole to fill an overhead storage tank as well as monitoring the various

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pre-defined levels via the LEDs of the incorporated display unit. Whenever the level of waterfalls below the lower threshold of the water level sensor of the designed system, a relay is energized; this relay turns 'ON' the water-pump and the overhead tank receives water until the water level exceeds the predefined upper threshold of the sensor in which case the relay is de-energized thus cutting off the power supply to the water-pump and automatically turning it 'OFF'. The designed automatic liquid-level monitoring and control system has an inhibitor switch that enables the user to switch to either automatic operation mode where automatic monitoring and control take place or manual operation mode where manual monitoring and control take place (Murthy, 2008; Jawarkar, 2008; Ejiofor and Oladipo, 2013). This is so done to enable a user(s) to be able to pump water manually in case the need to carry out maintenance on the automatic monitoring and control (mode) system arises.

REVIEW OF RELATED WORKS

Many researchers and authors have worked on designing and developing cost-effective automatic liquid monitoring and control system incorporating current technology for ease of operation and maintenance whilst retaining their high efficiency and reliability.

The authors (Ajinkya and Milind, 2017), proposed an automatic water level indicator and controller, a system that can indicate the level of water in an overhead whenever water is being pumped into the overhead tank using LEDs. They incorporated a system in the proposed design that cuts the power supply to the water pump whenever the upper pre-set threshold is reached to avoid waste of water. Thus, this design is only concerned with knowing the water level during pumping which is indicated on the LEDs and cutting power supply to when the overhead tank is filled. It does not automatically initiate pumping. In a water level monitoring system using the internet of things (IoT) (Priya and Sailusha, 2017), the authors designed a system where ultrasonic sensors placed over a water reservoir detect the level of the liquid and compare it with the reservoir depth. The status of the liquid level displayed on an LCD. The incorporated microcontroller, Wi-Fi modem and other components of the system work together

to send data to a buzzer which is with the user whenever the pre-set limits are exceeded. In this way, the user is informed about the liquid levels in the water reservoir and as a consequence takes the necessary action. The authors (Eiyike *et al*, 2018), proposed a GSM-Based water level monitoring system with Graphical User Interface (GUI) capabilities. The system focuses on the use of an automated method of water level detection, monitoring and control. In this system, an ultrasonic sensor senses the level of water in the storage tank and sends the information to a microcontroller. The microcontroller converts this information to digital data which is then transmitted using IOT technology to a GUI for control and monitoring from any remote area (Delgado, 2006; Ciubotaru *et al*, 2006; Murthy, 2008; Jawarkar *et al*, 2008). In (Ejiofor and Oladipo, 2013; Khaled Reza, *et al*, 2010), designed microcontroller-based automatic water level control system aims to automate the process of pumping water into an overhead tank storage system with the ability to detect the level of water in the tank and display the status on an LCD as well as turn ON/OFF the water pump accordingly.

In this paper, we present the design and construction of an automatic liquid level monitoring and control system. It is solely based on a float switch; it is simple and rugged compared to other designs. It incorporates an inhibitor switch, a feature that is absent in other designs, which enables the user to select the manual mode of operation if the automatic mode is to be maintained.

MATERIALS AND METHOD

The work is focused on designing and implementing an automatic liquid level monitoring and control system. The automatic liquid level monitoring and control system consists of the following units: power supply, automatic water level control, water level sensor, water level monitoring, water pump, and water storage units.

The overall design is broken into a functional block diagram where each block in the diagram represents a unit that performs a specific function. Also depicted in the block diagram is the flow of operation in the system as well as the interoperability of the various units.

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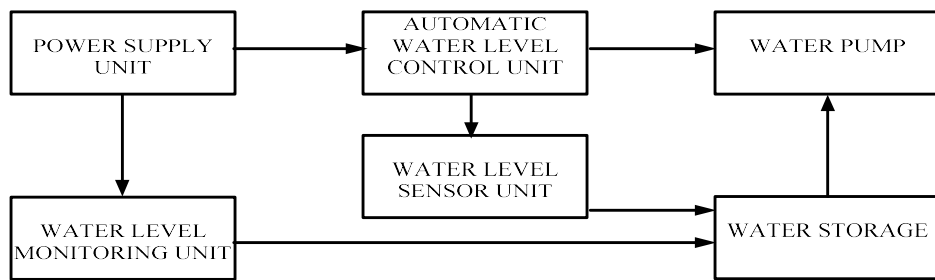


Figure 1: Functional block diagram of the water level monitoring and control system.

Power Supply Unit

Figures 2(a) and 2(b) below show the power supply circuit of the system. The power circuit for the monitoring and sensor units comprises four main parts- transformer,

rectifier, filter, and voltage regulator. It gives a constant 5V output to the sensor and monitoring circuits. While the power circuit for the control unit has four main components: switch, circuit breaker, contactor and thermal overload relay.

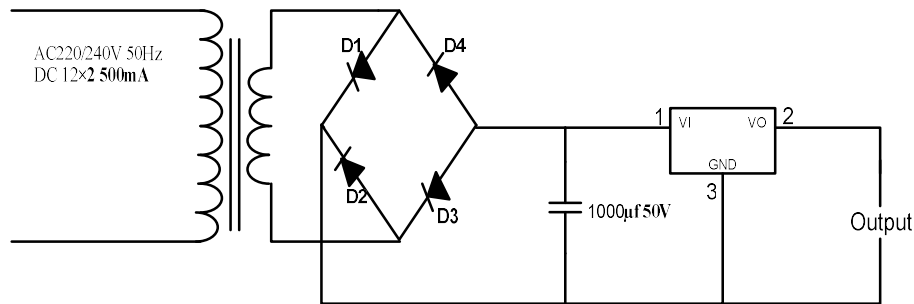


Figure 2(a): Power circuit for the monitoring circuit.

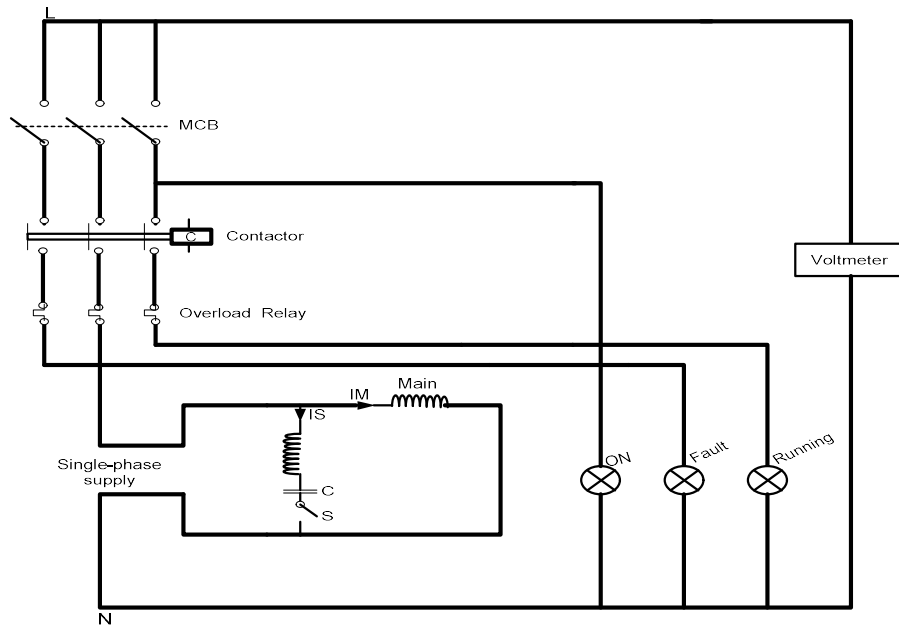


Figure 2(b): Power circuit for the control unit

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Control Unit

The control unit of this design consists of a motor contactor with normally open (NO) contacts namely the power and auxiliary contacts. One of the coil terminals, A1, of the contactor is connected to a water level sensor through an inhibitor switch which sends a signal

to the contactor for its automatic operation. The other terminal, A2, was connected to the neutral line.

The control circuit either turns ON the pump or turns it OFF depending on the output of the sensor.

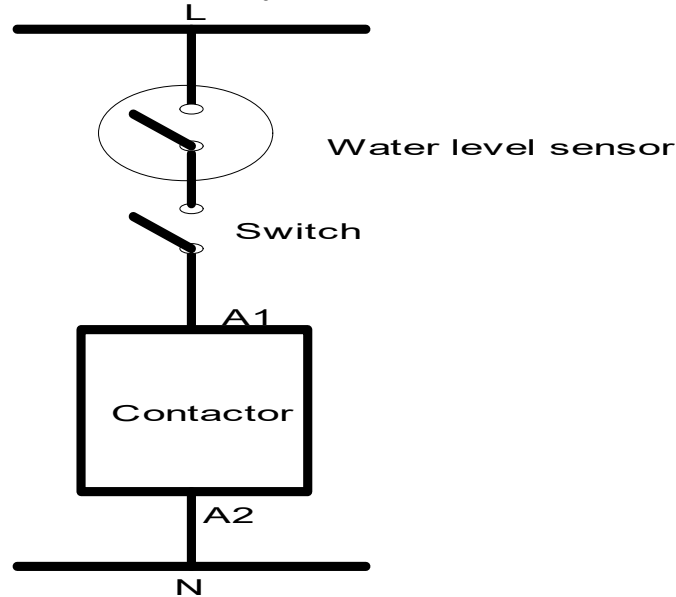


Figure 3: Control circuit of the control unit

Monitoring Unit

The monitoring unit is built from probes 3, 4, 5, and 6 respectively of a seven probes water level sensor- multi-point float

switch. Other components of the monitoring circuit are HCF 4066BE, a quad-bilateral switch, resistors, and LEDs

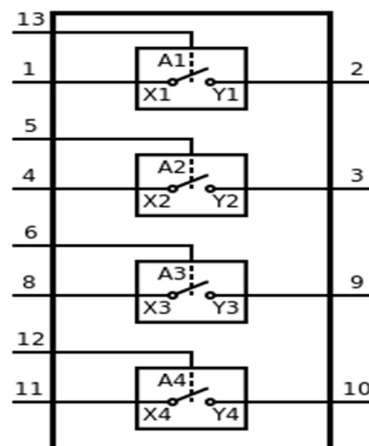


Figure 4: Functional diagram of HCF 4066BE

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The various input and output pins of the quad bilateral switch HCF 4066BE (switches A1-A4) were connected with resistors and LEDs to realize the water level monitoring unit. Successive LEDs are turned ON once the water level drops a little below a predetermined point on the sensor attached to their corresponding probes (Sensor probe). Thus when the tank is

filled i.e at the point at which power is cut OFF from the water pump, no LED comes up. But as the water is being used, at a level a little below the upper part of the sensor head, the 4th LED, green LED comes up. The same occurs for LEDs 3, 2, and 1. This way, the user can tell the approximate volume of water left in the overhead tank.

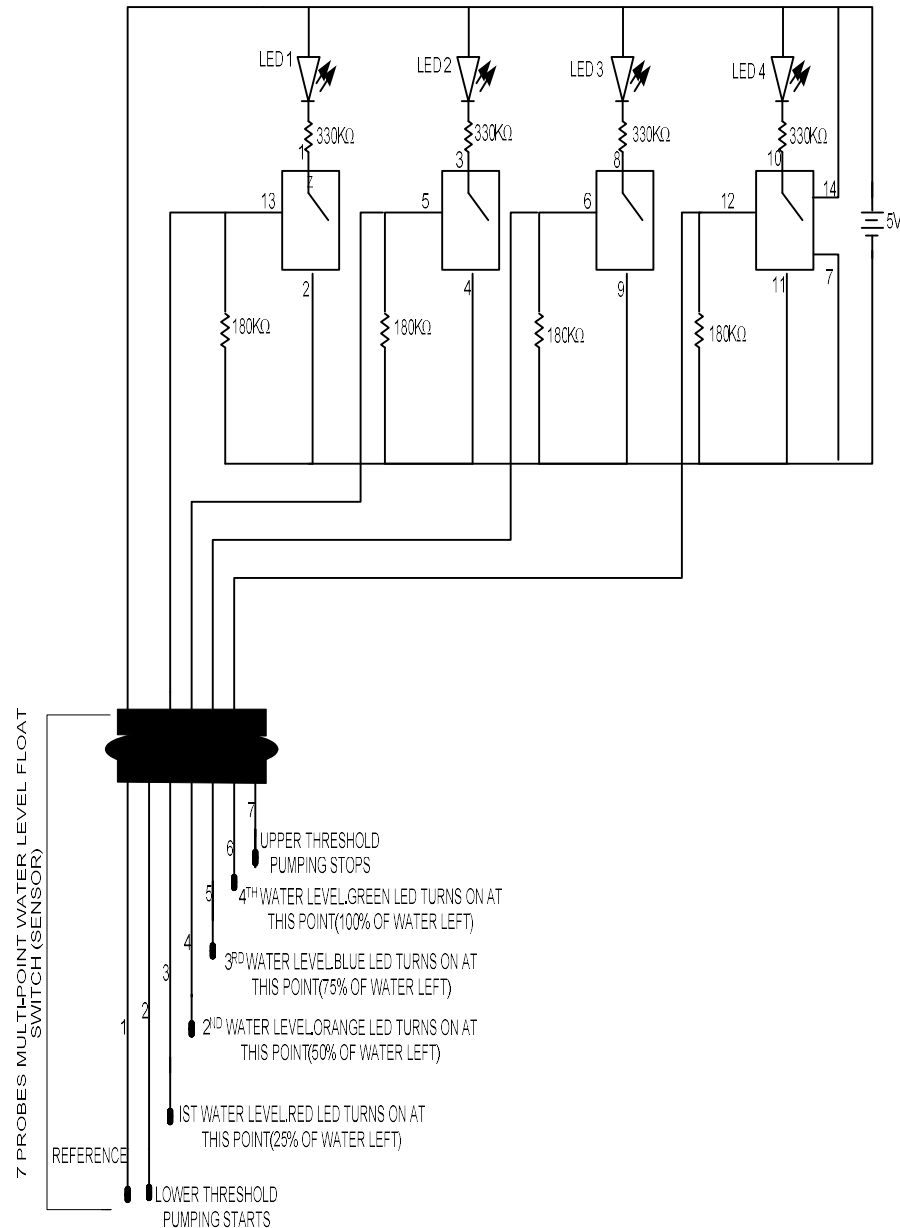


Figure 5: Circuit diagram of the monitoring unit

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The Water Level Sensor Unit

The water level sensor used in this work is a 7-Probes Multi-point float switch sensor whose probes were configured to carry out different commands. While probes 3, 4, 5 and 6 were configured to switch on the LEDs of the display unit, probes 2, and 7 were configured to turn ON the water pump and turn it OFF respectively. Probes 2 and 7 are the lower and the upper pre-set thresholds

respectively. Thus, when the water in the tank drops a little below the upper part of the sensor head of probe 2, the circuit is closed and the incorporated contactor switches ON the water pump and the tank starts getting filled. When the tank gets filled, and water gets a little above the sensor head of probe 7, the circuit is opened and the power supply to the water pump is cut OFF, this automatically stops the pumping process.

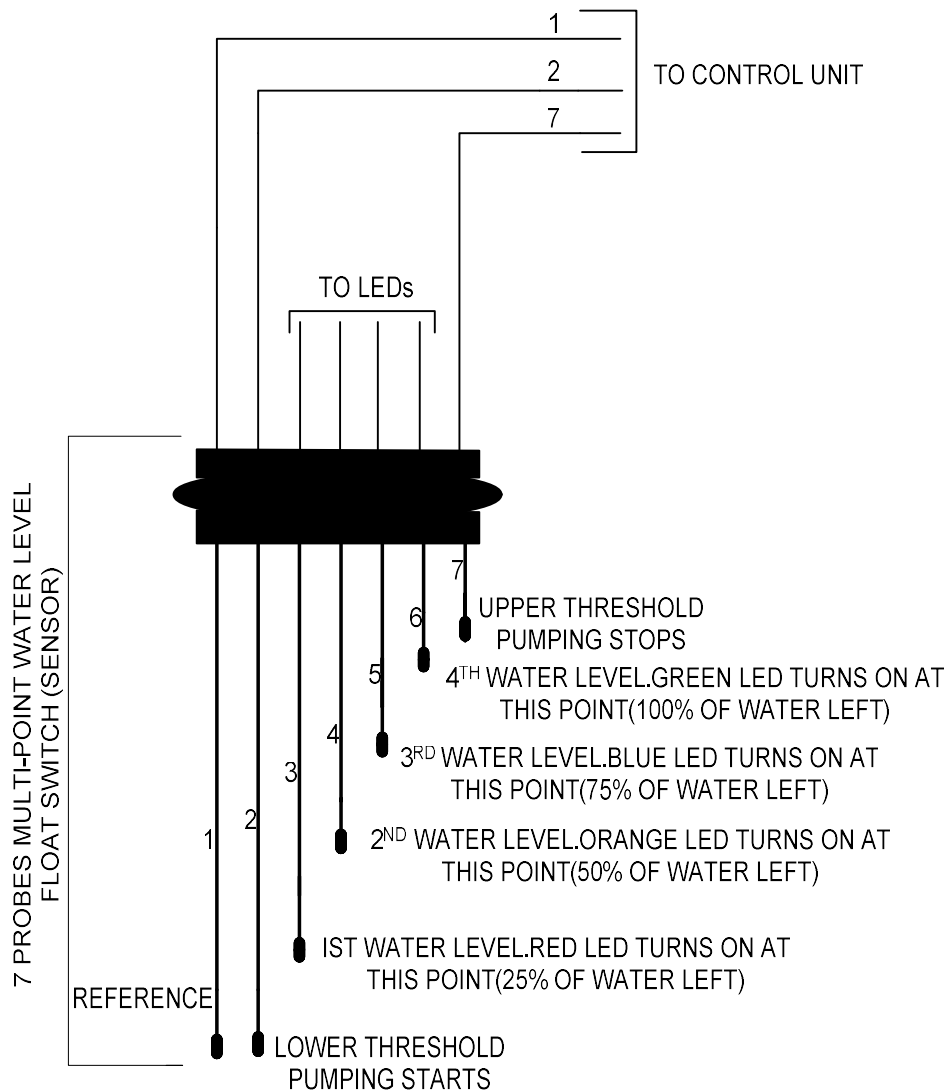


Figure 6: The sensor unit

Pump Unit.

The water pump used in this work is a single-phase, surface mount 220/50Hz, 400W water pump.

Flow Chart of the System

This is the operational flow chart of the designed system

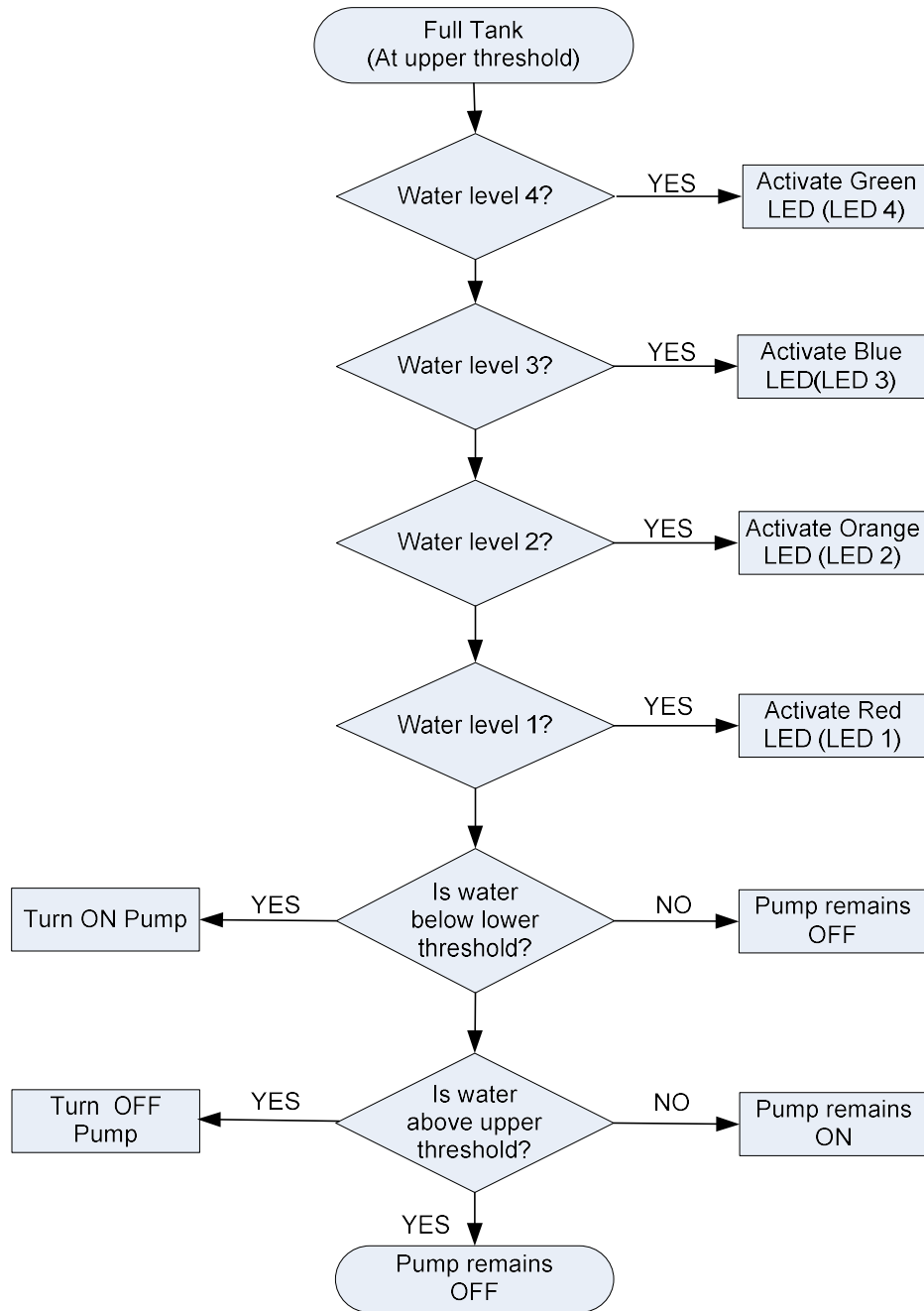


Figure 7: System's operational flow chart

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Mode of Operations

The automatic liquid level monitoring and control was designed and implemented to continuously measure the level of water in the storage, start the water when the water drops below a predefined threshold as well as stop the water pump when water gets to an upper threshold as the tank is being filled. The different sensor probes of the multi-point float switch, the heart of this design, carry out different function. Sensor-probes 3, 4, 5, and 6 indicate the level of water through the different LEDs of the display unit, while Sensor-probes 2, and 7 automatically start and stop pumping operation. The first Sensor-probe is a reference probe.

When the tank is filled and the system is automatically turned OFF, no LED is activated but as the water is being used, the 4th LED which is green is activated the moment the water level drops a little below the upper part of the sensor head of probe 6. This indicates that 100% of the water content of the tank is present. The next water level is the third water level which is 75% of water content and indicated by the 3rd and blue LED when water drops a little below the top of the sensor head of probe 5. As the water is depleted, the next water level, the second water level is reached. The 2nd and orange LED is activated when water drops a little below the top of the sensor head of probe 4. This level indicates that 50% of water is remaining in the tank. As the water is used continuously, the next water level, the 1st water level is reached. As in other cases, when the water drops a little below the top of the sensor head of probe 3, the 1st and red LED is activated. This indicates that 25% of water is left.

Pumping starts automatically when the water in the tank falls below the lower threshold indicated by the top of the sensor head of sensor-probe 2. When water drops below the sensor head of probe 2, the signal is sent to the coil of the contactor; this energizes the contactor and the normally open contacts of the contactor become closed. This sends power to the water pump and it is turned ON. As the tank is being filled up, the water level rises until it reaches the upper threshold. When the water level gets to the upper threshold which is indicated by the top of the sensor head of probe 7, the sensor sends a signal to the coil of the contactor by de-energizing it; as a result, the contact that was once closed becomes open

again thereby cutting supply to the water pump and turning it OFF. The whole process is repeated automatically. In this work, an overload relay is mounted at the output of the contactor to protect the water pump from damages that may result from overloading, short-circuit, and low or high voltage among other conditions.

RESULTS

Various tests were carried out on the different units of the designed system before assembly, the power circuit, the control unit, the monitoring unit and the sensor unit, they all functioned maximally. During the tests, the control circuit was set to turn the water pump ON at 10% calibration which is the lower pre-set threshold and OFF at 110% calibration which is the upper pre-set threshold.

CONCLUSION

This work has achieved its objectives and provides a system that continuously monitors the water level in a storage tank and reports the level at the monitoring unit via the appropriate LED. It was designed with the capability to detect an abysmally low level (10%) of the water in the tank and as a result automatically turns ON the pump which works to fill the tank with water, as well as to detect an excessively high level (110%) of the water in the tank and turn OFF the pump. The system was also designed to display the status of the water level at the monitoring unit via the appropriate LED. The series of tests conducted before and after assembling the various units to form the designed system revealed that the system was functioning well and according to design objectives. The designed system can be deployed in public places, homes, institutions and business outfits for proper water management.

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