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Design of Tank Water Level Control System for Automatic Sprinkler Irrigation

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ABSTRACT

Design of tank water level control system for automatic sprinkler irrigation was carried out to monitor water level in the tank and to control the pumping process. The system was designed such that when the water in tank is below minimum, the pump will automatically activate and refill the tank and also sprinkle the water within the giving interval of time. The Water Level Control System using non-contact Sensor was designed and constructed around microcontroller (ATmega16A) utilizing non-contact water level sensor called ultrasonic sensor (HC-SR04). The performance of the constructed system was evaluated. Result showed that mean experimented volume of water level in the tank and actual volume of water level in the tank were 8.0 and 8.11 litres, which had correlation coefficient value of 0.90. The automatic sprinkler reveals that, the initial delay from the system was 90 seconds before the sprinkler activate and sprinkle water for 10 seconds. This indicate that there was higher time delay at the initial time while the sprinkler continue to activate and sprinkle the water for every 10 seconds interval with system delayed at 25 seconds interval, respectively. The efficiency of the system designed was 98.4%which showed that the automatic sprinkler irrigation system can be used by farmers to monitor water level in the tank and control the pumping process to enhance efficient use of irrigation water to increase crop yield.

Keyword: *tank, water level, automatic, control, sprinkler, irrigation*

INTRODUCTION

Irrigation systems mostly employed are controlled by human beings and humans are inconsistent, inefficient and are characterized by forgetfulness. Their inability to offer effective control results in unnecessary wastage of water and over sprinkling of water. There is also high tendency of irrigation system failure or damage due to overworking. The task of replacing irrigation system is capital intensive. The needed solution therefore is to fully automate the sprinkler irrigation processes. Automatic Sprinkler Irrigation system is an automatic control system capable of controlling the water pump to sprinkle water at a given interval. The components of the sprinkler consist of sensors, controllers and actuators which serves as motor or water pump. According to Govinda, (2014) automatic control system is among the various techniques used in monitoring and controlling of liquid levels in industrial and domestic applications. He stated that float ball type liquid level control, a popular method of control was still used in practice for normal applications such as overhead tank overflow restrictors. Also, electrical methods of control which include microcontroller-based circuits automatically measure the liquid levels and accordingly activate the circuit to operate motors or pumps.

In the last few decades, many researchers have emerged with several liquid level control systems with varying designs. Ansarifar *et al.*, (2012) and Joseph (2013), worked on the construction of automatic water Level controller for both Overhead and Underground Tanks. The designers use water level indicator which indicates low and high levels in a tank. They stated that level of any conductive non corrosive liquids can be measured using a switching ability of a transistor. The measuring circuit they observed was based on five transistor switches; each transistor switched on to drive the corresponding LED, when its base was supplied with current through the water and the electrode probes. One electrode probe with 6V AC was placed at the bottom of tank and the next probes were placed step by step above the bottom probe. When water was rising, the base of each transistor got electrical connection to 6V AC through water and the corresponding probe, which in turn made the transistors conduct to glow LED and indicated the level of water. The ends of probes were connected to corresponding base of a transistor. The probes were arranged in order on a PVC pipe according to the depth in the tank. AC voltage was used to prevent electrolysis at the probes.

Rahayu, (2009) worked on the Microcontroller Based Automated Water Level Sensing and Controlling. He observed that in the implementation of the systems he introduced the notion of water level monitoring and management within the context of electrical conductivity of the water and utilizing AC supply to prevent electrolysis at the probes. RiaSood and Hement, (2013) designed and developed low cost automatic water level control aimed at monitoring water flow into a reservoir and sprinkling of water to the farm land. Also Osama et al., (2012) worked on water level sensing using programmable logic controller utilizing inductive proximity sensors and motor to pump water into the water tank. Venkata, (2013)stated that using materials such as humidity sensor, comparator, and temperature sensor, microcontroller and sprinkler system a micro controller based automatic plant irrigation system could be developed. The system is an irrigation system based on overhead sprinklers, sprays or guns, installed on permanent risers. The system can be buried underground and the sprinklers rise up when water pressure rises, which is a popular irrigation system for use on golf courses and parks. The system provides several benefits and can operate with less manpower. The system supplies water only when the humidity in the soil goes below the reference. Due to the direct transfer of water to the roots, water conservation akes place which helps to maintain the moisture to soil ratio at the root zone depth. Thus, the aim of this work is to design and construct water level control system using non-contact sensor which will be used in sprinkler irrigation to improve irrigation water application on the farm to increase crop production.

MATERIALS AND METHODS

Materials Used

Ultrasonic sensor, Microcontroller, Transformer, Bridge rectifier, Copper board, Transistor, Diodes, Capacitors, IC Regulators, Relay (EMR), Liquid Crystal Display (LCD), Resistors, LCD Cable, Switch, 40 Pins IC socket, Screws, DC Water pump, Horse pipe and clips, sprinkler Head, Plastic tank and Casing

DESIGN METHODS

System description

The design of the automatic water level control system consists of six functional blocks as illustrated in figure 1. The control units form the heartbeat of the system. It obtains the actual volume of water in the tank via the sensor unit and compares it against presets volume. The control unit activates the pump via the driver unit if the actual volume of water in the tank was below the minimum required so as to refill the tank. The water pump was deactivated when the actual volume reached the maximum. At all times, the control unit feeds back the user via the display unit, with the actual volume of water in the tank. The power supply unit provided the necessary power for the system to function.

The design of the system was splited into two phases: the hardware and the software phases, respectively.

Hardware design

The hardware design entails the design of each building block and interconnecting them thereafter to form the whole unit as shown in figure 1 below.

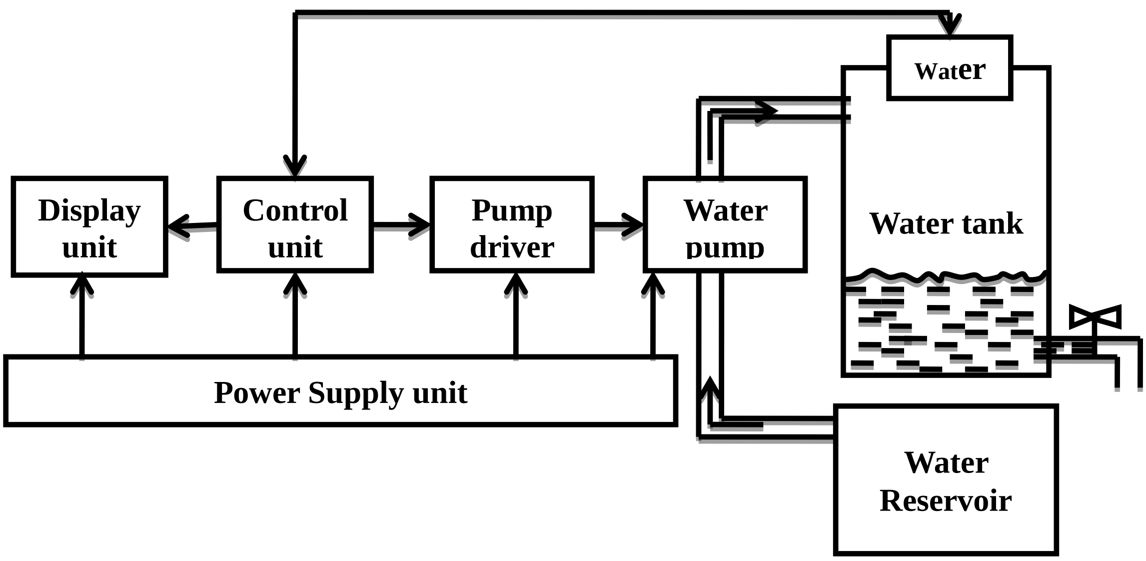

Figure 1: Functional block diagram of the automatic water level control system

Power supply unit

The power requirements of the system were as follows:

12V, 5A dc for water pump

12V, 1A dc for pump driver

5V, 1A dc for control unit, display unit and sensor unit

These requirements were met with the help of step down transformer and voltage regulators as shown in figure 2.

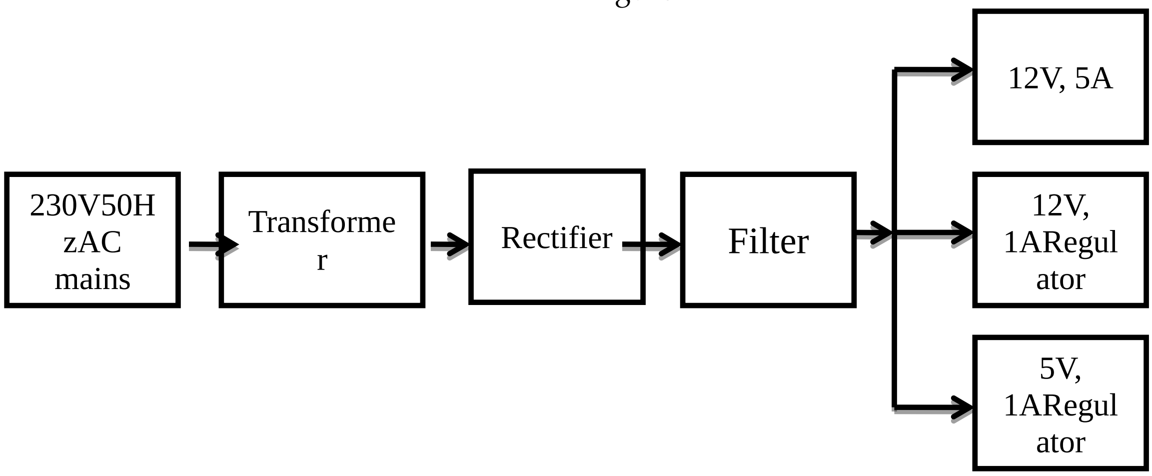

Figure: 2: Block diagram of step down transformer and voltage regulator

Step-Down Transformer

The transformer was designed using E and I laminated core obtained from scrapped UPS. The turns per volts of the transformer in line with (Ejiofor, and Oladipo, 2013) was determined from;

$$\frac{N}{V} = \frac{1}{4kfBA} \quad (1)$$

Where;

K= form factor = 1.11

f = frequency = 50Hz

B = flux density = 1.15 x 10^{-4}wb/cm^2

N = Number of turns

V = Required voltage

A = Core area = 13.76cm^2

Thus to obtain the number of turns, equation 1was modified as:

$$N = \frac{V}{4KfBA}$$

For a primary voltage of 230V, the primary number of turns was determined as:

$$N_p = \frac{230 \times 10000}{4 \times 1.11 \times 50 \times 1.15 \times 13.76} \cong 665 \, turns$$

For a secondary voltage of 12V, the secondary number of turns was determined as,

$$N_s = \frac{12 \times 10000}{4 \times 1.11 \times 50 \times 1.15 \times 13.76} \cong 34 \, turns$$

To meet up a total secondary current of 7A, wire gauges were used for the secondary and primary coils, respectively.

IC Regulators

IC regulators 7805 and 7812 were used for regulation purpose. These regulators deliver constant 12V and

5V at 1A to the circuit as shown in figure 3

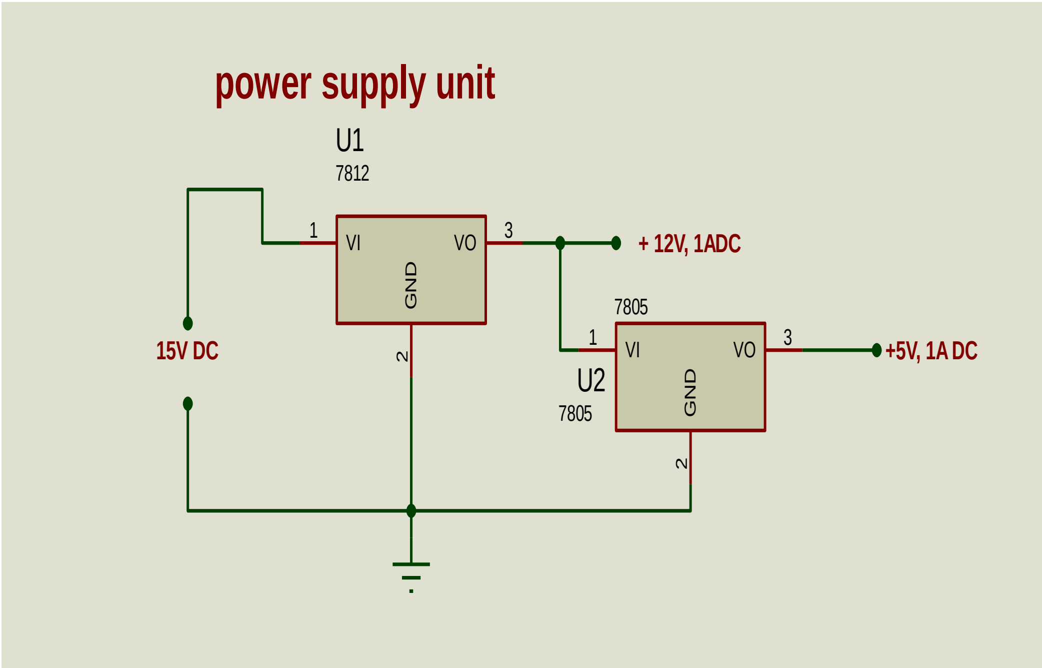

Figure3: Complete circuit diagram of power supply unit

DC Water Pump

This unit consisted of a DC water pump with the following ratings: Voltage 12V DC at 5A and power of 60watts. It was used as the main load of the system and it obtained power from the power supply via the relay as shown in figure 4.

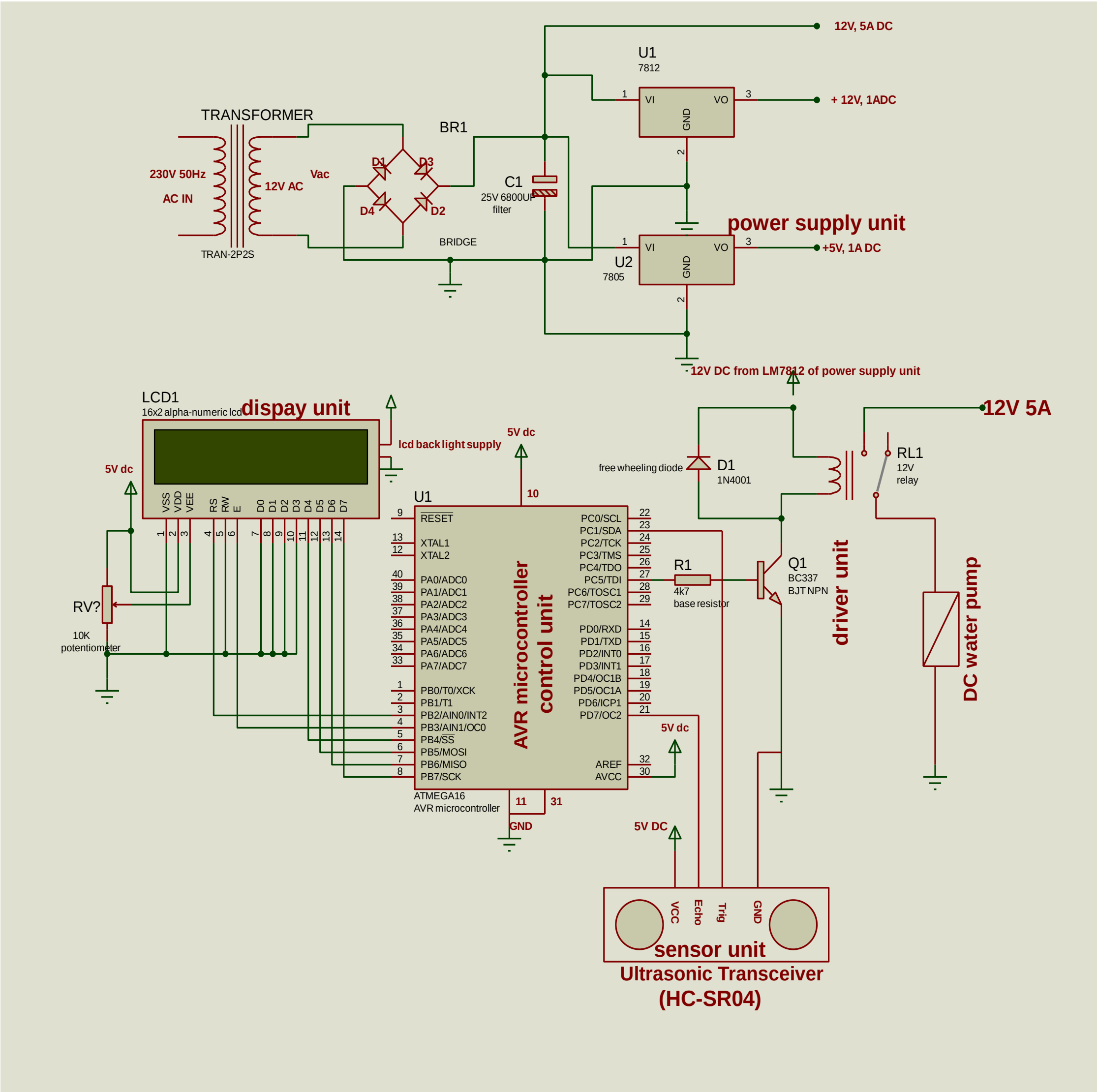

Figure 4: Complete functional circuit diagram of the system

System Software Design

The software design was tested with ultrasonic module by writing a control program in C-language which enabled the sensor sense water level. Ultrasonic burst was sent for at least 10 microseconds and the values were read of the echo in the timer/counter register of the microcontroller (TCNTH:L). Also, the overall program which included the display control program and relay switching control was added to the program as summarized in the flowchart shown in figure 5. The program was written and compiled in microprobe compiler version 3.3.

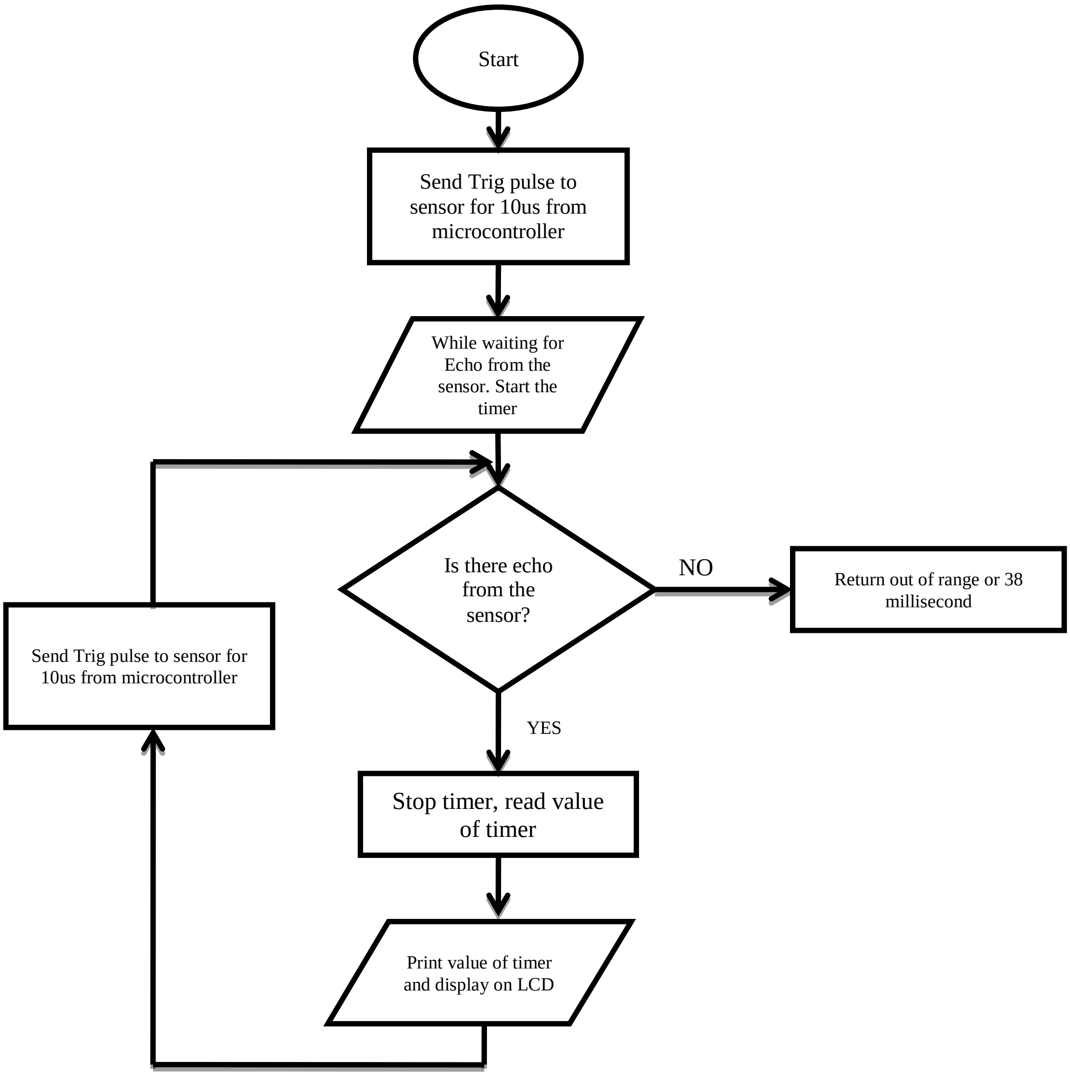

Figure5: Software design flowchart for sensor testing

Construction and Application

The construction started with the production of the circuit PCB layout. This was achieved using proteus ARES software. The layout was printed on a glossy paper and was transferred to plane copper board. This was achieved by placing the printed layout on the copper board. An electric iron was used to transfer the layout by heating. After transfer, the board was soaked in water to remove the glossy paper leaving the track of the layout on the board. The board was placed inside the solution of ferric chloride with warm water to remove copper or etch the part of the board that was uncovered with the track layout. After etching, holes were drilled to allow components terminals to pass through using hand drilling machine in the laboratory.

The Sensor and the Water Tank

A frustum was chosen as the water tank with the following parameters: base diameter, top diameter and height of the tank as 26.8, 29.7and 31.5cm, respectively. The ultrasonic sensor was mounted on top of the water tank, because it was meant to measure water level vertically as illustrated in figure.6 below.

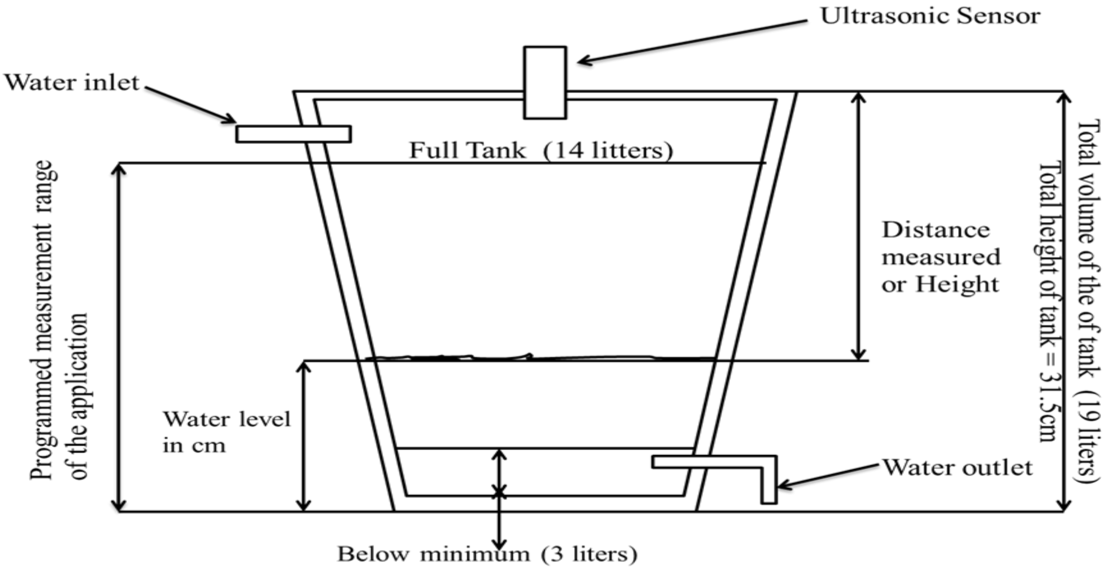

Figure 6: The Sensor and Water tank

Equation (3) was used to obtain the water level in the tank.

$$Water\ Level\ (cm) = Total\ Tank\ Height - Distance\ measured\ (cm) \quad (3)$$

The volume of water in the tank was determined using the experimental relationship obtained as;

$$Volume\ (litre) = 0.64 \times water\ level(cm) + 0.013 \quad (4)$$

The tank was calibrated such that when volume of water is 3 litres the tank is below minimum, and when the volume of water is 14 litres the tank is full. This calibration was incorporated in the system control program to achieve automatic control.

System of Operation Layout

The system design and principle of operation was achieved by the connections of the various components of the system. The layout and connection is as shown in figure 7below.

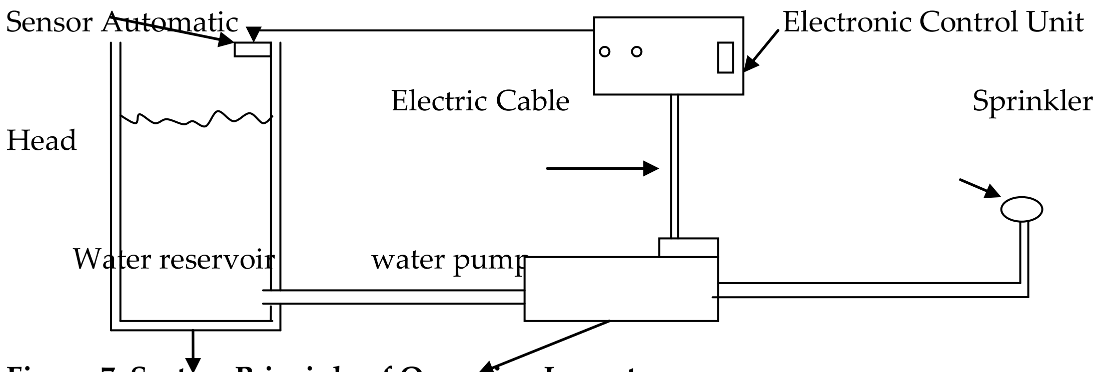

Figure 7: System Principle of Operation Layout

RESULTS AND DISCUSSION

Tank Water Level Control System

Table 1 showed the values of actual and experimented volumes of water level in tank control system. Table 1 reveals that there was little variation in volume of water in the tank throughout the process.Mean value of 8.00 and 8.11 litres were recorded for the actual and experimental volumes of water in the tank. This suggested that the higher the water in the tank, the more volume of water detected by the control system and LCD displayed the information operation process of the system. Figure 8 showed the relationship between the actual and the experimental water level measurement in the Tank. Figure 8, indicate that actual volume of water in the tank increased with increase in experimental volume of water in the tank which showed a linear relationship with correlation coefficient (r^2) value of 0.90. This value obtained is in line with Ejiofor and Oladipo, (2013).Efficiency of the system was the ratio of output (experimentalvolume of water in the tank) to the input (actual volume of water in the tank) of the system which had value of 98.4%. This shows that the system has a higher performance. Statistically using student's t-test, it was observed that there was no significant difference between the actual and the experimental volumes of water level in the control system at 5% level of significant.

Table1: Volume of Water in the Tank for Water Level Control System

Actual Volume (Litres)	Experimental Volume (Litres)	Difference in Volume (Litres)
1.00	1.10	0.1
2.00	2.10	0.1
3.00	3.20	0.2
4.00	4.20	0.2
5.00	5.20	0.2
6.00	6.20	0.2

7.00	7.10	0.1
8.00	8.10	0.1
9.00	9.00	0.0
10.00	10.00	0.0
11.00	11.10	0.1
12.00	12.10	0.1
13.00	13.20	0.2
14.00	14.10	0.1
15.00	15.00	0.0
Mean 8.00	**8.11**	**0.11**

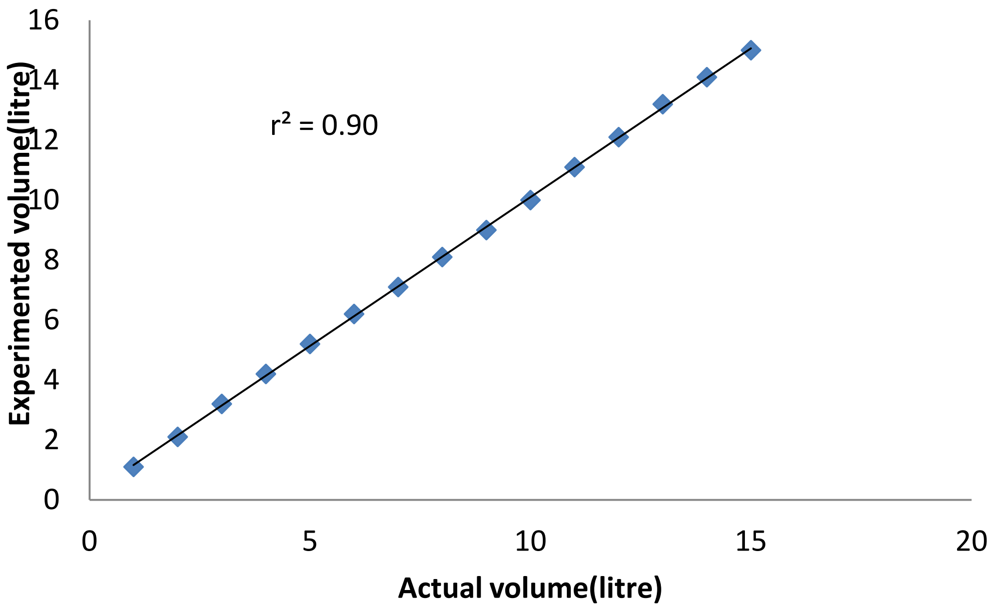

Figure 7 Relationship between the actual and the experimental water level in the tank.

Automatic Sprinkler Irrigation

Table 2 shows the effect of the water level in the control tank on the Sprinkler Irrigation system. It was revealed that the initial delay from the system was 90 seconds before the sprinkler started to activate and sprinkled water for 10 seconds. This indicate that there was higher time delay at the initial time, but as the sprinkler continued to activate the delayed reduced to 25 seconds and the sprinklersprinkled water for every 10 seconds interval for the subsequent delay. However mean delay values of 46.7 seconds was recorded to activate the sprinkler before it sprinkled water for 10 seconds in the system, which was in line with earlier study by Kotaiah et, al., (2013).

Table 2:Effect of the water level in the control on the Sprinkler Irrigation system

S/N	DelayedTime (seconds)	SprinklingTime (seconds)
1	90	10
2	25	10
3	25	10
Mean	**46.7**	**10**

CONCLUSIONS

Automatic tank water level control system was designed and constructed to automate the process of water pumping in an overhead tank-storage system. The relationship between the actual volume of water level and the experimental volume of water level in the tank was linear with correlation coefficient value of 0.90 and had an efficiency of 98.4% which implies that the automatic tank water level control system designed can be used as automatic sprinkler irrigation system that can be used by farmers to irrigate their crops and monitor the water level in the system and control the pumping process for efficient water use in the field to result in more crop production.

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