Automation of Water Pump Station of Kurutie Community using Programmable Logic Controller (PLC)

Isaac C. Febaide[1], Akpofure A. Enughwure[2]

[1]*Lecturer, Nigeria Maritime University, Okerenkoko, Delta State, Nigeria*
[2]*Lecturer, Nigeria Maritime University, Okerenkoko, Delta State, Nigeria*

Abstract - *Pump stations are very important facilities for transporting water from one place to another and the need for the automation of this pump station has given rise to different ways of automating a pump station. With the speed of changing technology today it is pertinent that the control of processes in the pump station is done with little or no human supervision, hence, the use of PLC to automate the pump station at kurutie community is employed. The system comprised of two unit: the hardware and software unit. The hardware unit consist of Mitsubishi Fxis-20mi-001 switch mode power supply, micrologix 1000 PLC, six OMRON MYAN-1 relays, 10 pilot lights and a float level sensor. The software codes were written in Ladder Logic using RsLogix1500 and RsLinx drivers to establish communication. On full implementation and interfacing of hardware and software units, the indicator board showed that the program in the PLC memory was running as programmed and each states of the pumps, valves and sensors were displayed on it.*

Key Words: PLC, Automation, Valve, Ladder logic, Sensor, pump

1. INTRODUCTION

Almost Seventy-five percent (75%) of the earth is made up of water; however over ninety percent of the water is salty water especially for lowly places like Kurutie community in Warri-South West Local Government Area in the Niger-Delta region of Nigeria. Kurutie community is a small island with an estimated population of about 5500 persons which is the temporal campus of Nigeria Maritime University is posed with the challenge of access to clean and quality water. The access to water and proper water distribution are key indicators when measuring a country's performance in achieving the United Nations Sustainable Development Goals.

The current water system in kurutie community is made up of rectangular shaped overhead steel tank with a storage capacity of about 5200 litres. The pumping machine pumps water from the ground which has a high salt content is sent to the purification system where it is cleansed. After this purification process, the water is sent to the distribution tank where it is distributed to various access points in the community.

The current water system has several flaws in its operation and performance. Firstly, most times, the pumping machine is overworked especially where the water in the distribution tanks overflow and secondly, there are occasions where the villagers don't get access to water because the operators do not turn on the pumping machine at the pump station at the appropriate time. The sustainable and efficient use of water is of vital importance, and the uneven distribution of water in the community demands a modification to the current water system in the community.

Given the nature of these flaws, the dear need to implement an automated water system using programmable logic circuit that will monitor the water levels in the distribution tanks thereby managing the water usage in the current water set-up in kurutie community motivated this research.

1.1 Literature Review

The use of programmable logic control otherwise referred to as PLC has been in existence from as far back as the 1960s and has proven to be a very valuable control system. PLC is applicable to a variety of purposes and has a wide usage ranging from heavy industrial activities to even temperature control.

Bayindir and Centiceviz [1] conducted an experimental setup in an industrial plant on how PLC can be used in a water pumping control system. PLCs are usually a main part of automatic control systems in industries. They are used to internally store instructions used to implement control functions such as logic, sequencing, timing, counting and arithmetic. They control various types of machines and processes through digital or input/output modules. They are also used to control plants or equipment in industries such as telecommunications, water and waste control, energy, oil and gas refining and transportation with the help of wireless connections.

Similarly, Su, Luo, Feng and Liu [2] describe the application of Siemens PLC in thermal simulator control system. They show how the thermal simulator control system is built by Siemens S7-400PLC and V90 PN servo system to complete various closed-loop control tasks. The PLC is used as the main controller and controls the flow of oil, which in turn controls the position of the hydraulic cylinder.

Tsagaris [3] considers PLC as an integral tool for the control of automated storage systems. He acknowledges that PLCs are better used than the traditional industrial control system where all control devices are wired directly to each other, depending on their operation guidelines. Whereas, in a PLC based system, the PLC replaces the wiring between the devices and instead of them being wired directly to each other, all equipment are directly wired to the PLC. The soft-wiring advantage provided by programmable controllers is of a great deal and stresses the importance of the PLCs themselves.

In his research, Suresh [4] presents a series of laboratory experiments to allow students to learn and test their understanding of PLC and ladder logic programming. Using practical applications of PLCs in various industries such as electronics, automotive, power and oil and gas, he is able to expand the understanding of students even those with no prior knowledge of PLCs.

In addition, Alphonsus and Abdullah [5] carried out an extensive review on the applications of PLCs. This review gives a detailed overview of the evolution of PLCs, its application in various industries, advantages and even limitations. In comparison with PCs, which are also capable of handling programming functions and more, the weaknesses of PLCs tend to be glaring. PCs are more readily available for purchase than PLCs.

In order to meet the growing demand for water in urbanized settings, Yuan et al [2] examine the role of proper instrumentation, control and automation (ICA) to meet up with the urban water system. The focus on ICA in relation to the urban water system has recorded substantial benefits such as improved performance, reduced operational costs and increased capacity of the water plants.

Clearly, with advancements in technological industries the need for automated and control systems are very critical for various industries like water pump stations to ensure advanced ways of achieving results faster and more effectively.

1.2 Methodology

The system design approach is in two phase; the hardware and software approach.

1.2.1 Hardware Unit

The hardware comprises of the following,

- Power supply unit
- Control unit
- Sensing unit
- Switching unit
- Indicator unit

Fig 1 shows the block diagram of the hardware unit.

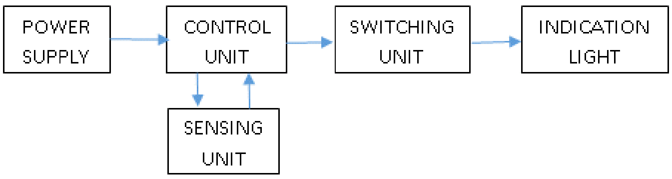

Fig.3: Block Diagram of the Hardware Unit.

The Power Supply Unit

The power supply unit consist of a Mitsubishi FX1s-20MT-001 Switch Mode Power Supply (SMPS), it is an electronic device that converts an AC voltage into a DC voltage which the PLC uses; making use of rectification circuit and step down transformer. The specification of the SMPS that we used is:
Model: Mitsubishi FX1s-20MT-001, Voltage: 85-264VAC, Input Voltage: 230VAC, Output Voltage: 24VDC.

The power supply is tapped from the mains 230VAC into the SMPS which converts it to 24V DC owing to the fact that the PLC can only be powered with 24V DC.

The Control Unit

The control unit is made up of the Allen Bradley MicroLogix 1000 Programmable Logic Controller. The PLC receives inputs from the sensors and sends output signals to carry out different operations. The specification of the PLC used is; Model: Allen Bradley MicroLogix 1000, Input Voltage: 24VDC, Output Voltage: 5V, No. of Input: 14, No. of Output: 10. The input signals are discrete that is ON and OFF. Power supply through the switches is 24V DC. Each input channel has an inbuilt opto-coupler that converts the 24V DC to 5V. The relay connections are also tied to the labels. The PLC inputs and outputs are tied with sink connection.

The Switching Unit

The switching unit is made up of six OMRON MY4N-J relays, four of them are powered with 24VDC and have current ratings of 5A, while the other two are powered by 230VAC and have current ratings of 10A. The relays used are the double pole double throw type. These relays send output signals to the pumps, valves and the indicating unit. The specifications of the relays are;

RELAY 1: Model: OMRON MY4N-J, Voltage: 24VDC, Current: 5A.

RELAY 2: Model: OMRON MY4N-J, Voltage: 230VAC, Current: 10A.

Indicating Unit:

The indicating unit comprises of 10 pilot lights which indicates the states of the pumps and valves, i.e if they are switched ON or switched OFF. Below is the specification of the pilot light used; Model: AD16-22DS, Voltage: 220VAC, Current: 20mA.

Sensing Unit:

The sensing unit comprises of a float switch that is used to detect the level of water in the tank. It has the following specification: Model: T80 Voltage: 250VAC Current: 15(8) A.

1.2.2 Software Unit

Codes were written in Ladder Logic using RSLogix1500 software while RSLinx is a driver software which was used to establish communication between the PLC and the PC. When the programs were downloaded into the PLC, it was monitored in the Diagram Workspace during execution. The RSLogix provide easy user interface to download the program, to upload the program, and to go back at online mode to see program desirable state. The program was written with the RSLogix using the Ladder Logic programming language. After the program was written and tested, it was downloaded into the PLC memory. Figure 2 shows the flow chart of the software algorithm.

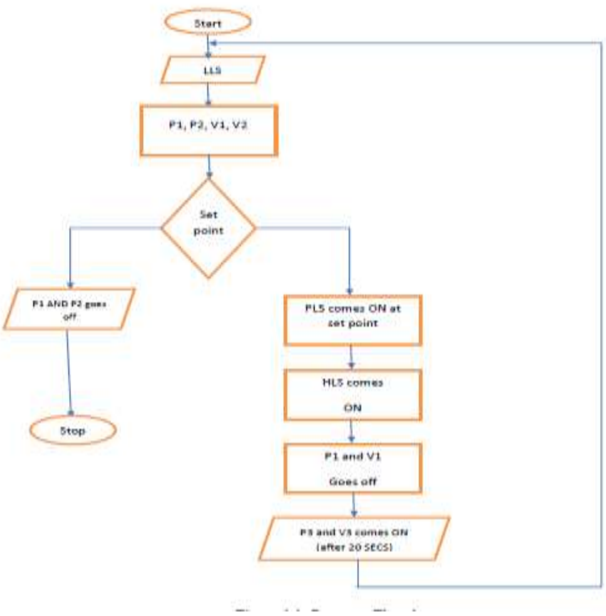

Fig.2: Software flow chart

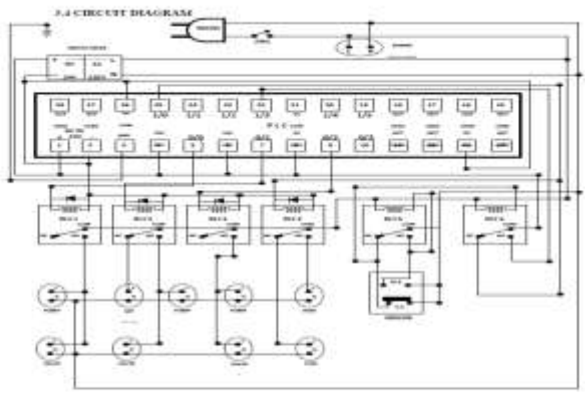

Fig. 3: System Circuit diagram

1.2.3 Mode of Operation

When the mains plug is connected to 220 VAC and switch SW1 closed, power indicator comes on implying that there is current flow in the circuit. The 220 VAC is fed to the input of the switch mode power supply (SMPS) unit, and the output of the SMPS which is 24 VDC is fed to the input of the Programmable Logic Controller (PLC) PIN 1 and PIN2. The positive output of the PLC is also fed to PIN 4, PIN 6 and PIN 8 of the PLC and also to the common of relay RLY 6. The negative output of the power supply is also fed to PIN 13 and PIN 26 of the PLC and also to one terminal of the coil of relay RLY 1, RLY 2, RLY 3 and RLY 4. The live of the 220 VAC is connected to the common of relay RLY 1, RLY 2, RLY 3 and RLY 4 and also to one terminal of the coil of relay RLY 5 and RLY 6 as shown in the circuit diagram. Assuming the water in the tank is at low level when switch SW1 is powered ON, the low level sensor comes on because relay RLY 4 is not energized. The sensor in the storage tank internally makes contact and the neutral of the 220 VAC is connected to the second terminal of the coil of relay RLY 6 making it to be energized and the 24 VDC at the common of relay RLY 6 is fed through the normally open contact of relay RLY 6 to the input, PIN 22 of the PLC and the PLC gives an output at PIN 5 and PIN 7 which energizes relay RLY 1 and RLY 2, and the live of the 220 VAC present at the common of relay RLY 1 and RLY 2 is fed through the normally open contact of the relays to power ON pump 1, pump 2, and open up valve 1, valve 2. When the water level in the tank gets to the set point as programmed in the PLC, the output of PIN 7 will be cut-off and relay RLY 2 de-energizes thereby switching OFF pump 2 and closing valve 2 and the live of the 220 VAC at the common of relay RLY 2 is fed through the normally closed (N.C) contact of relay RLY 2 to power ON the set point indicator. When the water in the tank gets to full level, the sensor internally disconnects the low level contact and connects the high level contact, the neutral of the 220 VAC is then fed through the normally open (N.O) contact of relay RLY 5 to the second terminal of the coil of relay RLY 5 to energize it and relay RLY 6 is de-energized. The 24 VDC present at the common of relay RLY 6 is fed through the normally closed (N.C) contact of relay RLY 6 to the input, PIN 25 of the PLC and the output from PIN 5 is cut-off to switch OFF pump 1 and close valve 1. The high level indicator comes on because relay RLY 4 is energized and the live of the 220 VAC is connected through the normally open (N.O) contact of relay RLY 4. The system delays for about 20 seconds and the output, PIN 9 of the PLC produces an output voltage to energize relay RLY 3 and the live of the 220 VAC at the common of relay RLY 3 is connected through the normally opened contact of the relay to power on pump 3 and open valve 3 and water starts to drain out of the tank. When the water in the tank gets to low level, the entire process starts again.

A ladder logic diagram was developed to suit our proposed design. The ladder diagram is one of the programming language used in programming PLCs. RSLogix software was used for writing the program which was downloaded into the memory of the PLC after it was tested. The panel was built on a flat thick metal sheet which was later firmly fixed inside a metallic rectangular box of dimension 0.3×0.2×0.4m which is the casing. The panel was properly designed using the rail system. It is made up of three rails which were fixed on a flat thick metal sheet on which the PLC, SMPS and the relays where mounted. Two trunkings were also fixed vertically where the control cables that was used to connect the system passed through. Figure 4 shows the flat metal sheet on which the rails and trunkings were fixed and the metallic rectangular box where the panel was installed.

Fig. 4: System Panel

The indicator board has a dimension of 2×4ft, it is made of plywood. 10 pilot lights and the switch attached to it. The pilot lights are what give feedback to the operator in the control room of the state of the system in the field and the switch is used to start the system.

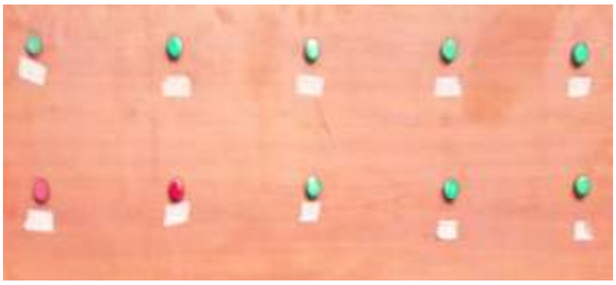

Fig.5: Indicator Board

2. RESULT/TEST

Hardware and software portions of this project were developed separately. Building and testing of the work bit by bit helped us in making good use of resources available and also increased our efficiency by reducing our debugging and troubleshooting time. The power supply unit was first tested with a multi meter to be sure if it will give the required amount of power supply needed to power the system. Continuity test was carried out on the pilot lights on the indicator board. Also the sensor was tested by pouring water into the storage tank to check if the pump will automatically switch ON when the water is at low level and switch OFF when the water is at high level.

At the end of the entire implementation stage, the project was powered and it came up as expected and we were able to observe from the indicator board that the program in the PLC memory was running as programmed and each states of the pumps, valves and sensor were displayed on the indicator board. Table 1 shows the states of the pumps, valves, at the various level of water in the tank

Table.1: States of Pump and Valves at Various Water Level

WATER LEVEL	PUMP 1	PUMP 2	PUMP 3	VALVE 1	VALVE 2	VALVE 3
LOW	ON	ON	OFF	OPEN	OPEN	CLOSE
	ON	OFF	OFF	OPEN	CLOSE	CLOSE
HIGH	OFF	OFF	ON	CLOSE	CLOSE	OPEN

3. CONCLUSIONS

Pump stations are very important facilities for transporting water from one place to another and the need for the automation of this pump station has given rise to different ways of automating a pump station. With the speed of changing technology today it is pertinent that the control of processes in the pump station is done with little or no human supervision, hence, the use of PLC to control the process is employed. This project has shown to a reasonable extent how a PLC can be used in automating a pump station by controlling the level making it easier to control and achieve desired results. This will also help in reducing the risk and errors that would have occurred if it were to be done manually and also eliminates the setbacks associated with using other means of automation. Based on this, a control panel for the automation of a pump station using PLC has been designed, constructed and tested. The result obtained from the test carried out shows that the system is capable of controlling level as a process parameter.

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