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The Design of Fluid Holding Tank Control System Using Programmable Logic Controller (PLC)

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Abstract— In the midst of technological advancements, there are a number of industries in Liberia that uses primitive techniques in controlling the daily operation of fluid storage tanks. These industries such as the Liberia Petroleum Refinery Corporation (LPRC), etc, still use the rudimentary methods of allowing personnel to carry on the daily operations of storage tanks during productions, which place the personnel involved into hazardous situation and also lead to inefficient productivity. However, to avoid workers physical interaction with these holding tanks that pose danger to their lives, industries operating in Liberia, need to employ an automatic control system that carries out the daily operations of these tanks without workers physical interaction with them. This laborious and risky task can be performed using automatic control system that both monitors the fluid level in the tanks during pumping and stops the pump when the desired fluid level has been achieved.

In this project we are concern with the one that provide level measurement capability. A flow control valve serving as a double acting valve is controlled automatically to respond to changes in pump pressure to fully open or partially open the valve to a desire flow percentage, regulating the flow rate of the fluid. Also, the pump response to changes in the fluid level in tank to either start filling if level is at it set low level or stop filling if level reaches safe filling height. The main components used in this project are: Programmable Logic Controller (PLC) and accessories, Level sensors, Indicators, DC source, and holding tank unit comprising of tank, pump and control valve.

It has been an achieving pleasure to work on practice & progress of PLC based fluid holding tank control system because it provides information about many topics relevant to control system or equipment automation. The great advantage of PLC based fluid holding tank control system is with maximum accuracy. Also the system has higher reliability, small space requirements, reduced cost and able to work as friendly with environment. This project is applicable in Fluid level control in sewage system; Fluid level control in boiler system; petroleum products level control in refinery, generator and automotive engine; chemical level control in washing plant; homely use water tank level and water treatment plant.

Index Terms — holding tank, solenoid, control valve, coil, Programmable Logic Controller, contacts, sensors

1 Introduction

1.1 Introduction

Technological advances in recent years have resulted in the development of the programmable logic controllers (PLC) and a consequential revolution of control engineering. PLC is a special form of microprocessor-based controller which includes programmable memory to store instructions and to implement functions such as logic, sequencing, timing, counting and arithmetic operations. The Programmable Logic Controller (PLC) is widely used in different plants like power generation, boiler, level control, chemical plants, paper plant, and water treatment plant, food processing plant, washing machine control, and control of machinery on factory assembly lines to expand and enhance productivity. In fact the PLC is used in every aspect of the industry where automation of typical industrial electromechanical processes is required *(W. Bolton, 2006)*. This project presents methods of designing an automatic control system that enables the pumping of fluid into a storage tank, monitors the fluid level in the tank during pumping, stops the pump when the fluid has reached desired level, and enables the reverse flow of the fluid from the tank using programmable controllers.

1.2 Background of Project

The advancement of the PLC began in 1968 with General Motors Corporation. The primary goal was to eliminate the high cost associated with inflexible relay-controlled systems. The specifications of the first PLC designed by General Motors required a solid-state system with computer flexibility able to (1) survive in industrial environment, (2) be easily programmed and maintained by plant engineers and technicians, and (3) be reusable. *(Karl-Henz John, et al, 2001).*

Such control system would reduce machine downtime and provides expandability for the future. The product implementation to satisfy General Motors' specifications was underway in 1968; and by 1969, the programmable controller had its first products. These early controllers met the original specifications and opened the door to the development of a new control technology. The first PLCs offered relay functionality, thus replacing the original hardwired relay logic, which used electrically operated devices to mechanically switch electrical circuits. They met the requirements of modularity, expandability, programmability, and ease of use in an industrial environment. The controllers were easily installed, used less space, and were reusable and were programmed using ladder diagrams.

In a short period, programmable controller use started to spread to other industries. By 1971, through the Hydromantic Division of the General Motors Corporation, PLCs were being used to provide relay replacement as the first steps toward control automation in other industries, such as food and beverage, metals, manufacturing, and pulp and paper. The first programmable controllers were more or less just relay replacers. Their primary function was to perform the sequential operations that were previously implemented with relays.

These operations included ON/OFF control of machines and processes that required repetitive operations, such as transfer lines and grinding and boring machines. However, these programmable controllers were vast improvement over the relays. They were easily installed, used considerably less space and energy, had diagnostic indicators that aided troubleshooting, and unlike relays, were reusable if a project was scrapped.

Although PLC functions, such as speed of operation, types of interfaces, and data-processing capabilities, have improved throughout the years, their specifications still hold to the designers' original intentions—they are simple to use and easy to maintain.

Many technological advances in the programmable controller industry continue today. These advances not only affect programmable controller design but also the philosophical approach to control system architecture. These advances have led to the automation of major industrial plants that have helped shape the modern world by changing the ways of processing, storing and distributing fluid in plants such as water treatment plant and oil processing and distribution plant.

PLCs can be used to control the flow rate of fluid in transmission and distribution pipes by automatically closing and opening valves.

They can also be used to monitor sensors on a holding tank in order to determine the fluid level in the tanks. By controlling the starter circuit of a pump, PLCs can be used to control the on and off status of an entire pumping system. As stated above, the PLC has brought lots of advancements to control engineering and this project highlights its usefulness in the industry. *(L.A & E.A Bryan, 1997).*

1.3 Problem Statement

Fluid treatment and processing plants in Liberia such as the Liberia Petroleum Refinery Corporation (LPRC) still use the rudimentary methods of allowing workers to climb on very large storage tanks to monitor product level as it is being pumped from the ship to the tanks and then send communication to the team on the ship's deck to manually stop the pump when the product in the tank has reached the desired level. This laborious and risky task can be performed using automatic control system that both monitors the product level in the tanks during pumping and stops the pump when the desired oil level has been achieved.

This same control system could be used in water treatment plants to control the pumping of water in storage tanks and the distribution of the water to the various networks. This project presents a design of such a control system using PLC that enables the pumping of fluid in a holding tank, monitors the fluid level in the tank and automatically stops the pump when the preset fluid level has been reached.

1.4 Objective of Project

The major objective of the project is to provide a viable engineering alternative to the laborious and sometimes risky task of using human to monitor fluid level in large holding tanks, to provide alternative to the manual switching ON/OFF of pumps in treatment and processing plants, and to avoid the manual opening and closing of certain strategic valves in treatment and processing plants. To achieve these dedicate tasks, we have designed a control system using programmable controllers to automatically switch ON/OFF the pump as required. A fluid level controller sensor is employed along with an indicator to detect and monitor fluid level in the tank and to feed the results to the PLC which then compares the result to the written instructions in its memory and then perform the required task.

1.5 Overview of fluid holding tank control system

Fluid holding tank control system is a control program design using PLC. Its consist of level sensors that are used to monitor the water level in the tank and transmit the level read to PLC and based on the level the PLC sends signal to the flow control valve and pump so as to control or stop the flow of fluid to holding tank in order to avoid overflow of fluid which results into wastage or possibly unavailability of fluid in case of emergency. The system pumping formed an integral part of the tank level control. At a pre-set maximum level, a control sensor will turn the pump OFF and the tank will automatically stop filling and then starts to distribute fluid to desire locations. As soon as the tank drains to its set minimum level, automatically the control will turn ON the pump to start filling the tank again. The instrumentation measurement of level is based on two major classifications which include Point level and Continuous level measurements. For the point level measurement it indicates fluid presence or absence in the tank at a certain point while continuous level measurement indicates the level of the fluid in the tank over a full range of possible measurements.

Some water level controls enable water level measurement capability and some do not, such as solenoid valves. In this project we are concern with the one that provide level measurement capability. A flow control valve serving as a double acting valve is controlled automatically to respond to changes in pump pressure to fully open or partially open the valve to a desire flow percentage, regulating the flow rate of the fluid. Also, the pump responds to changes in the fluid level in tank to either start filling if level is at it set low level or stop filling if level reaches high level.

1.6 Limitations of Project

This automatic control system design project like every other project has some limitations. The major limitation is with the software we used to simulate our design. The animation used by Multisim to portray the holding tank has only one pipe through which the fluid is pumped to and from the tank.

1.7 Organization and apparatus of the project

The main components used in this project are:

1. Programmable Logic Controller (PLC) and accessories
2. Level sensors,
3. Indicators
4. DC source
5. Holding tank unit

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2 Literature Review

2.1. Introduction

This chapter basically discusses the review of the project in accordance to fluid holding tank control system that is widely used in industries and residential areas. Summary of commonly used fluid holding tank controller technologies are also discussed in this chapter based on their description, advantages and disadvantages.

Fluid holding tank control technology such as Programmable logic controller is very important to discuss when designing the control program of fluid holding tank. This chapter also discusses the fluid level controller with regard to the type of fluid, shape of the tank and the tank capacity.

And finally, the chapter shows the functional description, operation and circuit diagram of the holding tank control program designed using PLC. This is important to compare the use of PLC or Conventional control in controlling the holding tank of a fluid.

2.2. Control system of fluid holding tank

Fluid holding tank is very important in the distribution of fluid in industries and residential areas depending on the kind of fluid one is considering. Since fluid when wasted are unable to be re-gathered, therefore, it is important to employ a control system, manual or automatic in order to monitor the flow of fluid in and out of the tank so as to avoid wastage or perhaps unavailability of fluid in case of emergency.

In the past, human physically controlled the operation of holding tank. However, quite recently the use of electrical control based on relays has been used to control operation of holding tanks. The switching on and off of power without a mechanical switch is performed by relays. Additionally, the development of low cost computer has brought the most recent revolution. The Programmable Logic Controller (PLC) is widely used in different plants like power generation, boiler, level control, chemical plants, textiles mills, paper plant, water treatment plant, petroleum refinery and food processing plant. Most of the present science and technology of the control system is based on microcontroller and PLC. (*Woodward Governor*).

2.2.1 Type of Control

2.2.1.1 Manual Control

Manual control requires the physical interference of operator with the operation process of the system. That is the operator operate the process to a desire condition, then the system carries out the corrective action. For instant, when manually controlling a fluid holding tank, the operator physically adjust the pump power switch(ON) to start the pumping of fluid into holding tank and again physically adjust the power switch(OFF) to stop the pumping of fluid as soon as the fluid starts to overflow. This type of control is very primitive and causes wastage of fluid therefore it is not advisable to be use in the midst of technological advancement.

2.2.1.2 Automatic control

For an automatic control, desire conditions or instructions are processed into the system by some logical software application design using programmable logic controller. Based on the instructions the instruments carry out the corrective actions automatically without human physical interference. Also, an automatic control system is developed using electrical control based on relays, contactors and timers.

Since the advancement of technology resulting to the development of low cost computer, automatic control system design using PLC is much preferable than the ones design using electrical control based on relays, contactors and timers because PLC program and electronic communication lines unlike the electrical control, does not require hard-wired control for its interconnections but instead uses common coded instructions design in control software application that are easy to be corrected and modified. Automatic control increases production, Improve quality, greater production uniformity, uses less raw materials and manpower. For these reasons automatic control is used most widely now a day in industries. *(Rojiha, C., 2013).*

2.3 Importance and usage of fluid holding tank

Fluid holding tanks are often the most visible and expensive component of fluid distribution system. They are used to stored wide range of fluid including drinking water, petroleum products, sewage, chemicals etc. Some of the fluid are kept in holding tanks to be use in the future in case of emergency while other fluid such as sewage and chemical are kept in holding tanks to avoid contaminating the environment. The fluid is safely disposed of.

Holding tanks are very important because they provide storage for treated drinking water before it is distributed to end users; provide storage for refined petroleum products before they are distributed; and provide storage for treated sewage before they are sent into the public sewage line. Holding tanks also accommodate the flows of fluid necessary for emergencies such as firefighting and provide equalize pumping rates for the supply and demand of fluid. It is also used to supply fluid during emergencies such as loss of pumping capacity as a result of power outage. These plus many more make holding tanks very important in the distribution of fluid.

2.4 Fluid level indicator and controller

The control or management of fluid level in holding tanks re-

duces power consumption and as well as overflowing of fluid. It also indicates the amount of fluid entering or leaving the holding tanks.
The lack of adequate and integrated fluid management has led to the unsustainable availability of fluid resource. In the Last few decades several monitoring system integrated with fluid level detection have become accepted. Fluid level control is simply to start the feed pump at low level and allow it to run until a higher fluid level is reached in the holding tank.
This simple method of level control is not properly supported for adequate controlling system. However, fluid level sensor which provide visual multi-level as well as continuous level indication, are widely used for monitoring fluid level in holding tanks now a days.
Fluid level monitoring and controlling system are concentrated with some basic parts which include fluid level indicator, fluid level sensor, fluid pump controlling system etc. When the power is switch on and the motor circuit is energized, the fluid pump controlling system gets on and starts to pump fluid into holding tank. As soon as the fluid level sensor senses fluid in the holding tank, the level indicator which is often LED light indicator as shown in figure 2.1, comes on to indicate the fluid level in the tank and then the sensor also, transmit the level of the fluid to PLC through it input module. The PLC through its output module sends a command to the pump to either start or stop the pumping of fluid into the holding tanks based on the low or high level of the tank. For this project a bar graph LED light indicator is used to indicate the fluid level. Each light on the graph comes on upon the pumping or draining of five liters.

2.5 Conventional Control System and Programmable Logic Controller

Both Conventional control System and PLC are automatic control systems. They only provide instructions to the instrument through electromechanical relays and timers if it is conventional control or through control programmable logic design using PLC.
These instructions are translated automatically by the instrument into its corrective action without human physical intervention. However, since the advancement of technology, the use of conventional control system has been widely replaced by PLC because unlike conventional control which uses electromechanical contactor, relays, timers, counters etc. that required hard-wired connections, PLC basically operates by examining the input signal connected from the process and carried out logic instructions on these input signal and then it produces output to a drive process, equipment, or machinery via less intermediate circuitry relay.
PLC are easy to program, highly reliable, and easy to maintenance unlike Conventional control which require rewiring of entire system hard-wired if any changed is required in the process.*(Middle Brooks, et al., 1977).*

2.5.1 Basic of Programmable Logic Controller

A Programmable Logic Controller is a mini computer used to control equipment in an industrial facility. The kinds of equipment that PLC controls varied as per industrial facilities themselves. Conveyor systems, food processing machinery, auto assembly lines, fluid holding tank system etc. are example of some equipment that are controlled by PLC. Formal in an industrial control system, all control devices are wired directly to each other according to how the system is supposed to operate.
However, the PLC replaces the wiring between the devices. Thus, instead of being wired directly to each other, all equipment are wired to the PLC. Then, the control program inside the PLC provides the "wiring" connection between the devices. The control program is the computer program stored in the PLC's memory that tells the PLC what's supposed to be going on in the system. The use of a PLC to provide the wiring connections between system devices is called soft wiring.
A programmable logic controller (PLC), also referred to as a programmable controller, is the name given to a type of computer commonly used in commercial and industrial control applications. Based on the tasks performed by PLCs and the hardware and software they require performing these tasks, they are different from ordinary office computers. While the specific applications vary widely, all PLC monitor inputs and other variable values, make decisions based on a stored program, and control outputs to automate a process or machine. *(Amunrud Alana., 2002).*

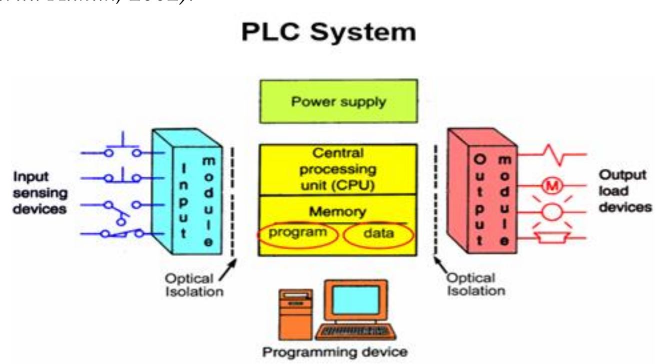

Figure2.1: A topology of a PLC system.

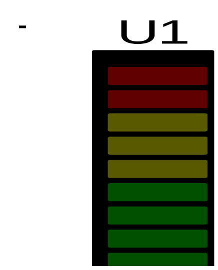

Figure2.2: A typical LED light bar graph used in this project as fluid level indicator.

2.5.2 The importance of PLC to this project

The development of low cost computer has brought the most recent revolution. Programmable Logic Controller (PLC) is widely used in different plants like power generation, boiler, level control, chemical plants, textiles mills, paper plant, water treatment plant and food processing plant nowadays. PLC is one of those present days' technologies that control system is based on.

The advance of the PLC began in the 1970s and has become the most common choice for manufacturing controls. PLC has been gaining popularity on the factory floor and will probably remain predominant for some time to come. Most of this is because of the advantages they offer. The PLC is not only capable of performing the same tasks as hard-wired control, but are also capable of many more complex applications.

In addition, the PLC program and electronic communication lines replace much of the interconnecting wires required by hard-wired control. Therefore, hard wiring, though still required to connect field devices, is less intensive. This also makes correcting errors and modifying the application easier.

2.5.3 Functional description of PLC.

PLC is actually an industrial microcontroller system where hardware and software specifically suited to industrial environment is designed. When considering PLC, one need to pay keen attention to the input and output blocks because in them there is protection needed in isolating a CPU blocks from damaging influences that industrial environment can bring to a CPU via input lines. Computer used for writing a program is referred to as a Program unit.

When using PLC to design a control system, one uses a simple form of high level language like ladder diagram, instruction code etc. to entered the control program into the PLC. The input device such as switch, push button, sensor and output device such as motor, relays, valves, lamps etc. are connected to PLC.

The operator then enters a sequence of instructions into the memory of the PLC. The controller then monitors the inputs and outputs according to these programs and carries out the control rules for which it has been programmed.

Power supply- electrical supply is used in bringing electrical energy to the central processing unit. Most PLC controllers work either at 12VDC, 24 VDC or 220 VAC. In some system, PLCs are electrically supply as a separate module. Those are usually bigger PLCs.

In this project, a simple form of high level language called ladder diagram is used to enter the control program into the PLC.

2.5.4 PLC components and operation

Basically the input and output modules or points, Central Processing Unit (CPU) comprising of the memory, program and data, and a programming device are elements a PLC consist of. PLC uses a type of input modules or points depending upon the types of input devices being used. If the input device is a digital or discrete input device which is either on or off, an input module that respond to it is used.

Also if it is an analog signal input device which represent machine or process conditions as a range of voltage or current values, a corresponding input modules or points that respond to analog signal is used.

The input circuitry of a PLC primary responsibility is to convert the signal provided by these various sensors and switches into some logical signal that can be used by the CPU.

2.5.4.1 Basic PLC Operation

Basically a PLC operates in such a way that the CPU evaluates the status of inputs, outputs, and other variables as it executes a stored program. The CPU then sends signals to update the status of outputs. Output modules convert control signals from the CPU into digital or analog values that can be used to control various output devices.

The programming device is used to enter or change the PLC's program or to monitor or change stored values. Once entered, the program and associated variables are stored in the CPU. In addition to these basic elements, a PLC system may also incorporate an operator interface device to simplify monitoring of the machine or process. (Moore, et al., 2010).

2.5.4.2 The Central Processing Unit (CPU)

The CPU is an essential component of a Programmable Controller. It is considered as the "brains" of a programmable controller because it perform all of the logical work of a PLC including retrieving, decoding, as storage and processing of information. It also executes the control program stored in the PLC's memory. The function of a PLC's CPU is no different from that of a regular computer's CPU except that it uses special instructions and coding to perform its functions.

The CPU of a PLC consists of three main parts which include the processor, the memory system, and the power supply. The processor codes, decodes, and computes data, the memory system stores both the control program and data from the equipment connected to the PLC and lastly the power supply provides the PLC with the voltage and current it needs to operate.

2.5.4.3 The Control program

The control program is a software program in the PLC's memory. It writes the control in a programmable controller.

The control program is developed or designed by the user or the system designer .It is made up of things called instructions which are, in essence, little computer codes that make the inputs and outputs do what the user or designer want in order to get the result he or she needs. Instructions or codes (add and subtract data, time and count events, compare information, etc.) may vary depending on what the user or designer want the PLC to do.

All you have to do is program the instructions in the proper order and make sure that they are telling the right devices what to do and what not to do…you have a PLC-controlled system. If you want the system to act differently, just change

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the instructions in the control program.
What make each type of PLC unique is that PLC offer different kinds of instructions depending on its type. However, all PLC use two basic types of instructions: Contacts and Coils,

2.5.4.3.1 Contacts

Contacts are instructions that refer to the input conditions of the control program that is, the information supplied by the input field devices. Each contact in the control program monitors a certain field device. The contact waits for the input to do something in particular (e.g., turn on, turn off, etc.—this all depends on what type of contact it is). Then, the contact tells the PLC's control program, "The input device just did what it's supposed to do. You'd better check to see if this is supposed to affect any of the output devices. An example of contacts found in ladder diagram is found in figure 2.2.

2.5.4.3.2 Coils

Coils are instructions that refer to the outputs of the control program that is, to what each particular output device is supposed to do in the system. Like a contact, each coil also monitors a certain field device. However, unlike a contact, which monitors the field device and then tells the PLC what to do, a coil monitors the PLC control program and then tells the field device what to do. It tells the output device, "Hey, the PLC just told me that the switch turned on. That means that you're supposed to turn on now. So let's go!"
Example- Let's talk again about that soaped-up switching circuit, in which a wall switch and an overhead light are connected to a PLC. Let's say that Turning on the switch is supposed to turn on the light.
In this situation, the PLC's control program would contain a contact that examines the input device the wall switch for an on condition and a coil that references the light. When the switch turns on, the contact will energize, meaning that it will tell the PLC that the condition it's been looking for has happened.
The PLC will relay this information to the coil instruction by energizing it. This will let the coil know that it needs to tell its referenced output the light to turn on. This example is demonstrated in figures2.4a & 2.4b.
In PLC talk, this three-step process of monitoring the inputs, executing the PLC control program, and changing the status of the outputs accordingly is called the scan.
Inputs monitor→ program execute→ Change outputs scan.

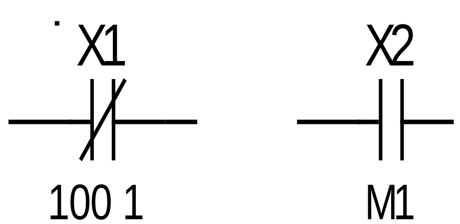

Figure 2.3: An example of contacts found in ladder diagram. X1 is a normally closed input contact and X2 is a normally opened relay contact.

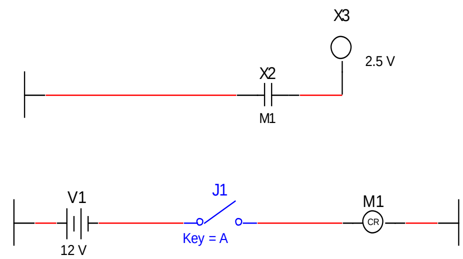

Figure 2.4a.: shows the initial stage where the switch is not yet trigger to energize the coil.

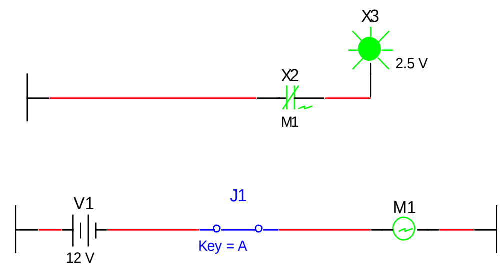

Figure 2.4b: shows that the switch has been triggered and coil is energized which in turn turns on the light.

2.5.5 Basic of Conventional control system

A conventional control system consists of electromagnetic relay, timer, and switch etc. which can be used to control a specify process operation. But if any changed is required in the process the whole control system has to be changed and rewiring is needed.
At the outset of the industrial revolution, especially during the sixties and seventies, relays were used to operate automated machines, and these were interconnected using wires inside the control panel. In some cases a control panel covered an entire wall. To discover an error in the system much time was needed especially with more complex process control systems. On top of everything, a lifetime of relay contacts was limited, so some relays had to be replaced. If replacement was required, machine had to be stopped and production too. Also, it could happen that there was not enough room for necessary changes.

2.5.6 The use of PLC instead of Conventional control system

PLC is not only capable of performing the same tasks as Conventional control (hard-wired control), but is also capable of many more complex applications. In addition, the PLC program and electronic communication lines replace much of the interconnecting wires required by Conventional control (hard-wired control). Therefore, hard wiring, though still required to connect field devices, is less intensive. PLC also makes correcting errors and modifying the application easier. Some of the additional advantages of PLC are as follows:

1. Smaller physical size than hard-wire solutions.
2. Easier and faster to make changes.
3. PLC has integrated diagnostics and override functions.
4. Diagnostics are centrally available.
5. Applications can be immediately documented.
6. Applications can be duplicated faster and less expensive.

The soft wiring advantage provided by programmable controllers is tremendous. In fact, it is one of the most important features of PLC's. It makes changes in the control system easy and cheap. If you want a device in a PLC system to behave differently or to control a different process element, all you have to do is change the control program.
In a Conventional system, making this type of change would involve physically changing the wiring between the devices, a costly and time-consuming endeavor.
In addition to the programming flexibility we just mentioned, PLC's offer other advantages over Conventional control systems. These advantages include:

1. High reliability
2. Small space requirements
3. Computing capabilities
4. Reduced costs
5. Ability to withstand harsh environments
6. Expandability

3 RESEARCH METHODOLOGY

3.1 . Introduction

This chapter explains the various techniques we used in the design of this project. It provides detailed explanation on every device used. Like every other automatic control system, the Fluid Holding Tank control system uses various sensors such as target sensor, level sensor, solenoid valves, and switches in its design.

3.2 Methodology

3.2.1 Systematic approach in designing the project

First, you need to select an instrument or a system that you wish to control. Automated system can be a machine or a process and can also be called a process control system. Function of a process control system is constantly watched by input devices (sensors) that give signals to a PLC. In response to this, the PLC sends a signal to external output devices (operative instruments) that actually control how system functions in an assigned manner.
Secondly, you need to specify all input and output instruments that will be connected to the PLC. Input devices are various switches and sensors that feed information from the field to the PLC. Output devices can be solenoids, electromagnetic valves, motors, relays, magnetic starters as well as instruments for sound and light signalization. Following an identification of all input and output instruments, corresponding designations are assigned to input and output lines of a PLC controller. Allotment of these designations is in fact an allocation of inputs and outputs on a PLC which corresponds to inputs and outputs of a system being designed.
Third, make a ladder diagram for a program by following the sequence of operations that was determined in the first step. Finally, program is entered into the PLC controller memory. When finished with programming, checkup is done for any existing errors in a program code and, if possible, an entire operation is simulated. Before this system is started, you need to check once again whether all input and output instruments are connected to correct inputs or outputs. By bringing supply in, system starts working.

3.3 Blocks and Components

3.3.1 Holding tank unit

This section briefly describes the components used in the design of the fluid holding tank control system. The following input and output devices were used in the project design. The Holding tank unit use in this project is shown in figure 3.1.

3.3.2 Solenoid valves

Solenoids form the basis of the output control actuators. The basic operating principle of solenoid is quite simple. When current passes through it, a magnetic field is produced and this can then attract ferrous metal components in its vicinity. When the output from the PLC is switched on, the solenoid magnetic field is produced and pulls the contact and so closes a switch. The combination of this method with a valve forms a very important device in the fluid industry called the solenoid valve. A solenoid valve is an electromechanical actuator to control fluid flow.
It has two main parts: the solenoid and the valve. As explained above, the valve is controlled by an electrical signal through a solenoid coil. The solenoid uses electrical signal and provides the mechanical work, which in turn, opens or closes the valve mechanically. The electrical signal, in this case, comes from the PLC.

3.3.3 Sensors

There are five sensors used in this project. A liquid level sensor (detector) is used on the holding tank to monitor the level of the fluid in the tank. Three sensors are used to control the closing and opening of the solenoid valves which controls the direction of flow of the fluid in the pipe. Another sensor called the pump control sensor is connected to the pump starter to control the pump ON/OFF status. The operations of these sensors are briefly described below:

1. Liquid level sensor: this is pressure sensor used to monitor the depth of a liquid in the tank. This sensor is placed at the bottom of the tank to measure the

height of the fluid above it and then send signal to the PLC when the height of the fluid in the tank has reached maximum value set or when the height of the fluid is zero. In other words, this sensor measures the gauge pressure of the fluid in the tank.

2. Here is the physics behind this: the pressure P due to a height of liquid h above some level is P=hρg, where ρ is the density of the liquid and g is the acceleration due to gravity.
3. Based on this principle, the sensor actually determines the level of the liquid in the tank by measuring the pressure due to the liquid above some datum level.
4. Pump control sensor: this is a simple switching mechanism attached to the pump starter. It is switched on and off by the PLC based on the signal received from the liquid level sensor.
5. Forward, reserve and stop sensors: these sensors are used to control the opening and closing of the solenoid valves that control the flow direction of the fluid in the tank. For example when the forward sensor receives signal from the PLC, it either opens or closes the solenoid valve that directs the forward flow of the fluid into the tank. The other two sensors operate in a similar manner. Figure 3.3a below shows a holding tank unit with sensors mounted.

3.4 Hierarchical block

In order to simulate the model of this control system, we use the National Instrument Design Tool, Multisim. Since Multisim has, as part of its Advanced Peripheries, an animation for fluid holding tank, we needed a block that would serve as PLC in which all the instructions for controlling the inputs and outputs of the system could be written. We used Hierarchical Block write the Ladder Logic for the PLC. In other words, the Hierarchical Block represents the PLC. Hierarchical Block is used in Multisim to organize functionally related parts of a design in a manageable piece. This construction allowed us to build a hierarchy of inter-connected circuit to simulate our design. The hierarchical block use in this project is shown in Figure 3.2. (Brooks, et al., 1977).

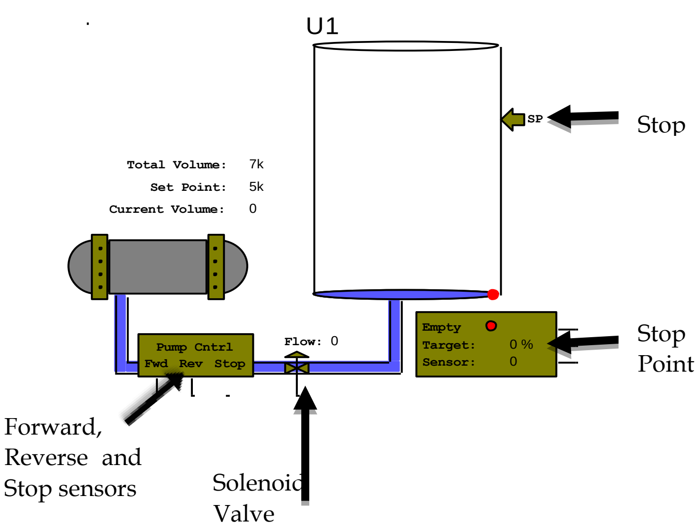

Figure 3.1: Shows a holding tank unit with sensors mounted.(Forward, Reverse and Stop sensors, liquid level sensor, solenoid valve and Stop point indicator).

3.5 Ladder Diagrams Language

Ladder Diagrams Language is one of the most common languages used in programming PLCs. Ladder Diagram uses electrical symbols as instructions compared to other languages which use words and other computer symbols. Ladder Diagrams are very easy for technicians and engineers to understand because they are very similar to the electrical circuit they represent. We used hierarchical block to hold ladder logic for the model simulation. In a ladder logic diagram:

1. Relay contacts are used to represent input conditions (field devices) to the PLC. These conditions could be a pushbutton, a proximity switch, limit switch, or the output of a sensor. These input devices are connected to the input module of the PLC. The programs written in the memory of the PLC instruct the output devices based on feedback from these devices.
2. Relay coils are sections of the ladder logic that are either energized by input devices or output devices to activate other input devices or output devices.
3. Ladder output coils are used to represent output conditions from the PLC. These output devices could be solenoid valves, the starter to a motor, or limit switch. These devices are connected to the output module of the PLC. They are directly driven by the program in the memory of the PLC. When these devices are activated, they can control real world machines such as motors, conveyor belts, drilling machines etc.
4. The Ladder Diagram also uses timers, sets and reset coils, counters and pulse coils to control some industrial processes. (L.A & E Bryan,. 1998).

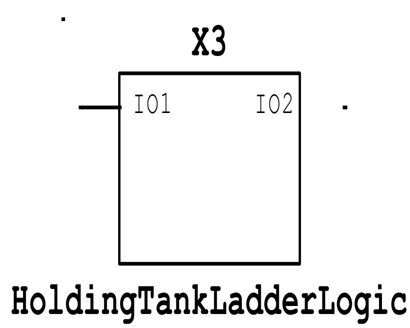

Figure 3.2 is a typical hierarchical block use in this project.

4.1 Introduction

This chapter basically analyzed the results from the project design as it is being simulated using the Multism software in accordance to the function of a fluid holding tank that is widely used in industries and residential areas. Summary of commonly used fluid holding tank controller technologies are also d tions. And finally, the chapter shows the functional description, operation and circuit diagram of the holding tank control program analyzed and simulated using the Multism software which is designed to help hardware designers' gain better understanding of circuit behavior. It also helps to close the gap between design and practical test, trains creative thinking and innovative abilities.

4.2 Results

As the simulation proceeds using the Multism software, the tank begins to fill. When the level of the fluid in the tank gets to the Stop Point, the pumping of fluid stopped. After a delay of five seconds, the tank begins to empty. When the tank is emptied, the flow stops. After another delay of ten seconds, the refill begins again. This process of filling and emptying of the holding tank will continue until one decides to stop or pause the process. To turn OFF the power at any point in the simulation, enable the stop switch. When Stop switch is enabled, X19 is also temporarily energized, which in turn temporarily energizes Output Coil which sends a pulse to pin Out3 of Output Module U3. This is wired to the Stop pin of the tank stops filling or emptying which is shown in figures 4.1a & 4.1b and figures 4.2a & 4.2.

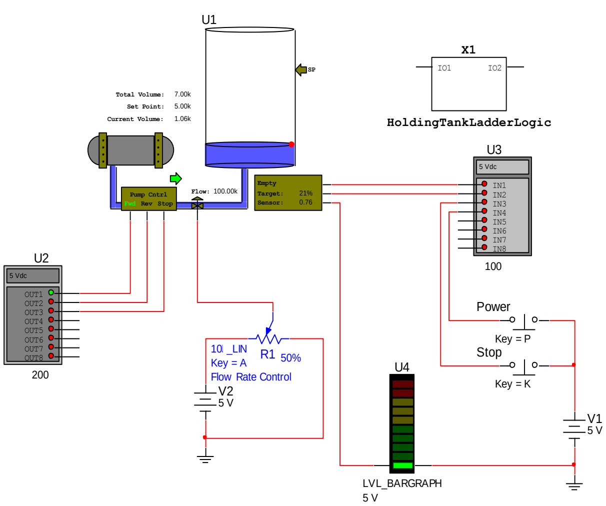

Figure 4.1a: Photo shows the filling (forward sensor) of holding tank.

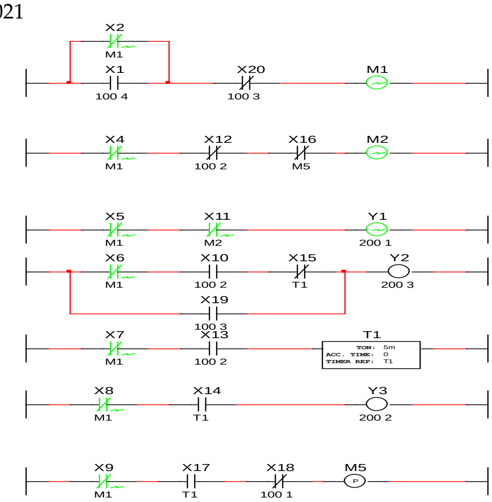

Figure 4.1b: Ladder Diagram that control the filling (forward sensor) of the holding tank

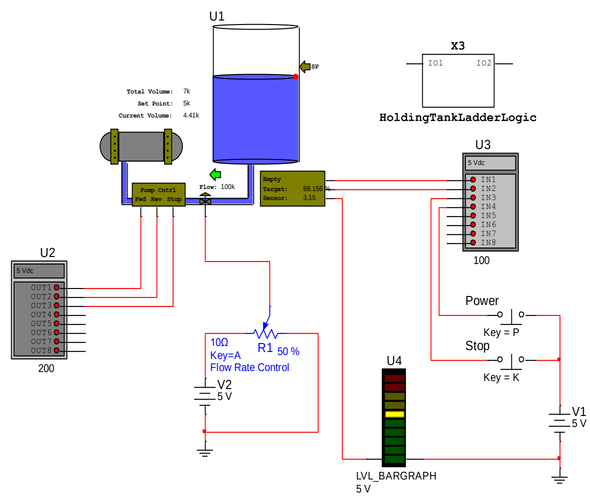

Figure 4.2a: Photo shows the emptying (Reverse sensor) of holding tank.

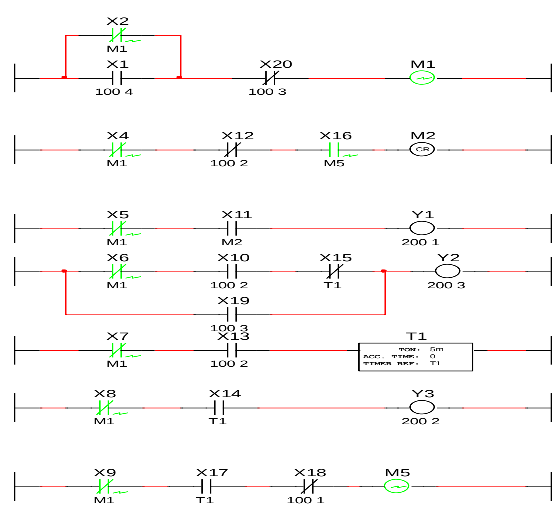

Figure 4.2b: Ladder Diagram that control the emptying (Reverse sensor) of the holding tank

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4.3 Discussion

4.3.1 Stages of Multisim Simulation

The simulation in Multisim has four main stages:

1. Input Stage—Simulator reads information about the circuit (after building schematic, assigned values and chosen an analysis). This is the process of net list generation.
2. Setup Stage—Simulator constructs and checks a set of data structures that contain a complete description of the circuit.
3. Analysis Stage—the circuit analysis specified in the input stage is performed. This stage occupies most of the CPU execution time and is actually the core of circuit simulation. The analysis stage formulates and solves circuit equations for the specified analyses and provides all the data for direct output or post processing.
4. Output Stage—Simulation results can be viewed on instruments such as the oscilloscope, on graphs that appear when you run an analysis, or in the log file/audit trail.

4.3.2 Time ON

As shown in figure 4.3a, this device is a Time ON timer for ladder diagrams. The associated contact is de-energized at the start of simulation, and is energized when this device "times out". In this project we have one time on device, T1. This lone time on device associated contact is energized to begin the emptying process and as well as the refilling of the tank.

4.3.3 Relay Coils

As shown in figure 4.3b, this device is a relay coil for ladder diagrams. When this coil is energized, corresponding contact(s) which reference this device will change their state. (For example, a normally open contact will close or a normally close contact will open). The model used for the ladder diagram in this project uses three relay coils, M1, M2 & M5. When the power switch is turn on, the M1 coil is energized to energize the entire circuit by closing all its normally open contacts associated with it. The second coil M2 will be energized when the fluid reaches its target. When M2 is energized, all its associated contacts will be energized also causing the pumping to stop and the timer starts to count.

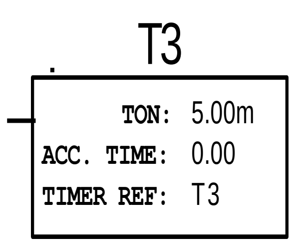

Figure 4.3a: Time ON timer for ladder diagrams

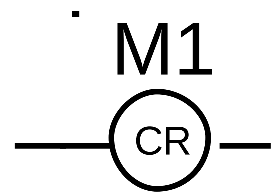

Figure 4.3b: Relay coil for ladder diagrams

5 Conclusion and Recommendations

5.1 Conclusion

It has been a great pleasure to work on practice & progress of PLC based fluid holding tank control system. It provides information about many topics relevant to controlling system or equipment automatically. We have learned more about the fluid holding tank control system. It can run automatically by the help of PLC. The great advantage of PLC based fluid holding tank control system is with maximum accuracy. Also the system has higher reliability, small space requirements, reduced cost and able to work as friendly with environment.

This project is applicable in Fluid level control in sewage system; Fluid level control in boiler; gasoline or diesel level control in any type of fuel station, generator and automotive engine; chemical level control in washing plant; homely use water tank level and water treatment plant.

It also can be used in arithmetic functions of different process in modern industries like pharmaceuticals, Fertilizer, Power station, Cement factory, packaging and so on.

5.2 Recommendations

As mentioned earlier in our problem statement, there are a number of industries in Liberia, including Liberia Petroleum Refinery Corporation (LPRC), Liberia Water and Sewage Corporation (LWSC), Liberia Agriculture Company (LAC) and Firestone Natural Rubber Plantation that uses primitive techniques in controlling the daily operation of fluid storage tanks. In the midst of technological advancements, these industries still use personnel to carry on the daily operations of storage tanks (i.e. the opening and closing of valves to control the flow of fluid in pipes and the monitoring of fluid level in storage tanks during pumping) which place the personnel involved into hazardous situation and also lead to inefficient productivity. For instant, in 2014 at LAC, the storage tank which stored the processed chemical from the robber heated at a very high temperature, bust-up due to technical error. This tragic incident at LAC led to the death of over ten (10) workers. These workers were the ones doing the monitoring of fluid level in the tank, and manually controlling the flow of fluid both in and out of the tank.

If there was an automatic control system design for the operation and control of the storage tanks, there wouldn't have been workers around doing the monitoring of fluid level and controlling the flow of fluid in and out of the tank and as a result there lives wouldn't have been at risk.

However, to avoid workers physical interaction with these holding tanks that pose danger to their lives, industries previously mentioned above, operating in Liberia, need to employ an automatic control system that carries out the daily operations of these tanks without workers physical interaction with them. With the help of an automatic control system these industries will tend to achieve the following:

1. Increase production
2. Improve quality
3. Greater production uniformity
4. Saving in raw materials
5. Saving in manpower

In this project we used Programmable Logic Controller as automation tool. It's a combination of solid state device to perform specific task using Ladder logic. It may easily run a control system with more system accuracy, smoothly and efficiently.

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