

# MIDLANDS STATE UNIVERSITY

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AUTOMATED WATER RETICULATION SYSTEM

By

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[HAPI 438 Dissertation]

## **DECLARATION**

I, Tendai Jameson Mtombeni hereby declare that I am the sole author of this thesis. I authorize the Midlands State University to lend this thesis to other institutions or individuals for the purpose of scholarly research.

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**Date**

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## **APPROVAL**

This dissertation/thesis entitled “Automatic Water Reticulation System” by Tendai Jameson Mtombeni meets the regulations governing the award of the degree of BSC APPLIED PHYSICS AND INSTRUMENTATION HONOURS of the Midlands State University, and is approved for its contribution to knowledge and literal presentation.

Supervisor(s).....

.....

Date .....

## **DEDICATION**

The research is dedicated with love to my father, mother, sisters and brothers. I thank you for your love, advice, encouragement and financial support, may the dear Lord bless you

## **ACKNOWLEDGEMENTS**

A project of this magnitude could not have been accomplished without the help and indispensable inspiration. My paramount gratitude is credited to the Almighty God who afforded me the opportunity to carry out this research. Personally I do not have the capacity of being where I am but the invisible hand of the Lord has stretched me this far.

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## **ABSTRACT**

Prior studies have identified many problems of having poor water sanitation system. The major problem being rise of water-borne diseases. This thesis is an advancement to an argument that the leading root cause of the water-borne disease outbreaks in Zimbabwe was the unsustainable urban environmental practice especially in the water reticulation system. The overarching purpose of this project is to give a solution to a case in which the failure in proper water reticulation system in urban towns mostly has ripple effects on the population of a country as an epidemic wreaks havoc. The scope of the thesis is on the inadequacy of safe and clean water in most of the suburbs in Zimbabwe. The collapse of the water supply and systems in the country and how the same instigated water-borne disease outbreaks. The thesis contributes to the body of knowledge and as a panacea to problems on water-borne diseases in cities of the developing world that face serious resource challenges and lack of modern technologies.

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# CHAPTER 1: INTRODUCTION

## 1.1 INTRODUCTION

Water is a lifetime fuel and no life can be tracked without water. Dangerous people of different categories collapse with drinking water, which arrives clean and safe, so that water needs to be checked regularly using agile technologies. The project automatically ensures the monitoring and control of water flow. Pipe leakages are the most common failures in water supply systems. Leakages can usually affect service, reduce service pressure and cause water loss [1]. Leakage can improve the quality of water by aspirating air or solid particles in negative pressure zones [1]. The deterioration of quality is considered to be the main cause of waterborne diseases [2].

Urban infrastructure monitoring, such as the water supply network for leak detection, changes in water quality and the prevention of contamination by unclean water sources, can save the government and municipalities millions of dollars a year and bring significant social benefits through the reduction of public health risks. The water leakage problem has been further exacerbated by the risk of contaminant intrusion [3, 4]. These operational challenges and threats to public health are incentives to develop new technologies for inline monitoring systems.

## 1.2 PROBLEM STATEMENT

The current water supply system typically consists of large supply lines, referred to as transfer networks, which supply water catchment or treatment plant to a distribution network that supplies reticulation networks [5]. These current systems were installed using iron pipes back in the 1960s. In this system, in times of water leakage and changes in water quality, the team responsible for monitoring and controlling this water reticulation system often relies on reports of human errors or physical inspections. It implies that in times of changing water quality control measures due to feedback from people, by using the system, however, there are some micro particles or that the water can be contaminated by intruding them through a burst point. This will have a tremendous impact on people because they cannot see them with naked eyes, but feel the effect of being attacked by waterborne diseases. This means that the water is now often dirty and contaminated, leaving no options for people who consume almost 1, 5 liters of this bad water per person per day. This is evident in schools in highly populated urban areas such as Mbare, Chitungwiza, Glen View, Budiro, Mkoba and Munhumutapa. If you look closely at Glen View 5 primary school, "Glen View 5 primary school was temporarily closed after the death of 2 children, 20 children in the school suffered from cholera [6]. We can arguably say the effects of this haven't been seen only but have also been felt, by taking lives of many due to water-borne diseases. According to The Herald, as of 22 August 2018, the death toll from the typhoid outbreak in Gweru has increased to 8, with the cumulative total of suspected cases rising to more than 1 500. [7] These threats to public health are important incentives to develop new technologies for inline monitoring systems that can optimize the operation of large - scale supply networks, prolong service life, evaluate performance and improve the safety of water supplies to people. In order to implement these critical applications, water utilities need a large number of spatially distributed measuring points to accurately represent the complex, highly non - linear time and spatial processes in water supply systems.

### **1.3 AIM**

To design a prototype of a system that automatically monitor and control the water reticulation system for a university so as to reduce the rise of water-borne diseases , loss of water due to leaking pipes and efficient time management.

### **1.4 OBJECTIVES**

#### Primary Objective

- To develop a system that automatically monitors and controls the water reticulation system for a typical university.

#### Secondary Objectives

- To assure students receive clean and safe water.
- To reduce water wastage due to pipe burst.
- To reduce the rise of water-borne diseases.

### **1.5 HYPOTHESIS**

The use of highly sophisticated water reticulation technology has the potential to provide people with clean and safe water free of harmful intruders of water such as bacteria and poison. With this system, fewer waterborne illnesses are recorded.

### **1.6 SIGNIFICANCE OF STUDY**

The results of this study will benefit the school in view of the importance of using water quality and water leakage detection technology in the water reticulation system. The increased demand for safe and clean water in schools justifies the need for a more efficient use of technology when it comes to water monitoring and control. Therefore, schools and institutions using the recommended approach derived from the results of this study will be able to provide safe and clean water for people.

### **1.7 JUSTIFICATION**

Prior studies identified many problems with poor sanitation systems for water. The main problem is the rise of diseases caused by water. The purpose of this project is to ensure people receive safe and clean water for consumption through monitoring and control of the water system

automatically to reduce intrusion of contaminants in the water. Although the lack of safe drinking water and sanitation leads to fecal oral diseases such as diarrhea, typhoid, cholera and malaria outbreaks due to leakage of water (WHO/UNICEF JMP. 2010) the overarching purpose of this project has been identified to provide a solution to this case in which failure to properly monitor and control the water reticulation system mainly has ripple effects on the population and human safety as an epidemic causes havoc [8].The collapse of the water reticulation systems and how the same instigated the water-borne disease outbreaks. The project contributes to the body of knowledge and as a panacea to problems on water-borne diseases, due to inefficient monitoring and control methods currently being used, which rely on people's reports of water leakage and complaints of bad water at a certain area and physical checkups of the system.

## **1.8 DISSERTATION LAYOUT**

**Chapter 2: *Literature Review*.** This is where a detailed review of the topic and method will be theoretical explained. This will provide the information that we expect from the system and other core factors that makes up a dissertation topic.

**Chapter 3: *Methodology*.** This chapter outlines the research designs and research procedures that will be taken to come up with data and data specifications will also be noted here that is the kind of data that will be obtained from the prototype.

**Chapter 4: *Results and Analysis*.** In this chapter, analysis of preliminary data will be done. Evidence of importance of the dissertation will expressed. Statement of limitations which will include alternatives, weaknesses and the use of the research will also be noted.

**Chapter 5: *Conclusion and recommendations*.** In this chapter will look closely on the contributions and importance of the project.

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## **CHAPTER 2: THEORETICAL ASPECTS**

### **2.1 Introduction**

This chapter provides a detailed analysis of the literature on system functionality and all components used to design an automated water reticulation system. This stage is very important in the design of the prototype, as the designer has a wider understanding of each component used in the project development. This step also gives the designer an understanding of the best way to interface these components.

### **2.2 Background on Water Reticulation System**

Early water distribution systems date back to the 13th century, when a 5.5 km lead pipeline in England was installed that transported water from Tybourne Brook to London [1]. The current water supply system typically consists of large supply lines, referred to as transfer networks, which supply water catchment or treatment plant to a distribution network that supplies reticulation networks [2]. Today, the distribution of large - scale water by water utilities ensures a portable water supply and centralized water treatment, so that consumers can drink clean and safe water near their residential, industrial and recreation areas. Water distribution systems mainly comprise of three primary components which are; water source, water treatment and water distribution networks [3]. Water distribution networks consist mainly of piped networks that are connected to a water treatment plant and to different distribution points where the water supplied can be used by the end user.

Water distribution systems can be designed to supply water to consumers by means of gravity flow, mechanical pumping or both techniques. Gravity flow is mainly carried out where the altitude of the water source is high compared to the distribution points in which the water is supplied. Gravity flow is seldom implemented because it cannot meet all the requirements of urban water systems and also because of its reduced flexibility. However, gravity flows can be achieved in rural areas where the demand for water is minimal. Therefore, a water distribution system can use pumps to supply students, but the use of pumps alone can be problematic due to variations in student requirements, so that most urban distribution systems use pumps together with high storage tanks.

#### **Branched network**

This network is similar to the branching of a tree. It consists of:-

- main (trunk) line
- sub-mains
- Branches.

The main water supply is the main source. There is no water distribution at mainline watering points. Sub-mains are connected to the main line and are normally located on the main roads of service or feed. Branches are connected to the submains and the watering points are located on the branches.

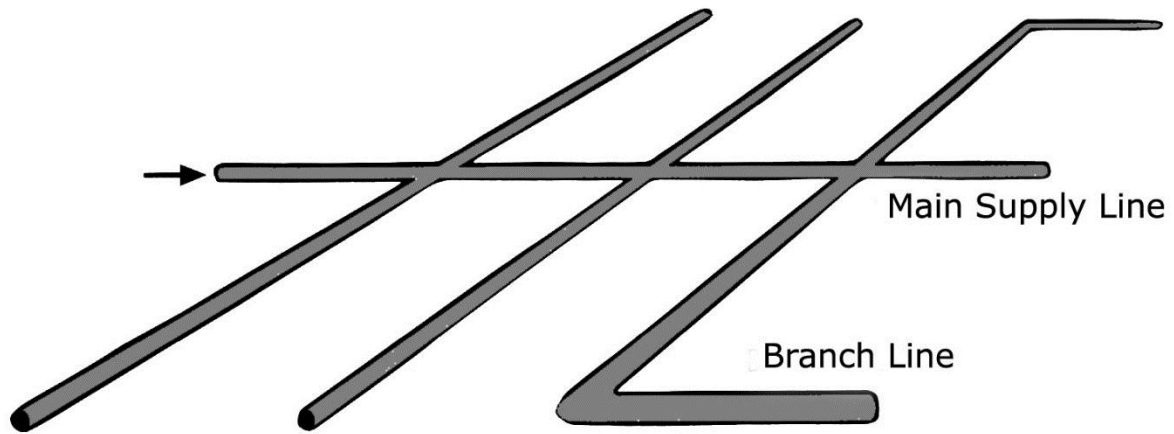


Figure 2.1: Branched Network

Grid pattern with loops. All pipes are interconnected in loops without dead ends in a grid pattern with a loop supply system. Water can reach any point from more than one direction, providing supply when the pipeline is blocked or broken, and more even pressure at all outlets.

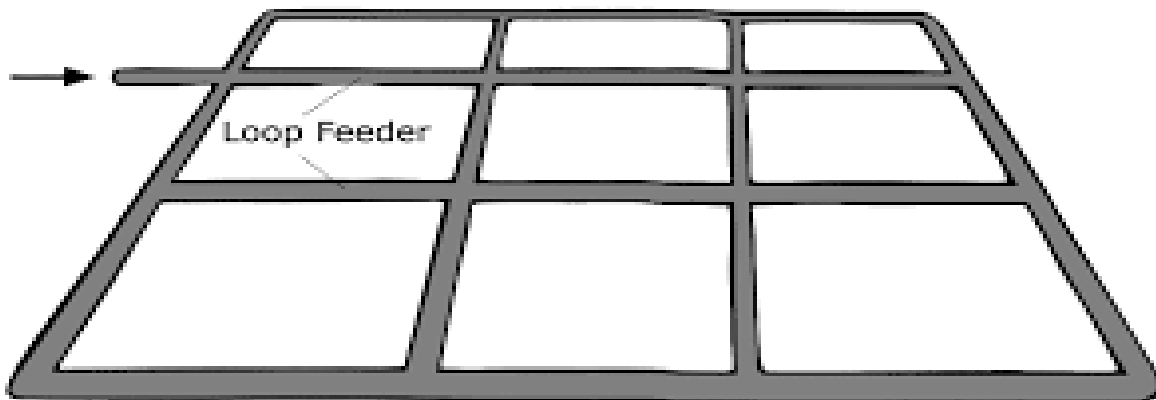


Figure 2.2: Grid Pattern With Loop



## **2.3 Theory on Water-borne Diseases**

Waterborne diseases are conditions caused by the transmission of pathogenic microorganisms in water. The disease can spread when you bathe, wash or drink water or eat food exposed to infected water [4]. The term waterborne disease is mainly reserved for infections transmitted mainly by contact or consumption of infected water.

## **2.4 Theory on Automated Water reticulation System.**

Previous studies identified many problems with poor sanitation systems for water. The main problem is the rise of diseases caused by water. The Automated Water Reticulation System ensures that the water pipes are monitored and controlled remotely online. This is to ensure that people receive clean and safe water for use. The system will use the water flow rate difference as an indication of leakage. In liquid mechanics, the system uses the law of continuity. Theoretically the system must have a process gain of 1 and 100% efficiency but for practicality of the system, there are some variations of flow rate due to :-

1. Systematic Errors/ bias – Is consistent repeatable error with a faulty tool
  - Offset Error – an error where the device is not zero when starting recording.
  - Scale Factor Errors – these are errors that are proportional to the true measurement.
2. Random Errors – These are unpredictable errors and cannot be repeated when the process is repeated.
3. Time Constant – it is the speed with controlled output responds to the process variable. The approximate time constant is 2 seconds for the system.

Use of the branched network water distribution system which consist of main trunk, sub-main, branches is made so as to illustrate the principle behind the system.

The Components which are used in the system are

- Solenoid Valve
- Water Flow Sensor
- Water Level indicators
- Water Pump
- Programmable Logic Controller

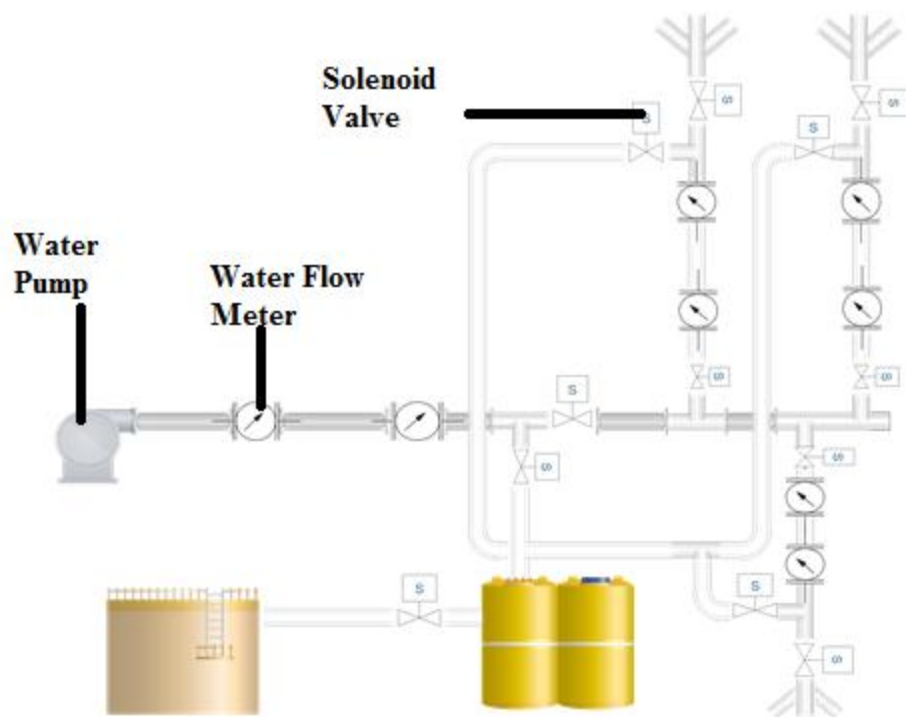


Figure 2.3: Water Reticulation System

## 2.5 Solenoid Valve

A solenoid valve is an electromechanical device in which the solenoid uses electricity to generate a magnetic field to control the fluid flow opening in a valve. A solenoid valve is a combination of two basic functional units that are a solenoid (electromagnet) and a valve body with an orifice [5]. When the solenoid is energized or de-energized, the liquid flow through the orifice is allowed or prevented by the movement of the core. Solenoid valves are normally closed to shut (close) the orifice when the solenoid is not energized and opens when the solenoid is energized [6]. The solenoid valves differ in their electrical current characteristics, in their magnetic field strength, in the mechanism used to regulate the fluid and in the type and characteristics of the fluid they control.



Figure 2.4: Solenoid Valve



Figure 2.5: Solenoid Valves

## **2.6 Water Flow Sensor**

A water flow meter is a device that measures the amount of water flowing through a pipe [7]. The water flow sensor is a Hall Effect water flow sensor which consists of a plastic valve body, a water rotor, and a hall-effect sensor [8]. When the water flows through the rotor, it rolls and changes its speed at different flow rates. The hall-effect sensor outputs the corresponding pulse signal. The output high signal level is above 4.5V and the output low signal level is less than 0.5V.

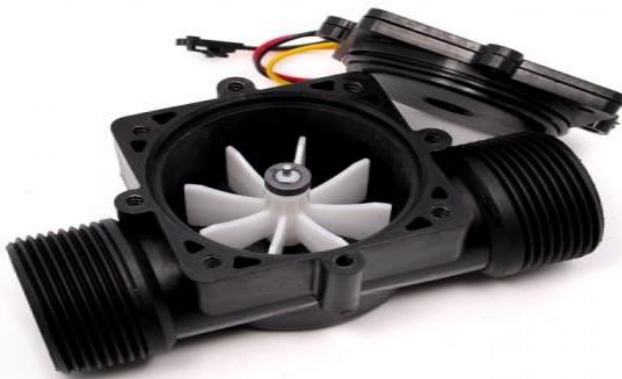


Figure 2.6: Water Flow Meter

## 2.7 Programmable Logic Controller

A programmable logic controller (PLC) or programmable controller is an industrial digital computer that has been robustly adjusted for manufacturing process control, such as assembly lines or robotic devices, or any activity requiring high reliability control and easy programming and process fault diagnosis [9].

In the automotive industry, they were first developed to provide flexible, robust and easily programmable controllers to replace hardwired relays, timers and sequencers. They have since been widely used as high reliability automation controllers for harsh environments.

A PLC is an example of a “hard “real - time system because the output results must be produced within a limited time in response to the input conditions.

### 2.7.1 Overview

The number and type of PLC input signals are diverse, including on / off switches and large and small analog signals, ranging from millivolts to tens of volts; milliamps to amps. In general, outputs control power devices, such as actuators, motors and relays [10].



Figure 2.7: PLC Micrologix 1400

### 2.7.2 Functionality

Over the years, the PLC's functionality has developed into sequential relay control, motion control, process control, distributed control systems and networking [11]. The data processing, storage, processing and communication capabilities of certain modern PLCs are roughly equivalent to desktop computers. In combination with remote I / O hardware, PLC-like programming allows a general purpose desktop computer to overlap some PLCs in some applications.

### 2.7.3 Basic functions

A programmable controller's most basic function is to emulate the functions of electromechanical relays. Discrete inputs have a unique address and a PLC command can test whether the input status is on or off. Just as a series of relay contacts perform a logical AND function that does not allow current to pass unless all contacts are closed, a series of instructions "examine if on" energizes its output storage bit if all input bits are on. Similarly, a parallel set of instructions will perform a logical OR.

A group of contacts controlling a coil is called a "rung" of a "ladder diagram" in an electro-mechanical relay wiring diagram, and this concept is also used to describe the PLC logic. Some PLC models limit the number of series and parallel instructions within a single logic "rung"

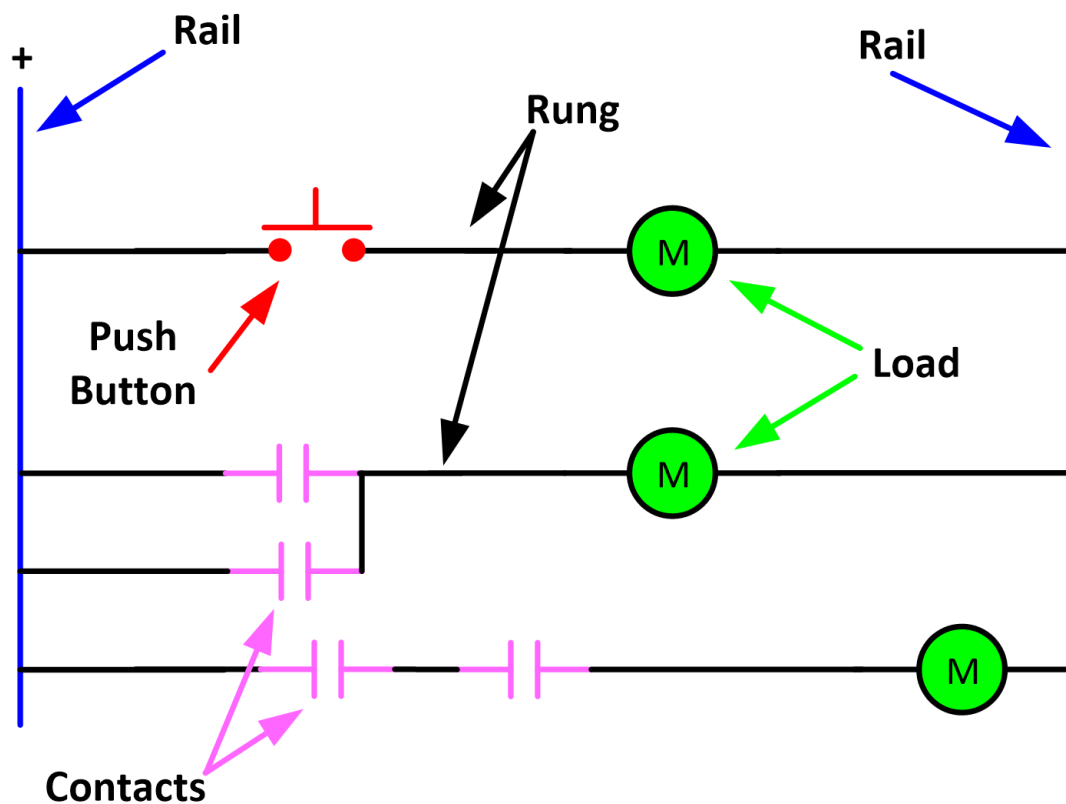


Figure 2.8: Ladder Logic Programming

The output of each rung sets or clears a storage bit that can be a physical output address or an “internal coil” without a physical connection [12]. For example, such internal coils can be used as a common element in several separate rungs. Unlike physical relays, there is usually no limit to the number of times an input, output or internal coil can be referenced in a PLC program.

Some PLCs comply with a strict execution order from left to right, top to bottom, to assess the logic of the rung. This is different from electro - mechanical relay contacts, which, depending on the surrounding contact configuration, can either pass the current left to right or right to left in a sufficiently complex circuit. The elimination of these "sneak paths" is either a bug or a feature, depending on programming style.

More advanced PLC instructions can be implemented as functional blocks that perform some operation when enabled by a logical input and that generate outputs to signal, e.g. completion or errors, while internally manipulating variable that may not correspond to discrete logic.

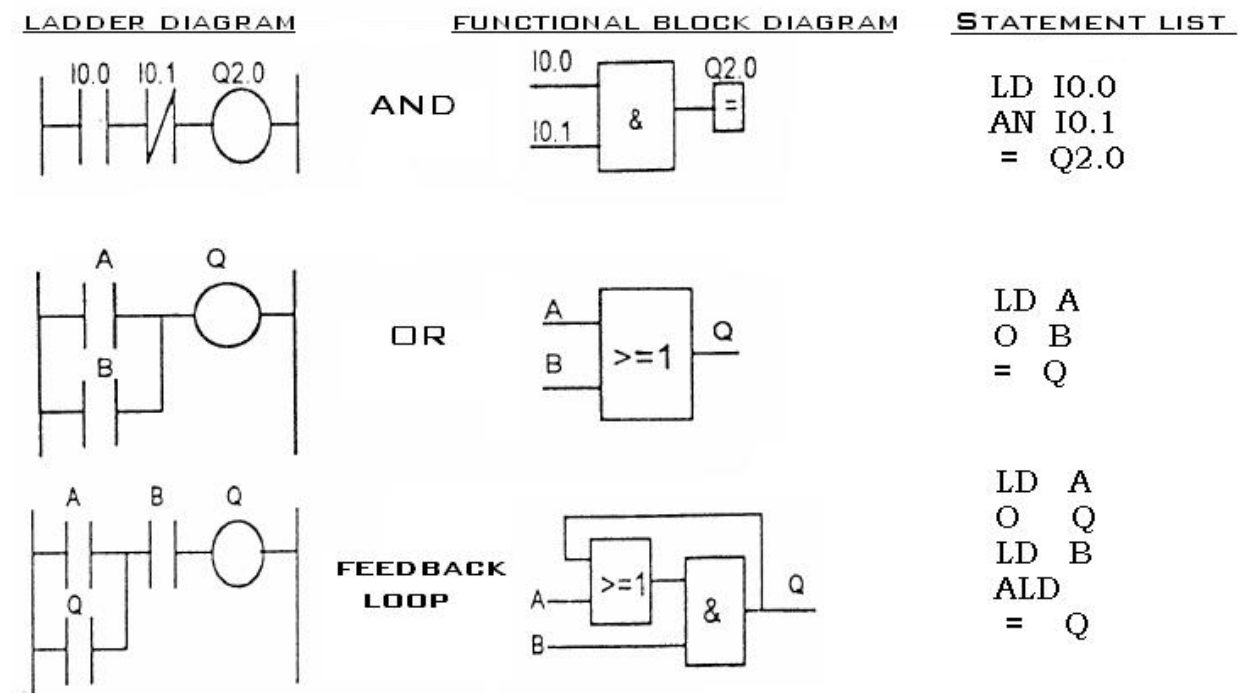


Figure 2.9 : Ladder Diagram

### 2.7.4 Timers and counters

The main function of a timer is to maintain the output for a certain duration. The commonly used three types of timers are a Delay-OFF, a Delay-ON and a Delay-ON-Retentive.

A Delay-OFF timer activates immediately when turned on, counts down from a programmed time before cutting off, and is cleared when the enabling input is off.



Figure 2.10 : Delay- Off Timer

A Delay-ON timer is activated by input and starts accumulating time, counts up to a programmed time before cutting off, and is cleared when the enabling input is turned off. A Delay-ON-Retentive timer is activated by input and starts accumulating time, retains the accumulated value even if the (ladder-logic) rung goes false, and can be reset only by a RESET contact.

Counters are used mainly to count items such as cans entering a box in the assembly line. This is important because when something is fully filled, the item must be moved to fill something else. There are three kinds of counters, up, down and up and down. The counter counts to the preset value, activates the CTU (Count Up output) when the preset value is reached and is cleared when a reset is received. Down counters count down from a predefined value, activate the CTD (Count Down output) when 0 is reached and are cleared after reset. Up / Down counters count on CU, count down on CD, switch on CTUD (Count Up / Down output) when the preset value is reached and reset.

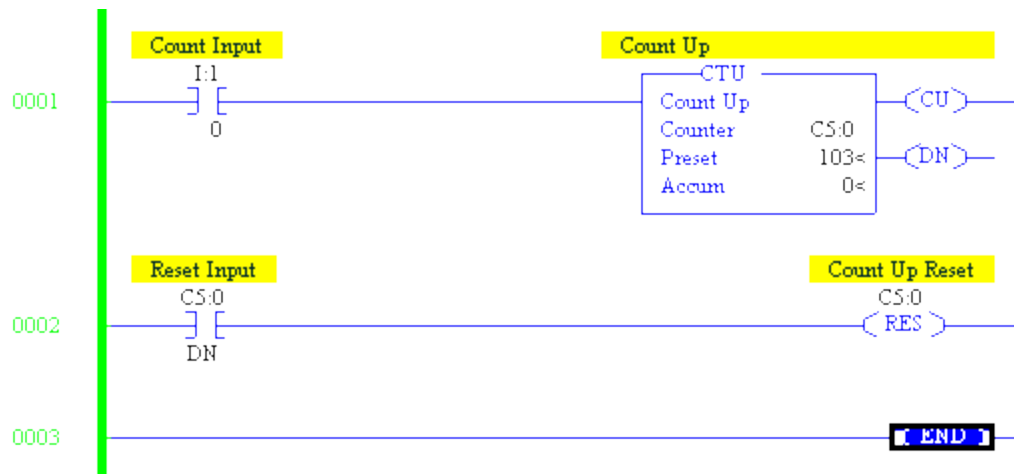


Figure 2.11: Counters

### **2.7.5 Scan time**

Generally, a PLC program loops i.e. repeatedly executes as long as the system is running. The status of all physical inputs is copied to a memory area at the beginning of each execution loop, sometimes called the “I / O Image Table,” which is accessible to the processor.

The program then runs from its first instruction rung down to the last rung. It takes some time for the processor of the PLC to evaluate all the rungs and update the I/O image table with the status of outputs [13]. Scan times of a few milliseconds can be found for small programs and fast processors, but much longer scan times (in the order of 100 ms) can be found for older processors and very large programs. Too long scanning times can mean that the PLC's response to changing inputs or process conditions is too slow to be useful.

As PLCs became more advanced, methods were developed to change the sequence of ladder execution, and subroutines were implemented[14]. This simplified programming could be used to save scan time for high-speed processes, newer PLCs now have the option to run the logic program synchronously with the IO scanning. This means that IO is updated in the background and the logic reads and writes the values during the logic scanning process.

Special I / O modules can be used if the PLC's scanning time is too long to allow predictable performance. Precision timing modules or counter modules for use with shaft encoders are used when the scanning time is too long to reliably count pulses or detect the encoder's sense of rotation. This allows even a relatively slow PLC to still interpret the counted values to control a machine, as the pulse accumulation is performed by a dedicated module which is not affected by the speed of execution of the program on the PLC.

#### **2.7.5.1 Process of a scan cycle**

There are 5 main steps in a scan cycle:



1. Reading inputs
2. Executing the program
3. Processing communication requests
4. Executing CPU diagnostics
5. Writing outputs

### **2.7.5 System scale**

A small PLC will have a fixed number of connections built in for inputs and outputs. Typically, expansions are available if the base model has insufficient I/O.

Modular PLCs have a chassis (also known as a rack), in which modules with various functions are placed. The processor and the selection of I / O modules for the specific application are customized. Several racks can be managed by a single processor and thousands of inputs and outputs are available. Either a special high - speed serial I / O connection or a comparable method of communication is used to distribute racks away from the processor, reducing the cost of wiring for large plants. There are also options for mounting I / O points directly to the machine and using fast cables to disconnect sensors and valves, saving time for wiring and replacing components.

### **2.7.6 User interface**

PLCs may have to interact with people for configuration, alarm reporting or everyday control purposes. A human - machine interface (HMI) is used for this purpose. Machine-man and graphical user interfaces (GUIs) are also called HMIs. A simple system can use buttons and lights to interact with the user. Text and touch - screen graphics are available. More complex systems use software to program and monitor via a communication interface on a computer connected to the PLC.

### **2.7.7 Communications**

Many PLC models are equipped with RS-232, RS-422, RS-485 or Ethernet communications ports. Various protocols are usually included. Most modern PLCs can communicate to another system over a network, such as a computer running a SCADA system (Supervisory Control And Data Acquisition) or a web browser. [15].

PLCs used in larger I / O systems can communicate with peer - to - peer (P2P) processors. This enables separate parts of a complex process to be controlled individually while allowing subsystems to coordinate via the communication link. These links are also frequently used for HMI devices such as keypads or PC workstations.

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## **CHAPTER 3: METHODOLOGY**

### **3.1 Introduction**

This chapter describes an efficient leakage detection approach that solves the water leakage problems using a change in water flow. The technique involves bracketing the test area with two flow meters that monitors the flow rate of the liquid at a given time, paying particular attention on the change of liquid flow rate. Working from the reference valve (V1), which is the first valve that the water passes through, to the measuring flow valve (V2) that is the second valve that measures water flow rate. A comparison on the measurements at V1 and V2 is done, a change in flow rate results in defying the parent theory of continuity principle. Defying of the continuity principle signifies tempering of water flow that means it must be a blockage or leakage, therefore flow of water in this pipe is stopped. The sequence is repeated on branches until it reach households.

The method can effectively narrow down leaks to specific pipe segments of the distribution system. It is an ongoing monitoring and controlling method to minimize supply interruption and inconvenience to households. The method should isolate a faulty section such that only households receiving from the faulty pipe must be affected and other households must receive their water without inconvenience.

A model with a population of 1000 students was used to determine the efficiency of the system in reducing the infection of water-borne diseases.

### **3.2 Continuity Principle**

“Stated simply, what flows into a defined volume in a defined time, minus what flows out of that volume in that time, must accumulate in that volume. If the sign of the accumulation is negative, then the material in that volume is being depleted” [1]. The principle is a consequence of the law of conservation of mass. The behaviour of fluids in motion is fully described by this equation, plus a second equation, based on the second of Newton’s laws of motion, and a third equation, based on the conservation of energy.

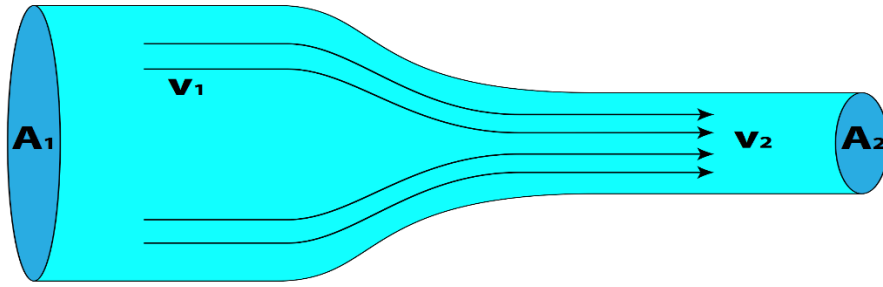
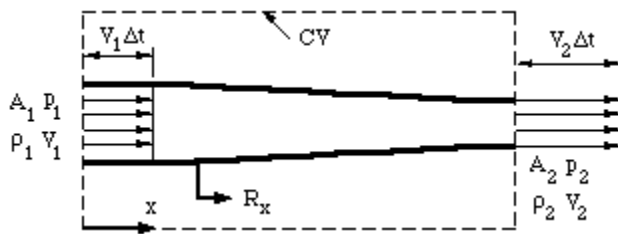


Figure 3.1: Law of Continuity

If the velocity at point P, where the tube has a cross-sectional area  $A_P$ , is  $v_P$  and the velocity in the constriction, where the area is  $A_Q$ , is  $v_Q$ , the continuity condition—the condition that the mass flowing through the pipe per unit time has to be the same at all points along its length—suggests that  $\rho_P A_P v_P = \rho_Q A_Q v_Q$ , or that  $A_P v_P = A_Q v_Q$  if the difference between  $\rho_P$  and  $\rho_Q$  is negligible [2].



$$\text{volume flow in over } A_1 = A_1 V_1 \Delta t$$

$$\text{volume flow out over } A_2 = A_2 V_2 \Delta t$$

Therefore

$$\text{mass in over } A = \rho A_1 V_1 \Delta t$$

$$\text{mass out over } A = \rho A_2 V_2 \Delta t$$

$$\text{So: } \boxed{\rho A_1 V_1 = \rho A_2 V_2}$$

### 3.3 Structure of the Overall System

The overall system consists of the following hardware components

- i. Programmable Logic Controller
- ii. Water flow sensor
- iii. Solenoid valve
- iv. Water level sensor
- v. Water pump
- vi. SCADA Software

The PLC is the central processing unit which is responsible for controlling all the processes and is interfaced with three main subsystems which include:

- The Sensing Unit- Consists of a water flow sensor that monitors the water flow rate and water level sensor in bad water holding tanks.
- Communication and Data Display Unit- consists of the SCADA Software which provides remote information on the reticulation system.
- Control Unit- consists of a DC water pump motor which drives the flow of water and a solenoid valve which controls the flow of water.

These sensors systems are all interfaced with the PLC which acts as the central processing unit. The PLC is then interfaced with the controlling devices which perform the intended actuation.

### **3.4 System Operation**

The project works on the basis of the law of continuity and conservation of mass. **What flows into a defined volume in a defined time, minus what flows out of that volume in that time, must accumulate in that volume [3].** If the sign of the accumulation is negative, then the material in that volume is being depleted. And it is said for a pipe of a the same diameter all way, volume of water at point A must be equal to volume of water at point B , thus no mass has been tempered with therefore satisfying the principle of continuity and conservation of mass. Given the system acts otherwise this implies that within the pipe there is change of water volume somewhere then that means the system is simply not enclosed therefore there is a leakage. Water flow sensors in this case are used to measure rate of flow of water in the pipe at two different points and the results are sent to the Controller Unit for comparison, if flow rate at A is not equal to flow rate at B then the system does not satisfy the principle then there must be a problem with the pipe. A signal is sent to the solenoid valves (to stop the flow further and to redirect the water to holding tanks). When the water in holding tanks is now full the water is automatically redirected to the water works for re-purification process. This whole system will happen remotely and there is need for constant monitoring of the system. Therefore the SCADA system is used to show the ongoing remote process in the control room.

### **3.4 Hardware Implementation**

Connection of the inputs is done directly to the PLC input points and Outputs are done via relay while a power supply is connected to start the PLC since it does not use power from the pc. No soldering is required, so it easy to change connections and replace components.

#### **3.4.2 Interfacing PLC with P.C**

RSLinx Classic is a software used to interface PLC with P.C. The most used methods of connection of PLC to P.C are making use of Ethernet/IP connections and use of RS-232 connections.

## RSLinx Classic

**RSLinx Classic** is an integrated communication server which provides plant-floor device connectivity [4].

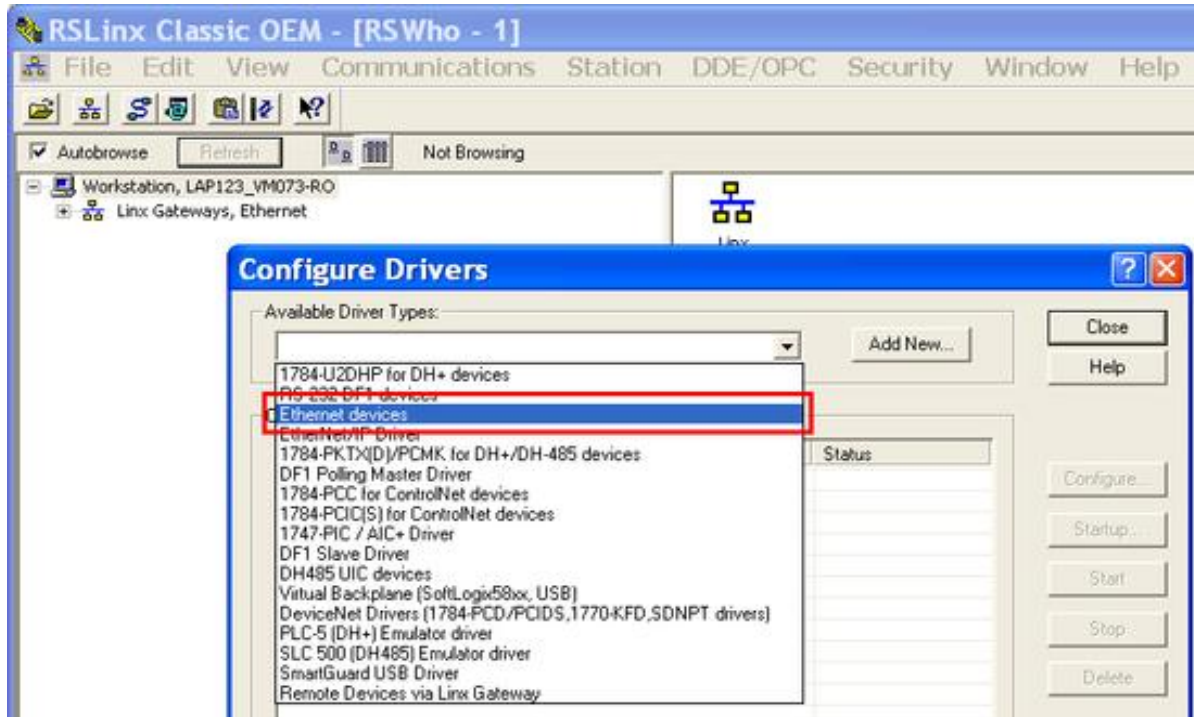


Figure 3.2: Configuring Drivers

### 3.4.2.1 Interfacing PLC with P.C using Ethernet/IP

#### **Step 1) Ethernet Connectivity**

The first step is to insure you have Ethernet connectivity between your PC and MicroLogix PLC by connecting them both to the same physical network and logical network.

1. Using an Ethernet switch is the easiest way to connect your PC to the same physical network as the MicroLogix PLC. You can also connect directly with a crossover Ethernet cable.
2. If a router is not passed, the next PC insured is on the same logical network (subnet) as the MicroLogix system. You can do this by comparing your PC's IP address and subnet mask to your MicroLogix to ensure that it is on the same subnet.
3. The default gateway must be set correctly in both the PLC and your PC when passing through a router.
4. Finally, to check that your PC is able to communicate to your PLC, open a Windows Command Prompt and “Ping” your PLC's Ethernet address (i.e. Ping 192.168.1.10)

**Step 2)** Launch RSLinx Classic, and then under the Communications menu select Configure Drivers:

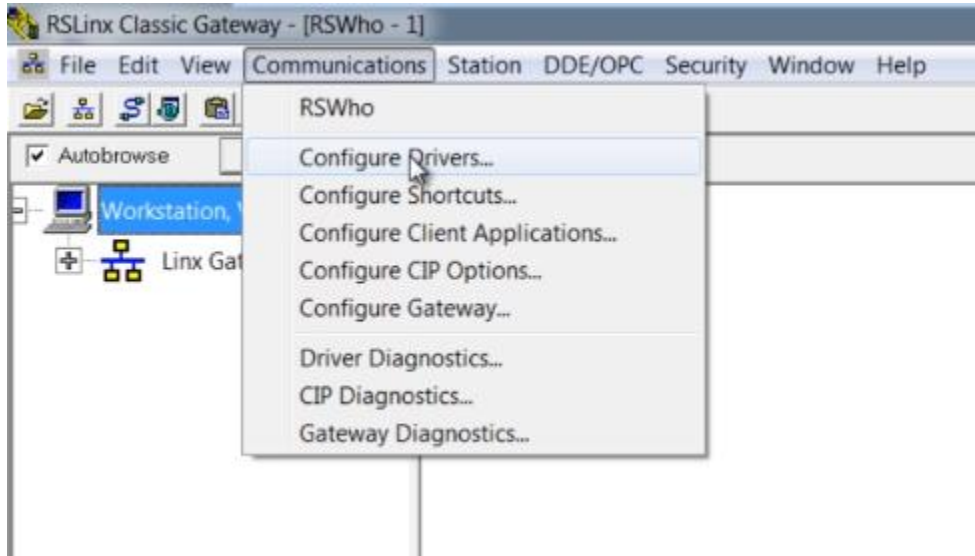


Figure 3.3: Communications

**Step 3)** From the Available Driver Types drop down list select the Ethernet/IP driver, a driver which will attempt to automatically find your MicroLogix on Ethernet:

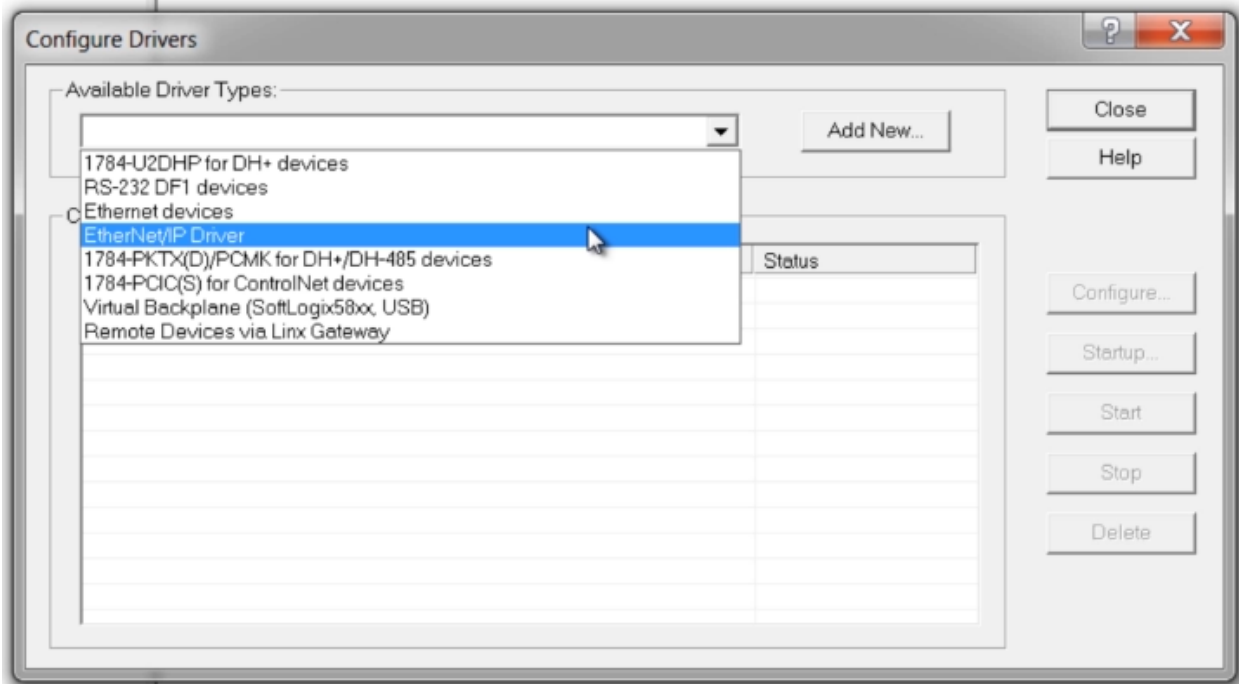


Figure 3.4: Connecting EtherNet/IP Driver

**Step 4)** Next click on Add New



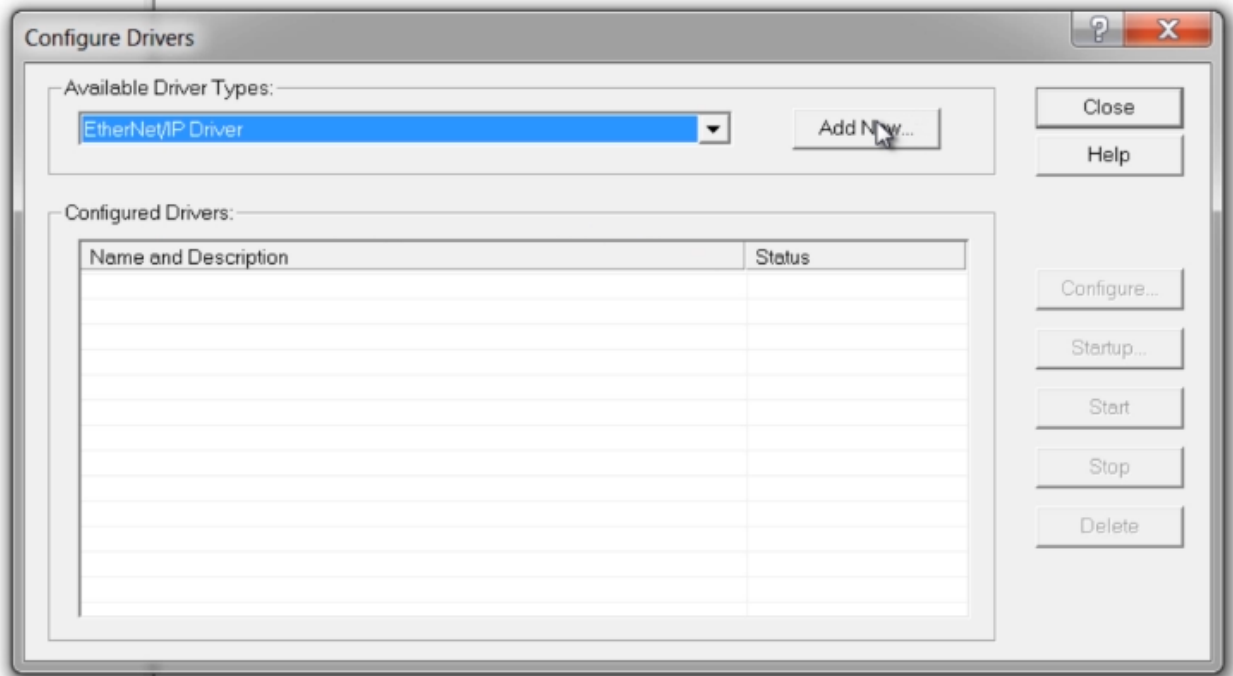


Figure 3.5: Configuring EtherNet/IP Driver

**Step 5)** Accept the default name by clicking on OK:

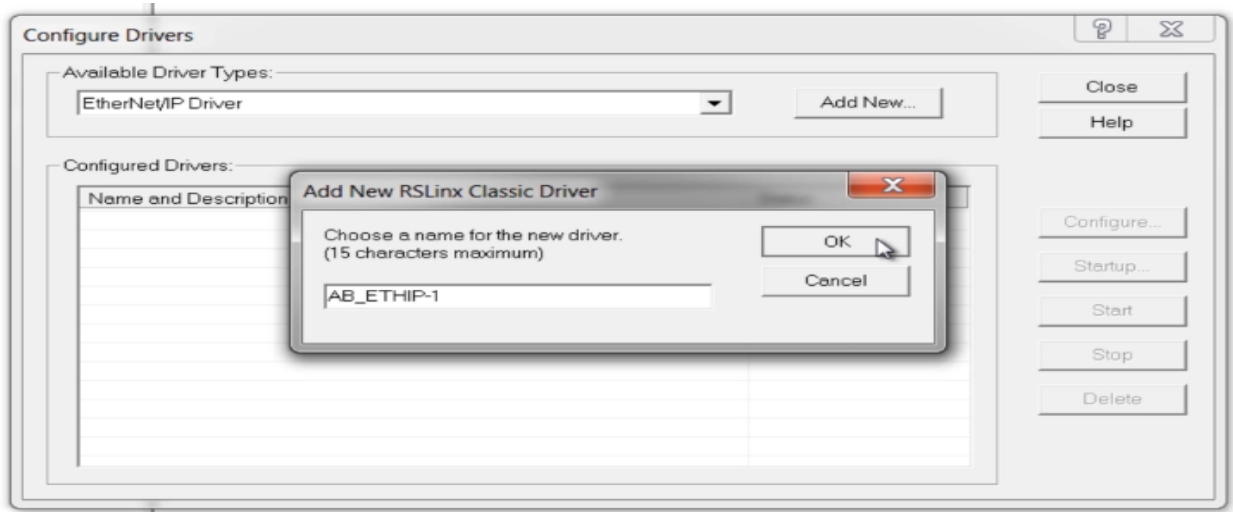
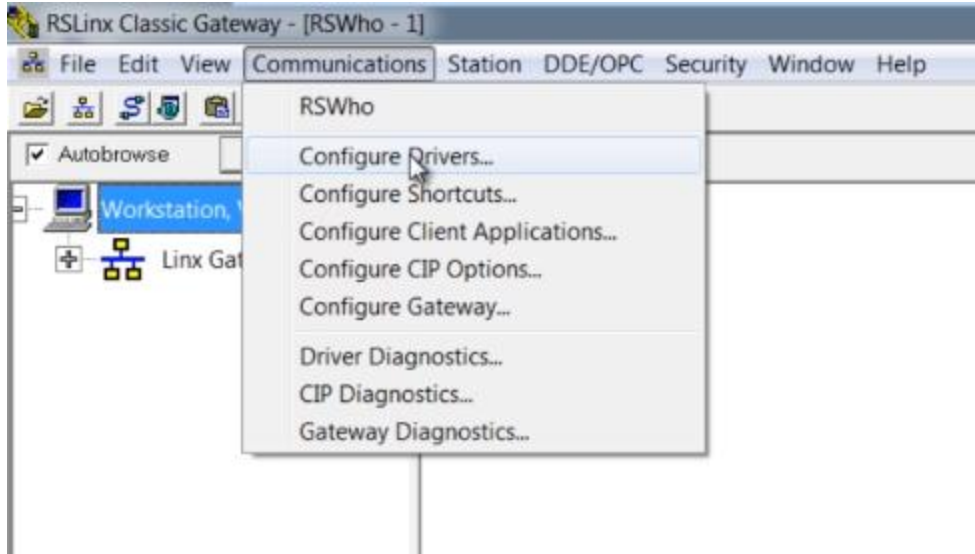


Figure 3.6: Adding New RSLinx Classic Driver

**Step 6)** Click on Close to close the Configure Drivers window:





**Step 3)** From the Available Driver Types drop down list select RS-232 DF1 Devices and then click on Add New:

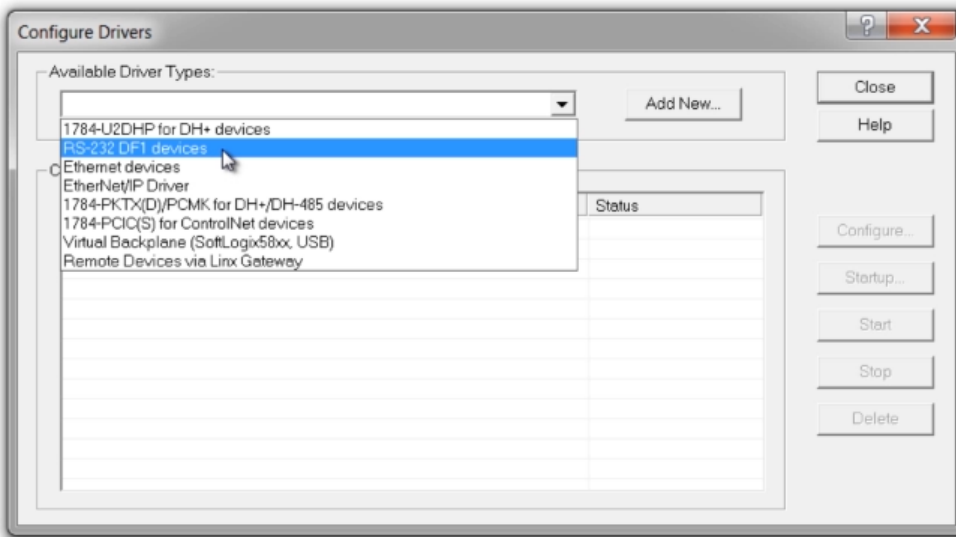


Figure 3.8: Selecting Driver Type

**Step 4)** Accept the default name by clicking on OK:

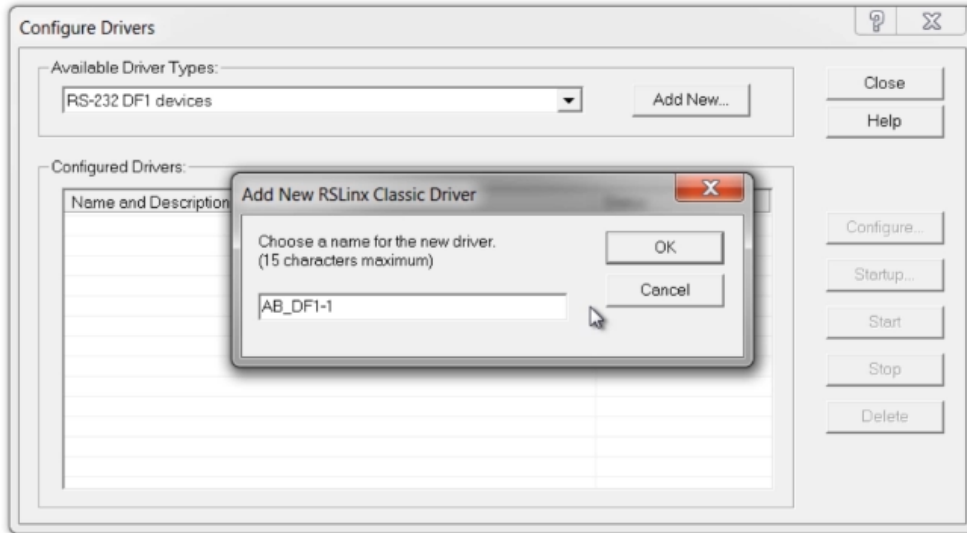


Figure 3.9: Adding New Driver

**Step 5)** Select the COM port you looked up earlier, and check to be sure you have plugged your MicroLogix 1400 into it:

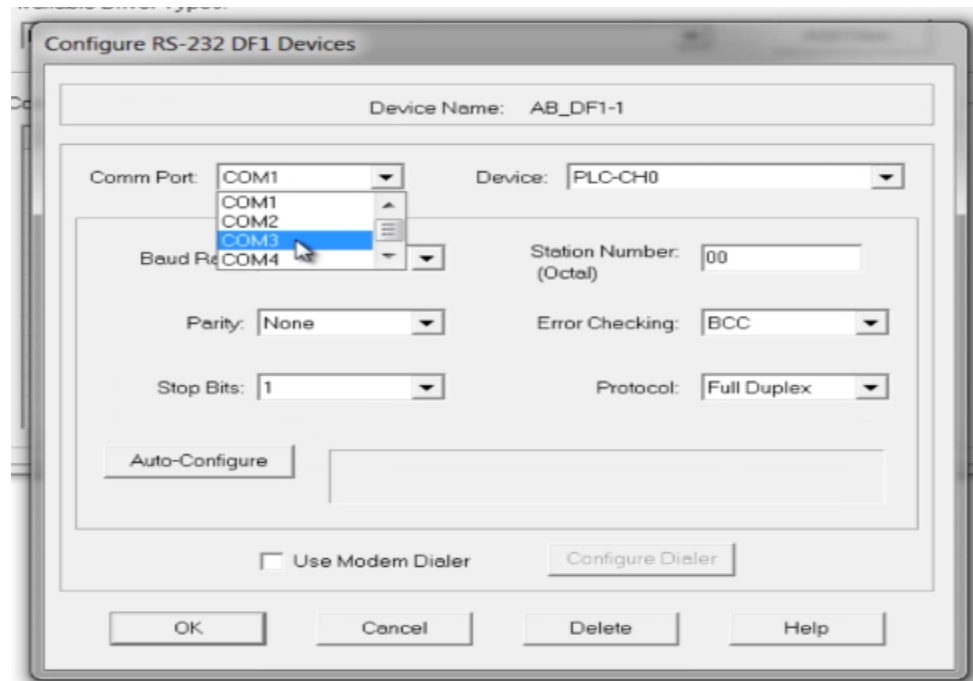


Figure 3.9 : Selecting COM Port

**Step 6)** Click Auto-Configure. If cables and Micro are in working condition, and Micro is set to the default DF1 protocol, then a message, “Auto Configuration Successful” is reflected:

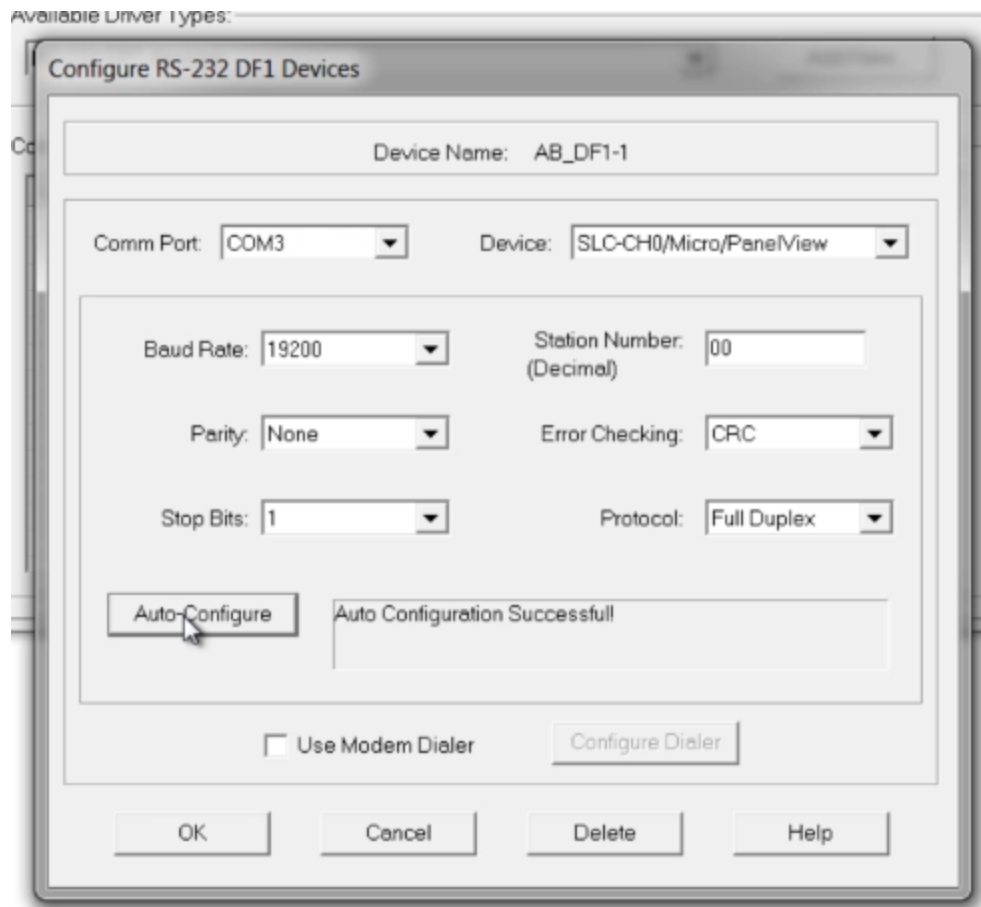
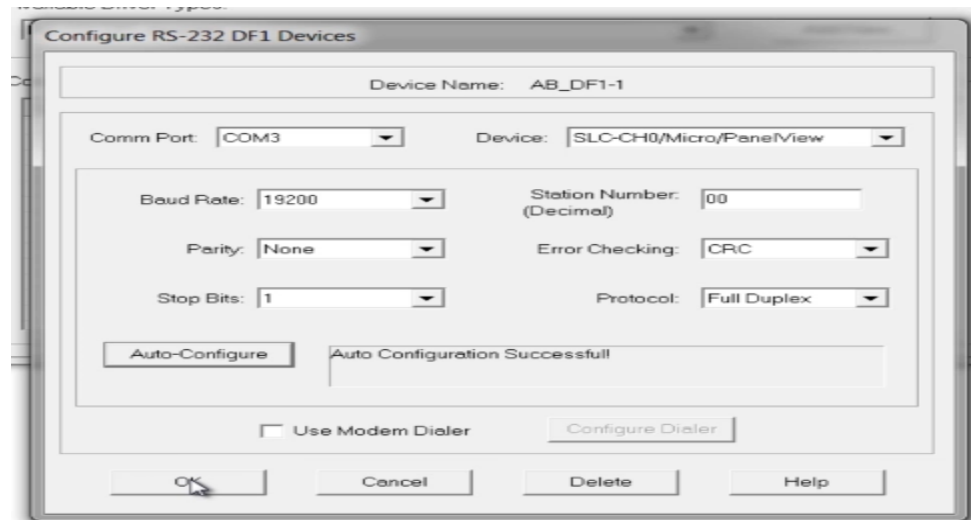
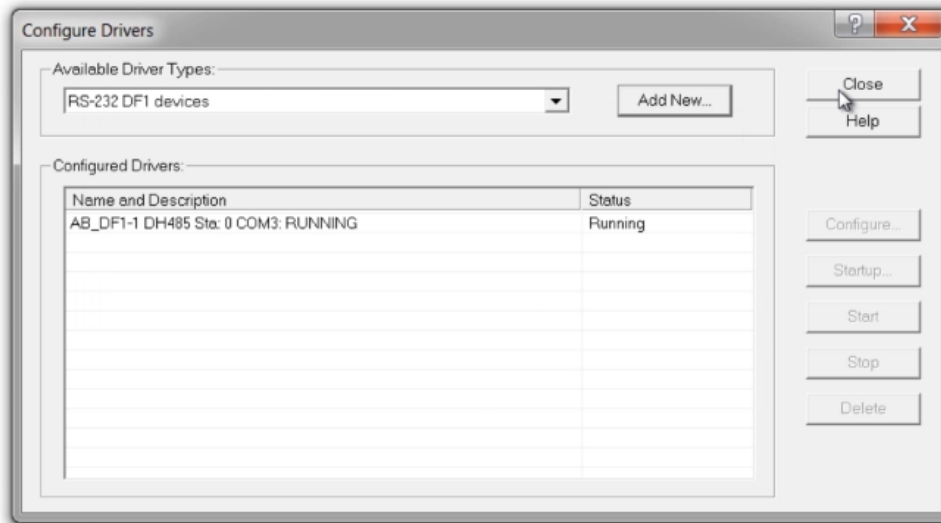


Figure 3.10 : AutoConfiguring

**Step 7)** Click OK to close the RS-232 DF1 Devices driver window:



**Step 8)** Close the Configure Drivers window:

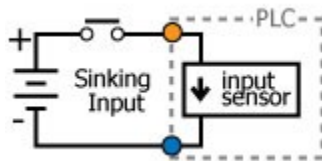


### **3.4.3 Configuring I/O Modules on Micrologix 1400**

#### **Sinking and Sourcing**

#### **NPN (Sinking) Inputs = Ace PLCs Inputs = Positive logic**

- Apply from VDC (+) on **her input**



- Common = **GND (-)**

#### **PNP (Sourcing) Inputs = Negative logic**

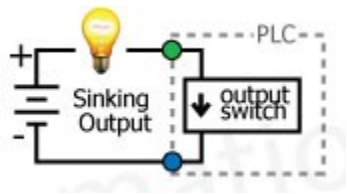
- Apply from GND (-) on **her input**



- Common = **VDC (+)**

### NPN (Sinking) Outputs = Ace PLCs Outputs = Negative logic

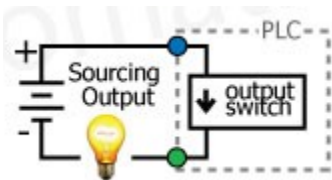
- Your device is connected on **her output** AND on VDC (+)



- Common = **GND (-)**

### PNP (Sourcing) Outputs = Positive logic

- Your device is connected on **her output** AND on GND (-)



- Common = **VDC (+)**

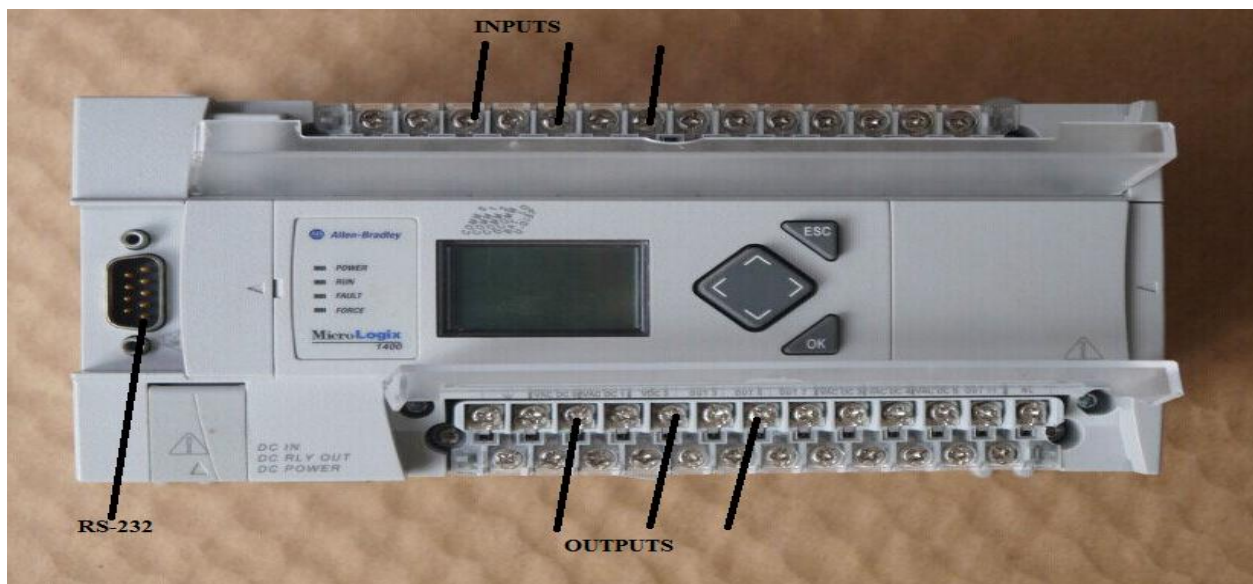


Figure 3.11 : PLC I/O Modules

### 3.4.4 Software Development

### 3.4.4.1 RSLogix 500

The RSLogix 500 has been used for programming. The software works hand in hand with the RSLogix Classic (used to interface the p.c with the PLC). The IEC-1131-compliant ladder logic package RSLogix family helps maximize performance and saves project development time and improve productivity [5].

This product family has been designed to work on Microsoft Windows operating systems, supporting the Allen-Bradley SLC 500 and MicroLogix processor families. The RSLogix 500 programming package is compatible with programs developed with Rockwell Software DOS-based programming packages for the SLC 500 and MicroLogix processor families. RSLogix programming packages are compatible with Rockwell Software DOS-based programming packages for processor families SLC 500 and MicroLogix, making it convenient and easy to maintain programming across hardware platforms. In addition, RSLogix 500 benefits include:

- Cross-reference information
- Drag-and-drop editing
- Diagnostics
- Dependable communications
- Database editing
- Reporting

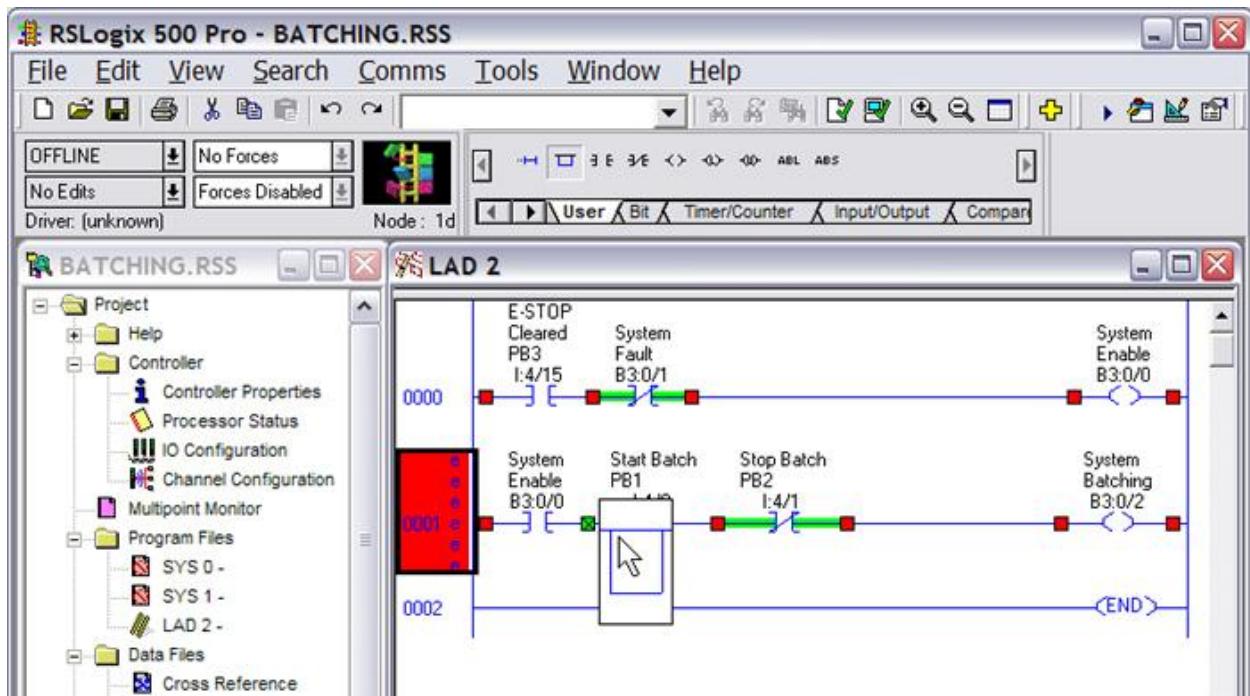


Figure 3.12: RSLogix500



### 3.4.4.2 Ladder Logic Programming

A PLC has many input terminals that interpret "high " and " low" logical states from sensors and switches. Their programming language has been designed to resemble ladder logic diagrams to facilitate programming of PLC. An industrial electrician or electrical engineer used to read the logic schematics of the ladder would therefore feel comfortable programming a PLC with the same control functions.

**Ladder logic** was originally a written method to document the design and construction of relay racks as used in manufacturing and process control [6]. Each device in the relay rack would have a symbol in the ladder diagram with links between the devices. Ladder logic uses switch or relay contacts to implement Boolean expressions. Ladder logic was made possible in the past with discrete relays and was sometimes referred to as "relay logic."

Ladder logic has evolved into a programming language using a graphic diagram based on the hardware circuit diagrams of the relay logic. Ladder logic is used for the development of software for programmable logic control (PLC) used in industrial control applications. The name derives from the observation that programs in this language resemble ladders with two vertical rails and a series of horizontal rungs. Although ladder diagrams were once the only notation available for programmable control programming

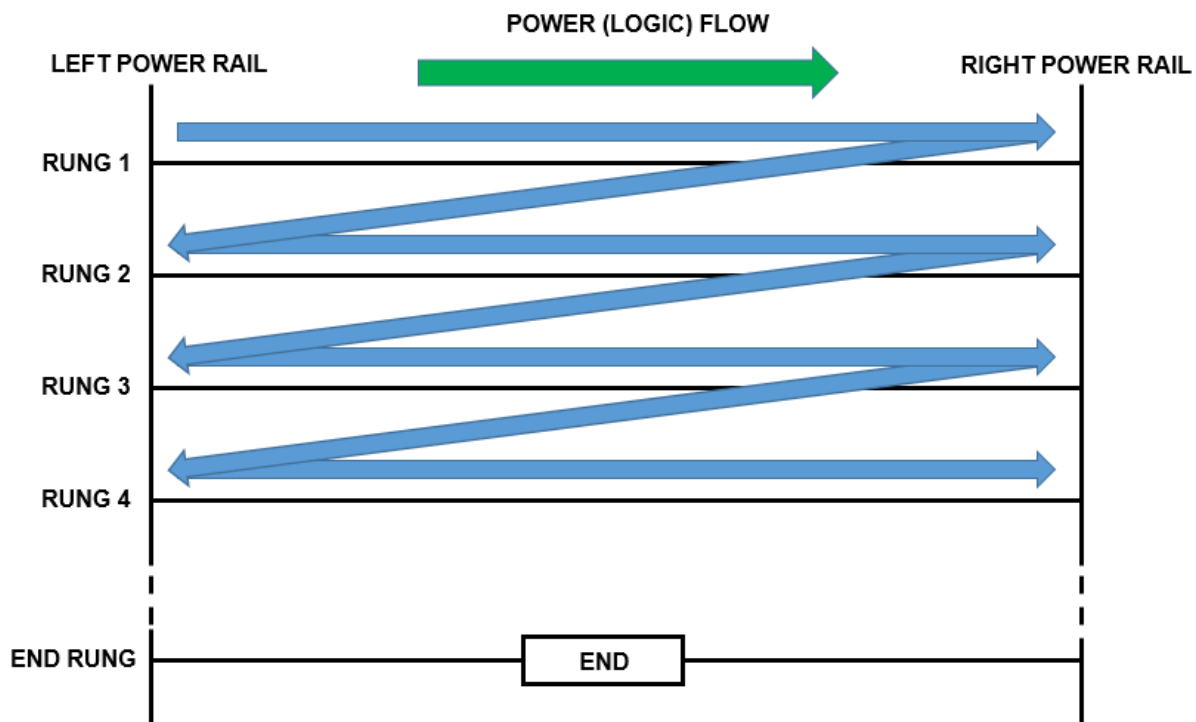


Figure 3.13: Ladder Logic Rungs

A PLC scans every rung from left to right and from top to bottom in the ladder diagram.

Ladder logic is widely used for programming PLCs where sequential process control or production operation is required. Ladder logic is useful for simple but critical control systems or ancient hardwired relay circuits. Due to the sophistication of programmable logic controllers, it was also used in very complex automation systems. The ladder logic program is often used with a HMI program running on a computer workstation.

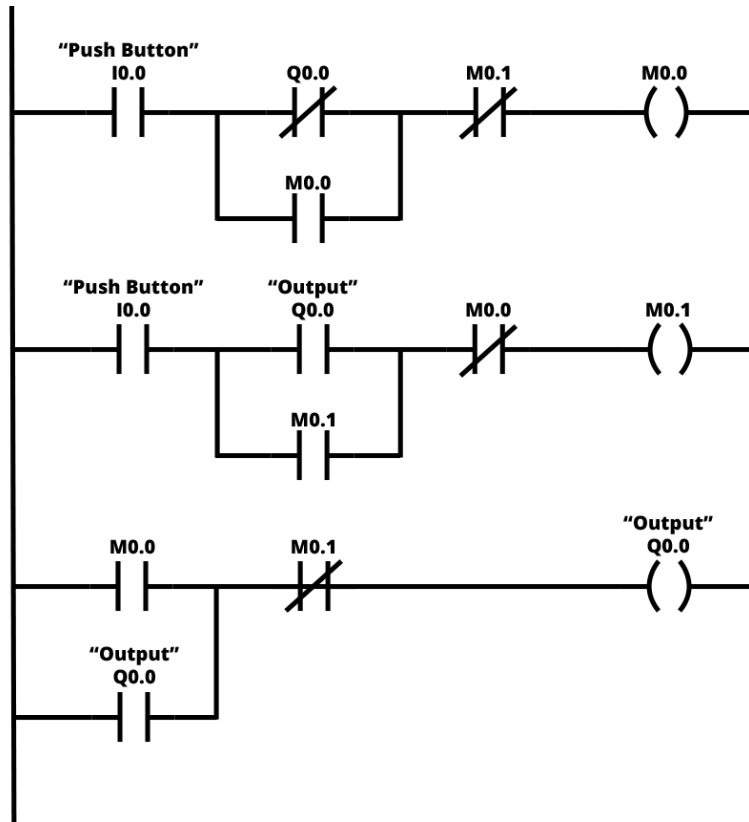


Figure 3.14: PLC program with Toggle or flip-flop function

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## CHAPTER 4: RESULTS AND ANALYSIS

### 4.1 INTRODUCTION

This chapter presents results on the project mainly focusing on the behavior of the system in bid to lower fault response time and reduce the risk of water-borne diseases infection by monitoring and controlling the water reticulation system by the use of PLC and remote terminal units using SCADA mechanism. Notation of the fault-response variation of the system was done. A tabular presentation of results is used to give clarity on the efficiency of the system. Data analysis anterior to the practical results was done to show the co-relation of instrumentation and control with water reticulation system. From a designed prototype and experiments, data was obtained. This data gives precise information on the behavior of water flow rate in support with the law of continuity in fluid mechanics. The resistance of the system to this law was used as a sign of pipe leakage.

### 4.2 Presentation of Results

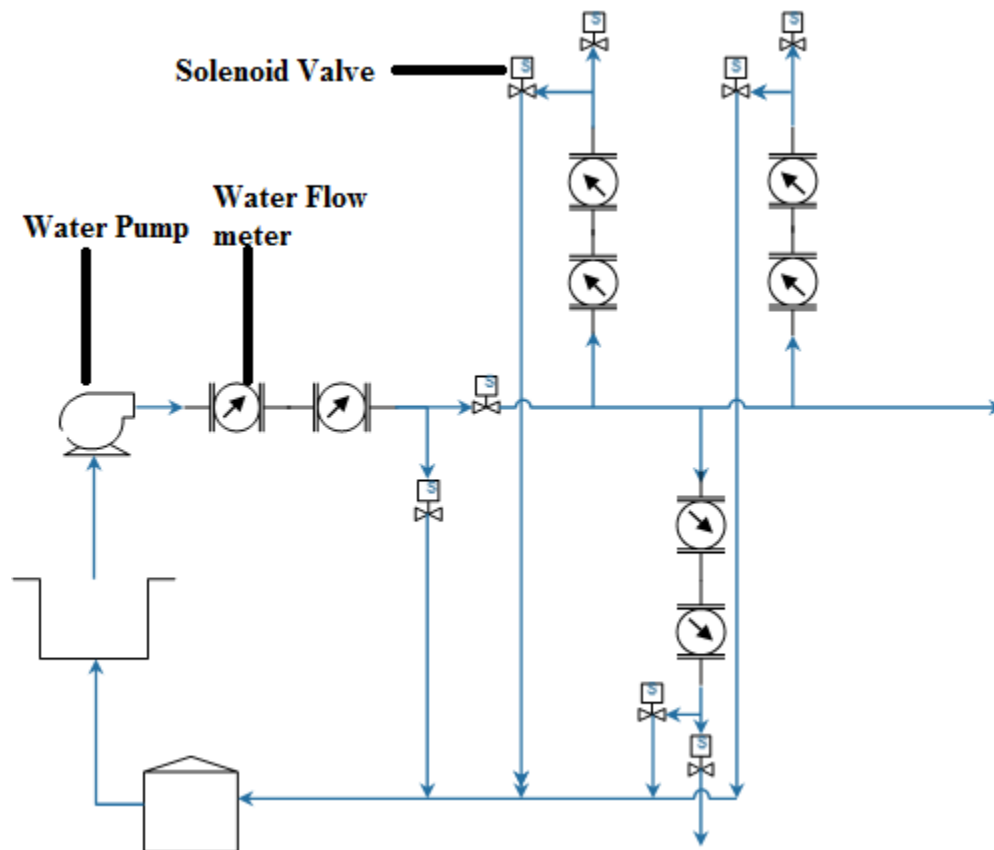


Figure 4.1: Water Reticulation System Connections

WFM_1 Condition	WFM_2 CONDITION	Solenoid Valve
7.6 l/m	$7.6 \pm 0.38$ l/m	High
7.6 l/m	$f < 7.6$ l/m : $f > 7.6$ l/m	Low

Table 4.1: The Effects and the relationship between both water flow meters with solenoid valves

Solenoid_main	Solenoid_main reserve	Solenoid_1	Solenoid_1 reserve	Solenoid_2	Solenoid_2 reserve
High	Low	High	Low	High	Low
High	Low	High	Low	Low	High
High	Low	Low	Low	High	Low
Low	High	Low	High	Low	High

Table 4.2: The Response of the system

### **4.3 Systematic Results, Analysis and Interpretation**

Table 4.1 shows the relationship between the two water flow meters and their effect to the solenoid valves. These results shows the variation of solenoid in response to a change in water flow rate. A change in water flow rate is used to detect pipe leakage since change of water flow rate within the pipe without an external effect defies the law of continuity and conservation of mass in fluid mechanics. Therefore a change recorded by these flow meters turns off the corresponding solenoid valves.

Table 4.2 shows the relationship between all the solenoid valves. These results further classifies the other objective of this project of improving reliability by isolating a fault so that it won't affect households without faulty system. It also shows the effect of a fault with the reserve system. The reserve system is used to hold the bad water when a fault occurs. In a bid to reduce the risk of water-borne disease infection, the system must not allow people to receive water that went through a pipe leakage because that water is no longer regulated. Therefore when a fault is detected as tabulated in table 4.1 solenoid valve is switched off and reserve water solenoid valve is switched on. This is there not to allow unregulated water which is referred to as bad water to reach households.

This system also improves the fault response time compared to the current system. This system notifies the monitoring and control room that there is a faulty pipe but the portal or section is now closed.

## **4.4 Statistical Results, Analysis and Interpretation**

### **4.4.1 Dead Time**

This is the delay when a controller output is issued until the system stabilizes. This is when the process variable (PV) begins to respond to the system. The approximate dead time of the system is 5 seconds.

### **4.4.2 Gain of the system**

Gain – is the sensitivity variable. It determines the relative distance that the Process Variable travels in response to a change in the Controller Output.

So to overcome such errors use of 5% error toleration, this percentage error toleration prevents the system from constantly faulting and it is lower than the estimated percentage change after a fault.

Therefore      Input = 7.6 l/m

$$\text{Output} = (7.6 \pm 0.38) \text{ l/m}$$

To determine efficiency of the machine minimum output will be used:

$$\begin{aligned} \text{Efficiency} &= \frac{\text{min output}}{\text{Input}} \times 100 \\ &= \frac{7.22}{7.60} \times 100 \\ &= \underline{\underline{92.56 \%}} \end{aligned}$$

### **4.4.3 Access of Water from the Water Authority**

Due to the sinking of the boreholes and wells, about 10% of the population now depend on their own sources of water, leaving 90% of the population depending on the water supplied by the council [1]. A model with a population of 1000 will be used in determination of the efficiency of the system in reducing the infection of water borne diseases. A total population of 900 will receive water from the system. The World Health Organization (WHO) estimates that a marginal percentage of the population in urban towns and cities in developing countries suffer from waterborne diseases every year and that some react slowly to these diseases because they act as carriers [2].

Modelling with a population of 1000, the system will show its effectiveness in lowering the risk of water-borne diseases infections.

$$\begin{aligned} \text{No of people depending on council water} &= \frac{90}{100} \times 1000 \\ &= \underline{\mathbf{900}} \end{aligned}$$

$$\begin{aligned} \text{No of infected people annually} &= \frac{30}{100} \times 900 \\ &= \underline{\mathbf{270}} \end{aligned}$$

**An estimated of 88% diarrhoeal disease cases are attribute to unsafe water.**

Therefore an annually estimation population of infected people is

$$\begin{aligned} &= \frac{88}{100} \times 270 \\ &= \underline{\mathbf{237}} \end{aligned}$$

*From the statistical analysis, 237 per 1000 annually are infected due to unsafe water. Therefore the system is 92.7% efficient in supplying people with safe and clean water.*

$$\begin{aligned} \text{Therefore} &= \frac{92.7}{100} \times 237 \\ &= \underline{\mathbf{219}} \end{aligned}$$

Percentage decrease in number of infected people who are infected annually

$$\begin{aligned} &= \frac{219}{270} \times 100 \\ &= \underline{\mathbf{81.1 \%}} \end{aligned}$$

The project decreases an annually rate of water-borne diseases infections with **81.1 %**.

#### **4.4.4 Presentation of Results**

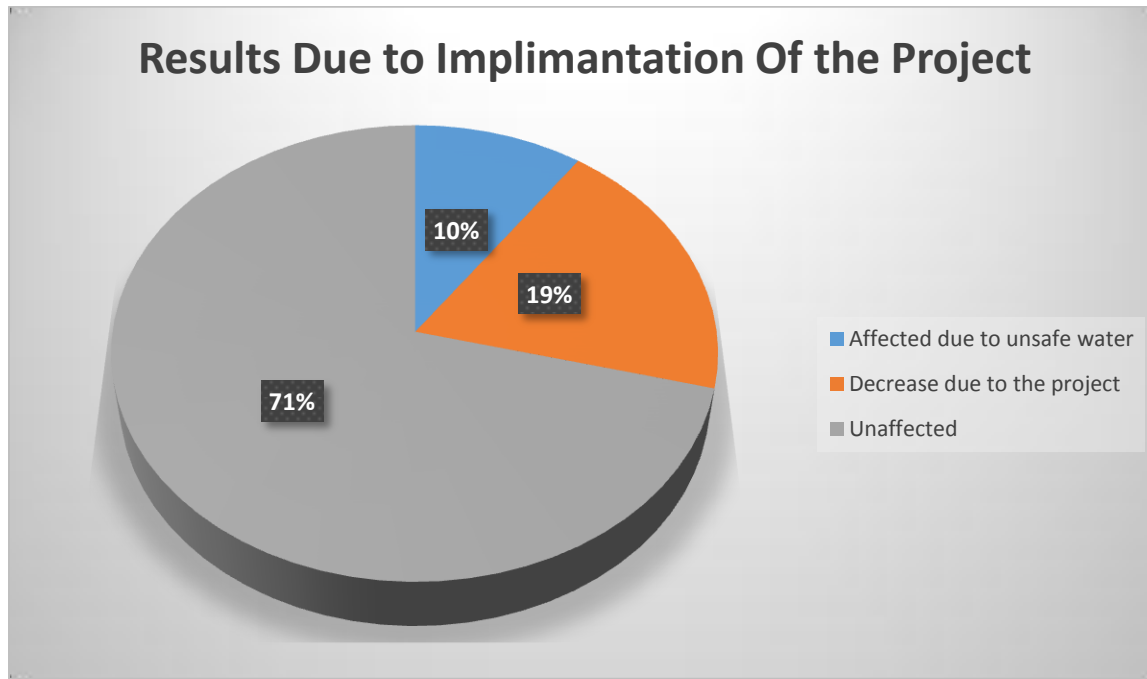


Figure 4.2: Results

#### **4.5 Prototype Overview**

The prototype and the HMI system was successfully designed within the planned time frame. The hardware components were successfully integrated into one complete working system and responded well to the ladder logic from the MicroLogix 1400 PLC. The developed system has seven inputs and nine outputs. The inputs are analog while the outputs are digital. At the input side there are sensors these are connected to input of the PLC on 24Vdc.

All the outputs are connected to the output pins of the PLC and assigned to fixed memory address, the output is digital. Output status is displayed on the HMI. The prototype automation system started working by running the water through all points to stabilize the system for an effective use of the system. The DC pump is always ON pumping water into the system, when a fault is detected, the distribution valve is closed. To identify the leakages in the pipes we used changes in flow rate.



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## **CHAPTER 5: CONCLUSION AND RECOMMENDATIONS**

### **5.1 Introduction**

The prototype which monitors and controls the water reticulation system using changes in flow rate was successfully built. The hardware components were successfully integrated with the PLC into a complete working system and operated well with the software.

### **5.2 Discussion**

Automated Water Reticulation system will help in reducing the water-borne disease cases. Furthermore it can indicate the amount of water flowing in the system and as well to lessen water loses for remote pipes. Whereby using the current system at water authority, all the processes are done manually and need human assistance. The prototype also assures students with clean and safe water to consume.

### **5.3 A Summary of the Results**

The mainline is the main source of water supply. There is no water distribution to watering points from the mainline. Sub-mains are connected to the main line and are usually located along the main service or feed delivery roads. Branches are connected to the submains and the watering points are located on the branches. The main controls all other lines. While isolation of a fault so that it won't affect people without faulty lines. A change in flow rate would switch a pipe section that it is under, such that water passing through that pipe won't be consumed by people. This project ensures that students receive safe and clean water, as the system quickly responds to faults.

### **5.4 Challenges Anticipated in the adoption of the Water Reticulation System**

#### **5.4.5 Solenoid Valves**

##### **5.4.5.1 Not Opening**

Solenoid valves may not open due to power failure, uneven pressure, incorrect voltage, and dirt below the diaphragm, corrosion, missing components or burning out of the coil. Since there are so many causes, however, you must try to solve the problem. In this process, the most important parts to evaluate are the valve diaphragm, diaphragm spring, coil power, flow control adjustment, valve inlet port, solenoid outlet port and the valve bleed port.

##### **5.4.5.2 Valves Partly Close**

Valves can sometimes fail to close. This can be due to manual override, difference in pressure, residual coil power, damaged tube, inverted or damaged valve seats and some missing components. Check your wiring, lead connections, components and diaphragm thoroughly to see what the specific problem is. You can also try to lift the spool slightly to check whether there is an electromagnetic field.

## **5.4.6 Water Flow Meter**

### **5.4.6.1 Scaling**

This describes objects created by metal ions in groundwater or tap water that have been crystallized and attached to the inner walls of the tube. They are made up of calcium, magnesium and sodium. If too many layers are built, the flow path inside the piping narrows and limits flow. There is also the possibility that the scaling is connected to the inside of the flow meter and affects its operation negatively.

### **5.4.6.2 Slime**

The flow pipe has a free - flowing structure with an electromagnetic flow meter, so that accumulation and clogging do not take place. It is also possible to detect because the slime itself has electrical conductivity.

### **5.4.6.3 Rust**

Corrosion inhibitors can be added to the fluid to prevent rust, but rust occurs if unused pipes come into contact with air. Once water flows again through the pipes, the rust becomes fragments that flake off and become the cause of clogging in the flow meter or attaching floating element flow meters to the window sections.

## **5.5 Recommendations**

- The system can be improved by using acoustic waves in order to pin point the exact location of a leak and they produce a distinct sound at the point of the leak.
- In order to ensure adequate pressure in the distribution network, a demand driven distribution system where the pumping rate is regulated by water demand using a VSD is recommended.
- Use of Geophone to detect micro location of the leak by the noise listening, this method is not efficient and reliable since it cannot detect remotely.

## **5.6 Conclusion**

The results obtained during testing and implementing of the project were as expected and fulfilled the objectives of the project. However, the behavior of the flow sensors was not consistent. This would have been due to their large tolerance of +/-10%.