CHAPTER 1
INTRODUCTION

1.1 Background of thesis

A firefighting system, as the name suggests is a system concerned with extinguishing fire using sensors. Such an automated Programmable Logical Controller (PLC) system uses a Jockey Pump, a Main Pump and a Diesel engine. The PLC also monitors the operation of the Diesel engine. In advent of a fire, there should be a continuous flow of water through the hydrant line, pressure of which is regulated using pressure switches. Depending upon the magnitude of fire, the PLC is programmed to interface one of the three, (Jockey Pump, Main Pump or the Diesel Engine) thus extinguishing the fire [1].

Automation is largely used in various industries taking into consideration its various advantages such as, reduction in manpower, improvement in accuracy, efficiency and speed of production.

This thesis entails how to extinguish fire using Programmable Logical Controller (PLC). In industries, malls and theatres during advent of fire, there should be a continuous flow of water through the hydrant line, pressure of which is monitored using pressure switches. If pressure of water goes below the specified level then the pumps connected to elimination of the hydrant line are turned ON, which results in increase of water pressure, thereby extinguishing the fire. In case of severe fire the mains supply has to be switched off. So to keep the pressure in the hydrant line constant, diesel engine is used to drive the pump. Thus the diesel engine should be in healthy condition to be able to extinguish the fire. Hence to control the parameters of diesel engine, we are developing the ladder logic for automatic control of Diesel Engine by converting the conventional PCB based control panel to PLC based control panel [2].

1.2 Problem Statement

The current firefighting pressure pumps controlled conventionally via mechanical relays and contactors. This type of control has many defects such as malefaction of contactors and relays, difficulty of wiring as well as it has no extending input/output arrangements.

1.3 Problem Solution

Obverse, PLC based pumps control will contribute to overcome these problems as PLC is a reliable and accurate control device that can control variety of automated systems. Moreover, PLC can easily be reprogrammed and rewired.

1.4 Aim and Objectives

The main aim is to design and implement PLC based firefighting system which will able to control firefighting pumps using PLC

The objectives are:

1. To propose a control system using PLC.
2. Simulation of the proposed system.

3. Practical implementation of the proposed system.
4. Performance evaluation.

1.5 Significance of the Thesis

The significance of this thesis is to provide a technical solution for the requirement of the Programmable Logic Controller (PLC) for a firefighting pumping system. Clearly, this system is not the only solution to the problem of a firefighting pumping system control, but it is an idea where PLC offers a unique and useful features that will be beneficial to current technology.

1.6 Limitations of the Thesis

- This thesis is considering only the pumping system not the fire sensing system.
- The water tank filling pump is controlled manually.

1.7 Organization of the Thesis

This thesis basically will discuss about the construction of the PLC based controlled fire fighting pumps. First chapter of this thesis discusses on the introduction of the project. Second chapter will discuss on the literature review while third chapter focuses on the research methodology, mechanical design, electronic design and software development. The result and analysis will be discussed in the fourth. The conclusion and recommendation of this thesis were described in the last chapter.

CHAPTER 2
LITERATURE REVIEW

2.1 Overview

Fire is the rapid oxidation of a material in the exothermic chemical process of combustion, releasing heat, light, and various reaction products. The flame is the visible portion of the fire. If hot enough, the gases may become ionized to produce plasma. Depending on the substances alight, and any impurities outside, the color of the flame and the fire's intensity will be different. Fire in its most common form can result in conflagration, which has the potential to cause physical damage through burning. Fire is an important process that affects ecological systems around the globe. The positive effects of fire include stimulating growth and maintaining various ecological systems. Fire has been used by humans for cooking, generating heat, light, signaling, and propulsion purposes [1].

The negative effects of fire include hazard to life and property, atmospheric pollution, and water contamination. Firefighting is the act of extinguishing fires. A firefighter suppresses and extinguishes fires to protect lives and prevent the destruction of property and the environment. Firefighters may provide many other valuable services to their communities including emergency medical services. Firefighting requires professionals with a high technical skill who spend years training in both general firefighting techniques and specialized areas of expertise. Some of the specialized areas of fire and rescue operations include Aircraft/airport rescue; Wild land fire suppression; and Search and rescue [1].

One of the major hazards associated with firefighting operations is the toxic environment created by combusting materials. The four major hazards associated with these situations are smoke, the oxygen deficient atmosphere, elevated temperatures, and toxic atmospheres. Additional risks of fire include falls and 5 structural collapses. To combat some of these risks, firefighters carry self-Contained breathing apparatuses [1].

The first step of a firefighting operation is a reconnaissance to search for the origin of the fire and identification of the specific risks and any possible casualties. A fire can be extinguished by water, fuel removal, or chemical flame inhibition. In the US, fires are sometimes categorized as "one alarm", "all hands", "two alarm", "three alarm" (or higher) fires. There is no standard definition for what this means quantifiable though it always refers to the level response by the local authorities. In some cities, the numeric rating refers to the number of fire stations that have been summoned to the fire. In others, the number counts the number of "dispatches" for additional personnel and equipment [2].

2.2 History of Fires

The earliest known firefighters were in the city of Rome. In 6 A.D., Emperor Augustus made the Corps of Vigils to protect Rome after a disastrous fire. The Corps of Vigils consisted of 7000 people. They were equipped with buckets and axes, and they fought fires and served as police [3].

2.2.1 Old Tactics and Tools

In 4th century B.C. , an Alexandrian Greek named Ctesibuis made a double force pump called a 'siphona'. As water rose in the chamber, it compressed the air inside which forced the water to eject in a steady stream through a pipe and nozzle [4].

In the 16th century, syringes were also used as firefighting tools. The larger ones were usually put on wheels.

Another tactic that was used was the bucket brigade. The villagers would form two lines between the water source and the fire. The men would pass along the full buckets of water to the fire. The women and children would pass back the empty buckets to be refilled.

In the 17th century, fire engines were being made and the best one was made in Amsterdam. In 1721, Richard Newsham made a fire engine that was very popular. It was basically a rectangular box on wheels. The bucket brigade would pour water into the machine and the men would supply the power to produce the water pressure [4].

The first American attempt at fire insurance failed after a large fire in Charlestown, Massachusetts in 1736. Later in 1740, Benjamin Franklin organized the Philadelphia Contribution ship to provide fire insurance, which was more successful. The Contribution ship adopted "fire marks" to easily identify insured buildings. Firefighting started to become formalized with rules to provide buckets, ladders, hooks, and the formation of volunteer companies. The chain of command was also established [5].

2.3 Classification of Fires

Fires are classified by the types of fuel they burn. As follow

Class A:

Ordinary, combustible materials i.e. wood, cloth, paper, some rubber and plastic materials.

Class B:

Class B includes Flammable liquids, gases, greases, and some rubber and plastic materials.

Class C:

Live electrical equipment, when equipment is reenergized, extinguishers for class A or B fires could be used safely; however, in fighting an electrical fire there are two important things to be taken into consideration: namely (a) damage to the equipment far beyond what the fire could do, and (b) danger to the individuals fighting the fire. To avoid these two possibilities, deenergize the circuit and use only the types of extinguishment recommended for class C fires.

Class D:

Combustible metals such as magnesium, titanium, sodium, potassium, lithium, and zirconium. The International Maritime Organization (IMO) mentions two standards in IMO Resolution A. 602(15) which define the various classes of fires. The first is the International Standards Organization (ISO) Standard 3941, and the second is the National Fire Protection Agency (NFPA), Table 1 identifies these classes of fire as they are listed in IMO

Resolution A. 602(15). IMO Resolution A. 602(15) is included in Annex of the International Code for Fire Safety System (IMO FSS Code).

Table 2.1: Fire Classification.

ISO Standard 3941	**NFPA 10**
Class A: Fires involving solid materials, usually of an organic nature, in which combustion normally takes place with the formation of glowing embers	Class A: Fires in ordinary combustible materials, such as wood, cloth, paper, rubber and many plastics.
Class B: Fires involving liquids or liquefiable solids.	Class B: Fires in flammable liquids, oils, greases, tars, oil-based paints, lacquers and flammable gases.
Class C: Fires involving gases.	Class C: Fires which involve energized electrical equipment where the electrical Non-conductivity of the extinguishing medium is of importance.
Class D: Fires involving metals.	Class D: Fires in combustible metals, such as magnesium, titanium, zirconium, sodium, lithium and potassium.

2.4 Fire Protection Engineering

Fire engineering is the application of science and engineering principles to protect people, property, and their environments from the harmful and destructive effects of fire and smoke. It encompasses fire protection engineering which focuses on fire detection, suppression and mitigation and fire safety engineering which focuses on human behavior and maintaining a tenable environment for evacuation from a fire. The discipline of fire engineering includes, but is not exclusive to:

- Fire detection: fire alarm systems and brigade call systems.
- Active fire protection: fire suppression systems
- Passive fire protection: fire and smoke barriers, space separation
- Smoke control and management
- Escape facilities: Emergency exits, Fire lifts etc.
- Building design, layout, and space planning
- Fire prevention programs
- Fire dynamics and fire modeling
- Risk analysis, including economic factors

Fire protection engineers identify risks and design safeguards that aid in preventing, controlling, and mitigating the effects of fires. Fire engineers assist architects, building owners and developers in evaluating buildings' life safety and property protection goals. Fire engineers are also employed as fire investigators, including such very large-scale cases as the analysis of the collapse of the World Trade Centers.

2.5 Fire-fighting Systems Classification

The firefighting system can be classified into five types.

2.5.1 Fire Main Systems

The fire main is a system consisting of sea inlet(s), suction piping, fire pumps and a distributed piping system supplying fire hydrants, hoses and nozzles located throughout the vessel. Its purpose is to provide a readily available source of water to any point throughout the vessel which can be used to combat a fire and is considered the backbone of the firefighting systems onboard a vessel [6].

Through the fire main system, the firefighter is provided with a reliable and versatile system capable of providing a number of different methods with which to engage a fire. Water can be supplied as a straight stream for combating deep seated fires, as a spray for combating combustible liquid fires where cooling and minimum agitation is desired or as a means to protect personnel where cooling is the primary effect desired [6].

2.5.2 Foam Fire Extinguishing Systems

Foam is produced by the combination of three materials:

- Water
- Air
- Foam making agent.

Foam is formed by first mixing the foam-making agent (foam concentrate) with water to create a foam solution. The actual foam bubbles are created by introducing air into the foam solution through an appropriate aerating device. The correctly chosen foam concentrate, when properly proportioned with water and expanded with air through an application device, will form finished foam. The foam concentrate is required to be thoroughly mixed with water at a particular concentration to produce the foam solution needed to create the desired foam. Two of the most common concentrations are 3% and 6% foams. These values are the percentages of the concentrate to be used in making the foam solution. Thus, if 3% concentrate is used, three parts of concentrate must be mixed with 97 parts of water to make 100 parts of foam solution. If 6% concentrate is used, six parts of concentrate must be mixed with 94 parts of water [7].

2.5.3 Gas Carrier Cargo Area Fire Extinguishing Systems

Gas carriers present a number of unique fire hazards. Therefore, the fire-fighting systems used must be carefully reviewed to ensure they are adequate for the dangers involved. The unique hazards associated with gas carriers include:

- Boiling Liquid Expanding Vapor Explosions (BLEVEs).
- Vapor release of cargo, leading to creation of gas clouds.
- Liquid pool fires, where discharge of water would only increase the evaporation rate and intensify the fire.
- Jet fires.

2.5.4 Water Spray Type Fixed Fire Fighting System

Water spray is defined as water in a specific form having a specific pattern, particle size, density and velocity which is discharged from specially designed nozzles or equivalent devices. Types of fire hazard are protected by water spray systems [8].

2.5.5 Foam Water Spray Fire Fighting Systems

Foam water systems generally work by allowing foam concentrate to mix with water flowing into the piping system. These systems are equipped with a bladder tank containing foam. When a fire is detected a signal is sent to the releasing panel to open the deluge valve allowing water to flow. At the same time, piping to the bladder tank flows and pressurizes the outer shell of the bladder tank which forces foam concentrate to travel into the system piping and then into the Foam Proportioner. The foam solution produced by water and foam concentrate flows into the system piping and is discharged through the open nozzles or sprinklers [9].

2.6 Fire Main Systems Structure

A firefighting system is probably the most important of the building services, as its aim is to protect human life and property, strictly in that order; it consists of three basic parts:

- a large store of water in tanks, either underground or on top of the building, called fire storage tanks
- a specialized pumping system,
- a large network of pipes ending in either hydrants or sprinklers (nearly all buildings require both of these systems).

2.7 Fire Pumping System

Fire pumps are usually housed in a pump room very close to the fire tanks. The key thing is that the pumps should be located at a level just below the bottom of the fire tank, so that all the water in the tanks can flow into the pumps by gravity [8].

Like all important systems, there must be backup pumps in case the main pump fails. There is a main pump that is electric, a backup pump that is electric, and a second backup pump that is diesel-powered, in case the electricity fails, which is common. Each of these pumps is capable of pumping the required amount of water individually; they are identical in capacity [8].

There is also a fourth type of pump called a jockey pump. This is a small pump attached to the system that continually switches on to maintain the correct pressure in the distribution systems, which is normally 7 Kg/cm2 or 100 psi. If there is a small leakage somewhere in the system, the jockey pump will switch on to compensate for it [8].

The pumps are controlled by pressure sensors. When a fire fighter opens a hydrant, or when a sprinkler comes on, water gushes out of the system and the pressure drops. The pressure sensors will detect this drop and send a digital signal to a PLC which switches the fire pumps on [8].

Figure 2.1: Firefighting Pumps.

2.8 Fire Hydrant

A fire hydrant is a vertical steel pipe with an outlet; close to which two fire hoses are stored (A fire hydrant is called a standpipe in America). During a fire, firefighters will go to the outlet, break open the hoses, attach one to the outlet, and manually open it so that water rushes out of the nozzle of the hose. The quantity and speed of the water is so great that it can knock over the firefighter holding the hose if he is not standing in the correct way. As soon as the fire fighter opens the hydrant, water will gush out, and sensors will detect a drop in pressure in the system. This drop in pressure will trigger the fire pumps to turn on and start pumping water at a tremendous flowrate [8].

Figure 2.2: Fire Hydrant.

2.9 Sprinkler

A sprinkler is a nozzle attached to a network of pipes, and installed just below the ceiling of a room. Every sprinkler has a small glass bulb with a liquid in it. This bulb normally blocks the flow of water. In a fire, the liquid in the bulb will become hot. It will then expand, and shatter the glass bulb, removing the obstacle and causing water to spray from the sprinkler. The main difference between a hydrant and a sprinkler is that a sprinkler will come on automatically in a fire. A fire hydrant has to be operated manually by trained firefighters - it cannot be operated by laymen. A sprinkler will usually be activated very quickly in a fire - possibly before the fire station has been informed of the fire - and therefore is very effective at putting out a fire in the early stages, before it grows into a large fire. For this reason, a sprinkler system is considered very well at putting out fires before they spread and become unmanageable. According to the NFPA of America, hotels with sprinklers suffered 78% less property damage from fire than hotels without in a study in the mid-1980s [4].

Figure 2.3: Sprinklers

2.10 Distribution System

The distribution system consists of steel or galvanized steel pipes that are painted red. These can be welded together to make secure joints, or attached with special clamps. When running underground, they are wrapped with a special coating that prevents corrosion and protects the pipe. There are basically two types of distribution systems:

Automatic Wet systems are networks of pipes filled with water connected to the pumps and storage tanks, as described so far.

Automatic Dry systems are networks of pipes filled with pressurized air instead of water. When a fire fighter opens a hydrant, the pressurized air will first rush out. The pressure sensors in the pump room will detect a drop in pressure, and start the water pumps, which will pump water to the system, reaching the hydrant that the fire fighter is holding after a gap of some seconds. This is done wherever there is a risk of the fire pipes freezing if filled with water, which would make them useless in a fire [9].

Some building codes also allow manual distribution systems that are not connected to fire pumps and fire tanks. These systems have an inlet for fire engines to pump water into the system. Once the fire engines are pumping water into the distribution system, fire fighters can then open hydrants at the right locations and start to direct water to the fire. The inlet that allows water from the fire engine into the distribution system is called a siamese connection [9].

In high-rise buildings it is mandatory that each staircase have a wet riser, a vertical firefighting pipe with a hydrant at every floor. It is important that the distribution system be designed with a ring main, a primary loop that is connected to the pumps so that there are two routes for water to flow in case one side gets blocked [4].

2.11 Literature Survey

The conventional methods need to be modernized and its various functions are required to be automated to achieve reduced cycle time, higher productivity, higher levels of accuracy and high reliability. The age of automation has brought a new meaning to electronics in industry. Modernization and Automation of industrial machines generally comprise modification into a state-of-art Programmable Logic Controller (PLC) wherein the conventional relay control is replaced [10].

The PLCs are being utilized for a wide variety of automation applications such as in automobile industries, in process industries and manufacturing industries etc. Automation is the use of control systems such as computers, microcontrollers or PLC to control industrial machinery and processes, replacing human operators. In the scope of industrialization, it is a step beyond mechanization. Automatic equipment is used in automation, instead of manual labour. This facilitates the human errors thereby increasing the accuracy of manufacturing a desired product [10].

2.12 PLC S7-200

The S7-200 series of micro-programmable logic controllers (Micro PLCs) can control a wide variety of devices to support your automation needs. The S7-200 monitors inputs and changes outputs as controlled by the user program, which can include Boolean logic, counting, timing, complex math operations, and communications with other intelligent devices. The compact design, flexible configuration, and powerful instruction set combine to make the S7-200 a perfect solution for controlling a wide variety of applications [10].

Figure 2.4: PLC S7-200

2.12.1 S7-200 CPU

The S7-200 CPU combines a microprocessor, an integrated power supply, input circuits, and output circuits in a compact housing to create a powerful Micro PLC. See Figure. After the program has been downloaded, the S7-200 contains the logic required to monitor and control the input and output devices in your application [5].

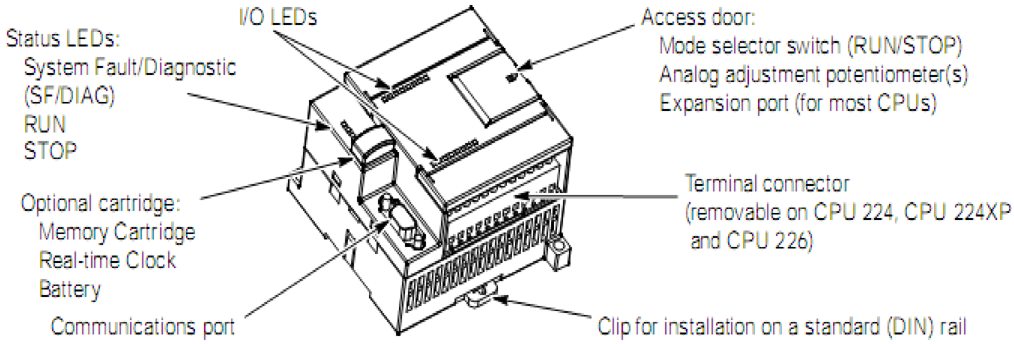


Figure 2.5: S7-200 Structure.

2.13 Benchmarking

2.13.1 Cost Benchmarking

Most of the existing automated firefighting systems use Printed circuit board (PCB) based panels. This panel monitors the pressure switches on hydrant line as well as the Diesel Engine. The panel consists of different components like IC 4011, IC 4081, IC 4017, IC 4020, Capacitors and relay cards. The system operates on 24VDC supply. Although such panels are reliable but they have high cost compared to PLC systems based, that due to the large number of components. Existing firefighting controller typically comprised of a steel cabinet, motor starter, circuit breaker, insolating switch, electronics components, and other control devices. Moreover, controllers for electric motor driven firefighting pumps are designed for three phase NEMA design “B” motors or equivalent. Controllers for diesel engine driven fire pumps are used with FM approved diesel engine drivers per FM approvals’ standard class 1333. Figures and show electric motor driver and diesel engine driver controllers respectively [6].

Figure 2.6: Electric Motor Controller

Figure 2.7: Diesel Engine Controller.

2.13.2 Maintenance and Process Benchmark

Large number of components makes the circuitry complicated. Such a complicated circuitry once employed cannot be altered to fulfill customer's demands. Large number of components also makes the detection of faults difficult and the faulty part has to be replaced immediately.

More components and more solder joints means more defect opportunities and lower yields. A higher number of components typically mean higher cost for each PCB, resulting in higher WIP cost (work in process) and scrap costs. The higher WIP costs and scrap costs are also because higher complexity typically means lower yields and more difficulty in diagnosing when failures occur [6].

2.14 Input Detection Units

Input system consists of three sensors. The mechanism of the input system is described as follow.

2.14.1 LM35 Temperature Sensor

The LM35 is an integrated circuit sensor that can be used to measure temperature with an electrical output proportional to the temperature (in oC),

- It has an output voltage that is proportional to the Celsius temperature.
- The scale factor is .01V/oC
- The LM35 does not require any external calibration or trimming and maintains an accuracy of +/-0.4 oC at room temperature and +/- 0.8 oC over a range of 0 oC to +100 oC.

- Another important characteristic of the LM35DZ is that it draws only 60 micro amps from its supply and possesses a low self-heating capability.

The sensor self-heating causes less than 0.1 oC temperature rise in still air.

The LM35 comes in many different packages:

TO-92 plastic transistor-like package,

T0-46 metals can transistor-like package3.2 Input Unit

8-lead surface mount SO-8 small outline package

TO-202 package [5].

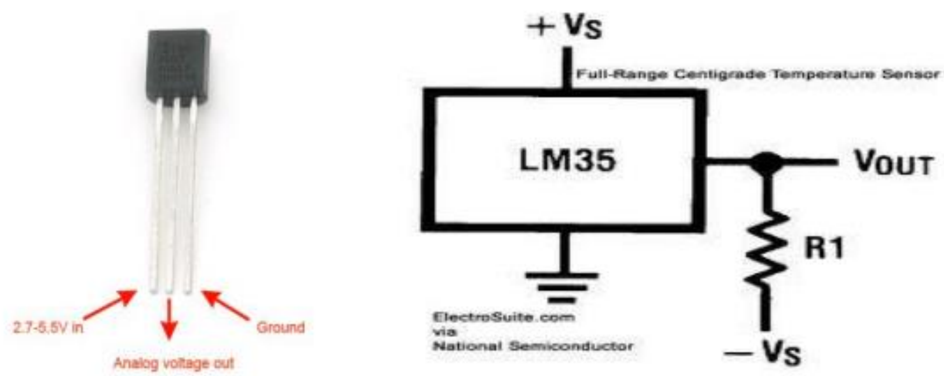


Figure 2.8: LM35 Temperature Sensor

2.14.2 Smoke Sensor

` A smoke detector is a device that detects smoke, typically as an indicator of fire. Commercial, industrial, and mass residential devices issue a signal to a fire alarm system, while household detectors, known as smoke alarms, generally issue a local audible or visual alarm from the detector itself. Smoke detectors are typically housed in a disk-shaped plastic enclosure about 150 millimeters (6 in) in diameter and 25 millimeters (1 in) thick, but the shape can vary by manufacturer or product line. Most smoke detectors work either by optical detection (photoelectric) or by physical process (ionization), while others use both detection methods to increase sensitivity to smoke. Sensitive alarms can be used to detect, and thus deter, smoking in areas where it is banned such as toilets and schools. Smoke detectors in large commercial, industrial, and residential buildings are usually powered by a central fire alarm system, which is powered by the building power with a battery backup. However, in many single family detached and smaller multiple family housings, a smoke alarm is often powered only by a single disposable battery [6].

Figure 2.9: Smoke Sensor

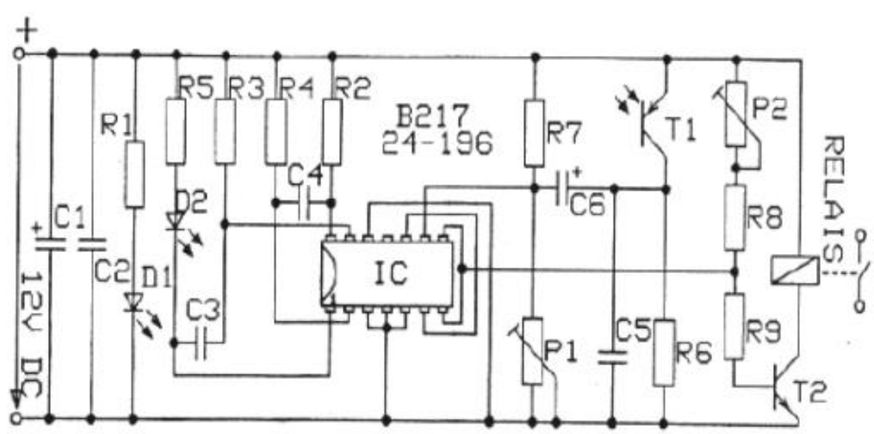


Figure 2.10: Smoke Sensor Circuit

2.14.3 Flame Sensor

Flame type detectors are sophisticated equipment to detect the flame phenomena of a fire. These detectors have various types depending on the light wavelength they use. Such as, ultraviolet, near infrared, infrared, and combination of UV/IR type detectors.

UV detectors generally work with wavelengths shorter than 300 nm. This type of detectors can detect fires and explosions situations within 3 - 4 milliseconds from the UV radiation emitted from the incident. However, to reduce false alarm triggered by UV sources such as lightning, arc welding etc. a time delay is often included in the UV flame detector. The near Infrared sensor or visual flame detectors work with wavelengths between 0.7to 1.1 μm. One of the most reliable technologies available for fire detection, namely multiple channel or pixel array sensors, monitors flames in the near IR band. The Infrared (IR) flame detectors work within the infrared spectral band (700 nm - 1 mm). Usual response time of these detectors is 3 - 5 seconds. Also, there is UV and IR combined flame detectors, which compare the threshold signal in two ranges to detect fire and minimize false alarms.

Flame detectors are expensive and complex, though they provide very reliable and accurate response. They can operate in highly sensitive environment where other detectors can’t be used. Aircraft maintenance facilities, fuel loading platforms, mines, refineries, high-tech industries etc. use these flame detectors for safety [6].

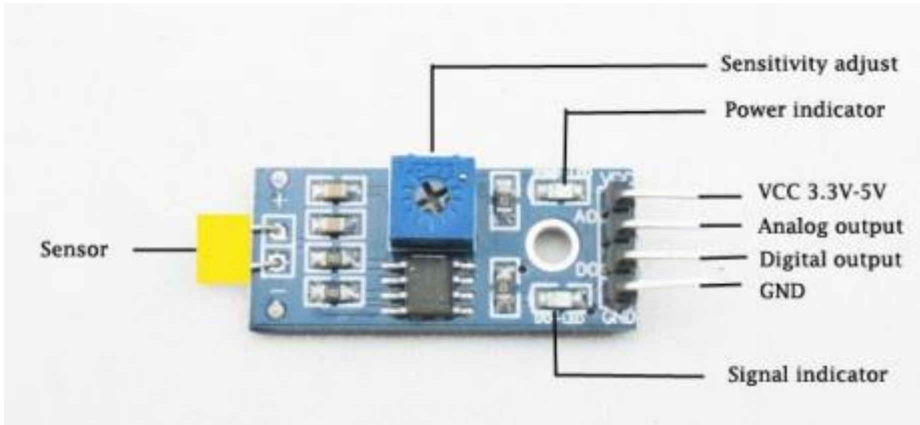


Figure 2.11: Flame Sensor

CHAPTER 3
METHODOLOGY

3.1 Overview

Fire pump controllers are intended to control drives of pumps or fire protection. They are critical components of a water protection sources. They shall control and monitor the pump driver under all conditions. They shall provide a high degree of reliability to the start the pump driver automatically upon sensing loss of fire protection system pressure or by other automatic fire detection equipment. The controller, circuit conductors, and driver considered to be sacrificial (temporary and permanent damage levels are permitted) in any attempt to start or continue the operation of a distressed pump.

When called upon to function by automatic signal, manual electrical signal or manual emergency actuation, the controller is expected start the pump driver (electrical motor or diesel engine) because “the building is on fire”. Failure to carry out its mission will increase the risk of fire damage to the building and its components; as well as increase the business interruption. Certain aspects of these controllers and fire pump installations are considered “sacrificial” in that, over current and other safety aspects of this equipment is relaxed from other typical motor or engine equipment, controllers and installations. This is to allow the equipment to “run to destruction” under certain conditions to ensure a continuous water supply for a maximum amount of time [7].

Fire pump controllers are designed to automatically run or to provide an audible alarm and visual indication in the event of a component or system malfunction. They are intended to be located in a compliance with local requirements which generally will place them in pump rooms or pump houses that have some specific degree of fire protection. These locations often have sweating overhead pipes, are possibly with sprinkler and are in the vicinity of vaults housing other building distribution equipment. Figure 3.1 and 3.2 show the fire pumps room and the overhead sprinklers respectively.

Figure 3.1: Fire Pumps Room.

Figure 3.2: Overhead Sprinklers.

3.2 PLC Based Firefighting System Principle

A PLC based firefighting system consists of jokey pump, electrical drive pump, and diesel engine drive pump. A Fire pump water supply system is a pillar of any Fire Fighting Application. The fire pump is an integral part of the water supply system with the pump intake either being connected to the public underground water supply piping, or a static water source like a tank, reservoir or a lake [8]. A fire pump is indispensable in a fire fighting system in that it provides water at very high pressures to the sprinkler system risers.

The operation of the fire pump varies depending on the method used to power the pump. An electric motor or a diesel engine is usually used to power the fire pump. In a few rare cases even a steam turbine may be used for this purpose.

On the onset of fire, the fire pump starts when the pressure in the hydrant line drops below a threshold value. This mechanism is made possible by the use of pressure switches for the main fire pump and the diesel engine driven fire pump. The hydrant line pressure drops significantly when one or more smoke detectors are exposed to heat above their designed temperature, and the sprinkler opens, releasing water.

Fire pumps serve a particularly important function of providing sufficient pressure when the local municipal water system is unable to provide sufficient pressure to meet the hydraulic design requirements of the firefighting system. In case of tall buildings, or in systems that require a relatively high terminal pressure at the fire sprinkler in order to provide a large volume of water, such as in storage warehouses, the problem of insufficient available pressure is likely to arise. In case of large reservoirs at the ground levels, a fire pump is needed to meet the sufficient pressure requirements at the sprinkler end.

Types of pumps used for fire service include: horizontal split case, vertical split case, vertical inline, vertical turbine, and end suction. Figure 3.3 shows the fire fighting system layout.

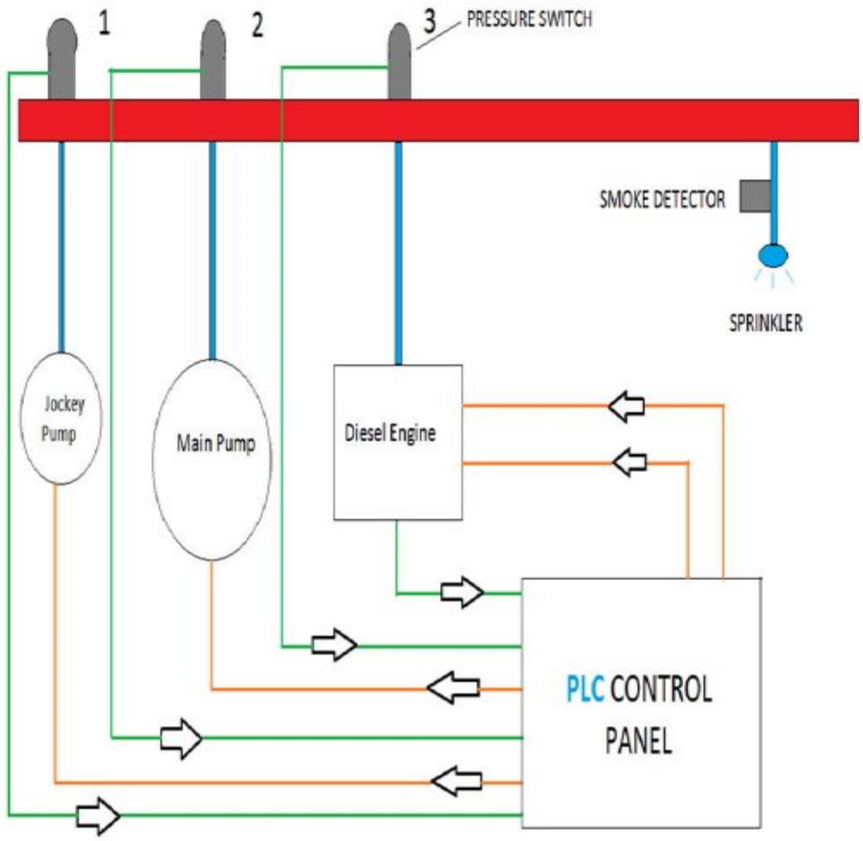


Figure 3.3: Schematic of PLC Based Firefighting System

3.3 Firefighting System's Drivers and Pumps

3.3.1 Jockey Pump

A jockey pump is a small pump connected to the firefighting system and is intended to maintain pressure in the hydrant line to an artificially high level so that the operation of a sprinkler in event of a fire will cause a pressure drop which will be sensed by the one of the pressure switches giving an input to the PLC which will then cause the fire pump to start. The jockey pump is essentially a portion of the fire pump's control system.

The jokey pump used on this thesis experiments has 3 L/S flow and 8 bar operated pressure driven by an electric motor "1% of main electrical pump as recommended". Figure 3.4 shows the jokey pump.

Figure 3.4: Jockey Pump.

3.3.2 Main Electric Motor Pump

The main electric motor driven firefighting pump designed to compensate the pressure drop on the firefighting system pipeline that jokey pump is disabled to substitute. The pump body and impeller in cast iron coupled by means of flexible spacer coupling to asynchronous three-phase electric motor designed to deliver the max power absorbed by the pump. The electric motor driver is a two-pole induction type, 50 Hz, n= 2,900 rpm, three-phase 380 V, rated power 5 kW, insulation class, and protection IP 54. Figure 3.5 shows the main electric motor driven firefighting pump.

Figure 3.5: Main Electric Pump.

3.3.3 Main Diesel Engine Pump

Diesel engine driven firefighting pump is designed to replace the main electric motor driven pump in case of electrical power interruption. In this thesis the diesel engine studied is a heavy duty diesel engine. The starting system of the diesel engine is electrical, being customized to the desired requirements.

The diesel engine is designed to operate at both automatic and manual operation as the universal standard recommends. Figure 3.6 shows the diesel engine driven firefighting pump.

Figure 3.6: Diesel Engine Pump.

Diesel engine motor pump, although more reliable than an electrically powered motor pump (because a Diesel engine is operational also during mains power losses), calls for special precautions to prevent excessive noise levels, vibration, exhaust gas contamination, and overheating. The following section lists several precautions to be taken to ensure the unit functions with the maximum possible efficiency.

1. Diesel Engine Exhaust Gas

The exhaust gas duct is attached to the celling, and the duct is protected from the weather and equipped with a drainage system to disgorge any condensate.

In order to remain below the maximum exhaust back pressure value (600 mm H2O for air-cooled engines and 1000 mm H2O for turbocharged – liquid cooled engines), design complied with the following prescriptions:

• Exhaust ducts must is longer than 10 meters.

• The cross section of the duct is equal to the cross section of the engine exhaust pipe.

2. Diesel Engine Ventilation

For optimal operation the heat irradiated from the engine and the exhaust pipes must be dispersed to the exterior of the pumps room. The engine also requires a suitable supply of clean air for the combustion process. In the majority of cases natural circulation caused by the temperature difference between the interior and exterior is insufficient.

The following measures are therefore necessary:

• Intake of fresh air by means of a dedicated intake opening protected by a fixed grille.

• An extractor fan to expel air from the pumps room.

3.4 Programmable Logic Controller

The PLC used is s7-200. It is a line of micro-programmable logic controllers (Micro PLCs) that can control a variety of automation applications. Compact design, low cost, and a powerful instruction set make the S7-200 a perfect solution for controlling small applications. The wide variety of S7-200 models and the Windows-based programming tool give you the flexibility you need to solve your automation problems. Figure shows s7-200 PLC used to control the firefighting system.

Figure 3.7: S7-200.

3.5 Components of PLC Panel

3.5.1 Switch Mode Power Supply

Switch mode power supply is the most commonly used power supply for dc source. It is very compact in size and works as a dc chopper [6]. It consists of L and C filters to filter the ripples arising due to rapid on off of the switch. The output dc voltage is controlled by varying duty cycles of chopper by Pulse width modulation or by frequency modulation. Ideally, a switched-mode power supply dissipates no power.

3.5.2 DC-DC Power Converter

A DC-to-DC converter is an electronic circuit which converts as source of direct current (DC) from one voltage level to another. It is a class of power converter is also used to give continuous supply of power irrespective of the ripples in the power supply.

3.5.3 Relay

A relay is an electro-mechanical switch. It uses electro-magnetism generated from a small voltage/current (for normal circuits it's typically around 5V/6V/12V, 200mA) to switch larger voltages/currents (around, 110V/220V, 16A) for household appliances. It provides electrical isolation between control and controlled circuits. Figure 3.8 shows the relay that used to energize the pumps' drivers.

Figure: 3.8 Relays.

3.5.4 Pressure Sensor

Water pressure control is done using pressure sensor to maintain a specified pressure point "responsive to water pressure in the fire protection system". The pressure switch has independent high and low calibrated and adjustable pressure set points.

The pressure sensing element of the switch shall be capable of withstanding a momentary surge pressure of 400 psi (27.6 bar) without losing its accuracy. Suitable provision shall be made for relieving pressure to the pressure-actuated switch to allow testing of the operation of the controller and the pumping unit. Figure 3.9 shows the pressure switches used in this system.

Figure 3.9: Pressure Sensors

3.6 Software Part

The software is mainly used in the process of designing, development, programming, and interfacing. STEP 7-Micro/WIN has been used to create the program and download it to the S7-200. STEP 7--Micro/WIN provides a variety of tools and features for designing, implementing, and debugging programs. Figure 3.10 shows program development.

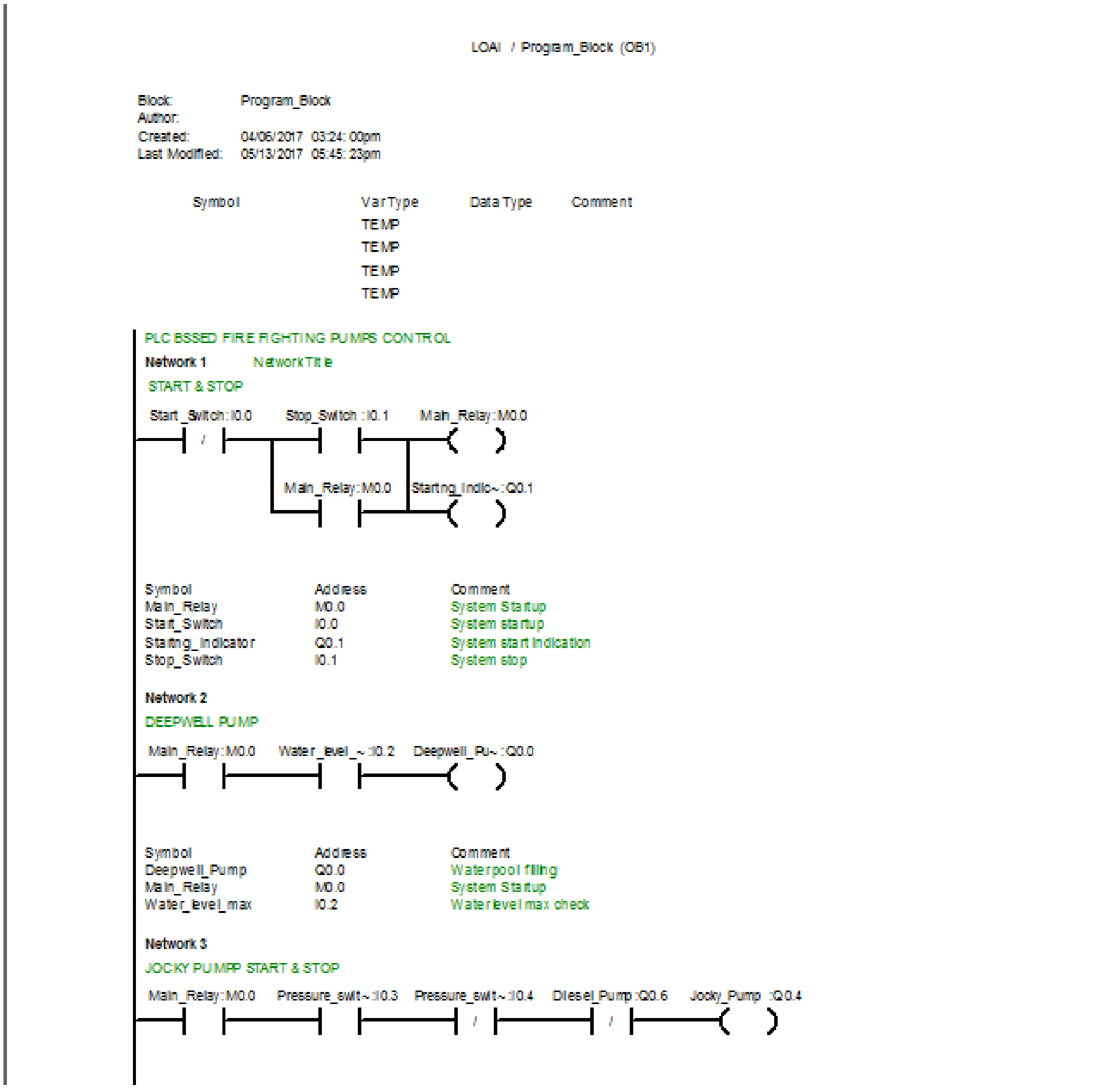


Figure 3.10: Program Development.

3.7 System Flowchart

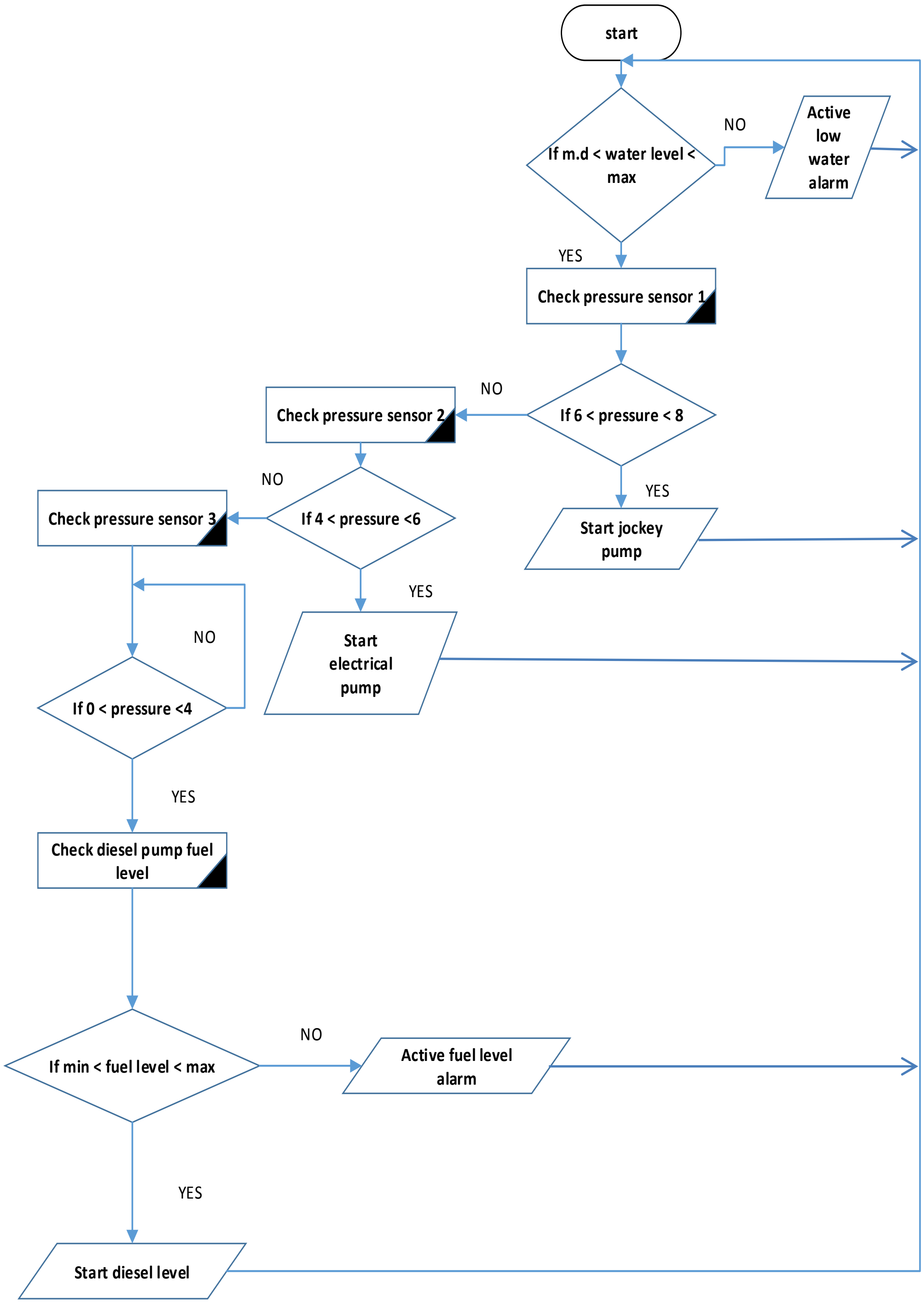


Figure 3.11: System Flowchart

3.8 System Operation

This system basically uses the drop in pressure across the hydrant line to infer the advent or for that matter, extent of fire. It thus becomes imperative to maintain the pressure across the hydrant line to a fixed pre-determined value.

The hydrant line in all probability may run across a large area with plenty of turns thereby posing many chances for a drop in pressure across it.

In order to nullify the effect of the turns and the long distances and to maintain the pressure across the hydrant line to a fixed predetermined value, a jockey pump is used. A pressure switch across the hydrant line is interfaced for the jockey pump which monitors the pressure across the hydrant line continuously and holds it to a fixed value.

In advent of a fire, the smoke detector detects the smoke to release the sprinkler valve. This causes a drop in pressure across the hydrant line.

Depending on the extent of fire, the corresponding pressure drop across the hydrant line will either fall within the range of the limit set on the pressure switch of the main pump or within the range of the limit set on the pressure switch of the diesel engine. The former case usually means that the fire is of medium proportion while the latter case most certainly means that the fire is quite large. Depending on the pressure drop the corresponding pressure switch will thus send a signal to the PLC which will acknowledge it to give an output in the form of an input pulse to either the main pump or the diesel engine.

The main pump or the diesel engine will then lift the water from the reservoir and into the hydrant line from where it will be used to extinguish the fire via sprinkler. Sometimes during fire, the main supply may be lost, either through a short circuit or by switching it off manually to avoid short circuit. In such a case, the main pump cannot be used to lift the water up into the hydrant line and this is when the diesel engine has to be used, irrespective of the pressure drop across the hydrant line. Thus, the health of the diesel engine is of prime importance as it is unaffordable to lose the diesel engine to some fault when it is in operation of extinguishing the fire.

3.8.1 Pressure Sensor Principle

The PLC also monitors the pressure in the main hydrant line. The panel gets the pressure drop feedback signal from hydrant line and acknowledges it. The system operates in manual and automatic mode. Manual mode is used on site to test the system before its actual operation on field. Generally, the system is in the automatic mode. It continuously monitors the diesel engine and keeps it in healthy condition. The automatic starting of the electrical and diesel engine is done by means of a pressure switch mounted on the delivery end of the fire water pump provided its rotary switch is kept in automatic mode. The normally open contact (NO) under low pressure of the pressure switch is wired to the control panel to ensure a fail safe operation.

On drop of pressure, the normally close contact (NC) of the pressure switch opens thereby giving command to the PLC. Figure 3.12 shows the pump connected to the diesel engine. When diesel engine is ON, it will turn

ON the pump and it will control the flow of water. The pump is connected to the main hydrant line.

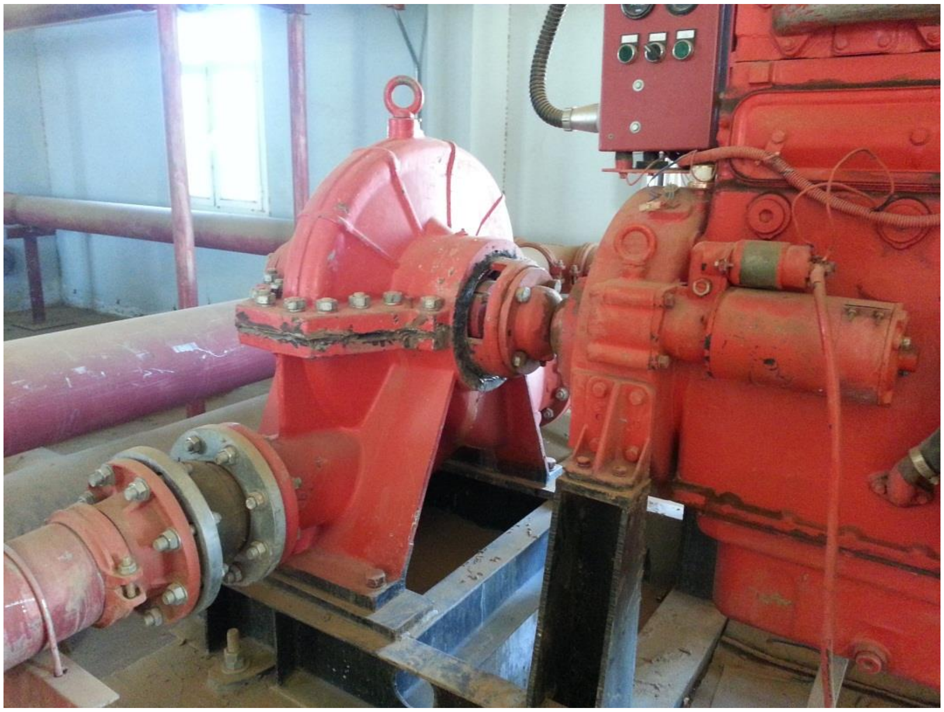


Figure 3.12: Pump Connected to Diesel Engine.

3.8.2 Diesel Engine Operation

When the Diesel Engine is in the running condition, few faults like Low lube oil pressure (LLOP), High water temperature (HWT), Engine Over-speed (OS), Fuel tank level low (FTLL) occur. It is of prime importance to acknowledge these faults.

As the diesel engine starts running, it consumes lubricant oil and thus the level of lubricant oil in the tank gets low, which sends a signal to the PLC panel through a pressure switch mounted on the lubricant oil tank. This signal is also taken as the feedback for 'ENGINE RUNNING' indication on the panel. Continuous running of the engine, heats the engine resulting in heating of water which is used as a coolant.

This sends a signal to panel in form of ‘HIGH WATER TEMPERATURE. A sensor, mounted on the shaft of the engine, gives the feedback of ‘ENGINE OVERSPEED’. As the fuel is being consumed, fuel level goes low and the signal is sent to the panel through a pressure switch. This is the signal of ‘FUEL TANK LEVEL LOW’. The faults are to be cleared as soon as possible. These faults are monitored by PLC and gives indication to the operator. The PLC is programmed in ladder logic to monitor the diesel engine and the pressure switches on the hydrant line.

CHAPTER 4
RESULT AND DICUSSION

4.1 Overview

A PLC controller intended for starting, controlling, and stopping centrifugal fire pumps, including automatic and manual types for alternating current electric motor and diesel engine driven fire pumps.

The system is designed to maintain a pressure of 8 bar across the hydrant line, thus three pressure switches are used to detect any pressure drop. During occurrence of pressure drop on the hydrant line, jockey's pump pressure switch sends a signal to the controller for starting up the jockey pump to compensate the pressure. The jockey's pump pressure switch set at 8 bar as high pressure setting and 6 bar as low pressure setting.

Main electrical pump used to replace jockey pump when a huge pressure drop occurs. It can be operated manually as well as automatic mode control. Main electrical pump's pressure switch is set at 6 bar as high pressure setting and 4 bar as low pressure setting.

Diesel engine driven fire pump used to substitute the main electrical pump and should be used when a power interruption happens. Lube oil pressure indicator should light on when the pressure detector sense the low oil pressure. When temperature of water goes above 93-94°C, then cooling water is supplied to engine. For example: Temperature sensor. The water temperature detectors used in high temperature and pressure environment are armored with stainless steel package and waterproof connection box. The sensing elements are PT1000 resistors.

4.2 System Startup Result

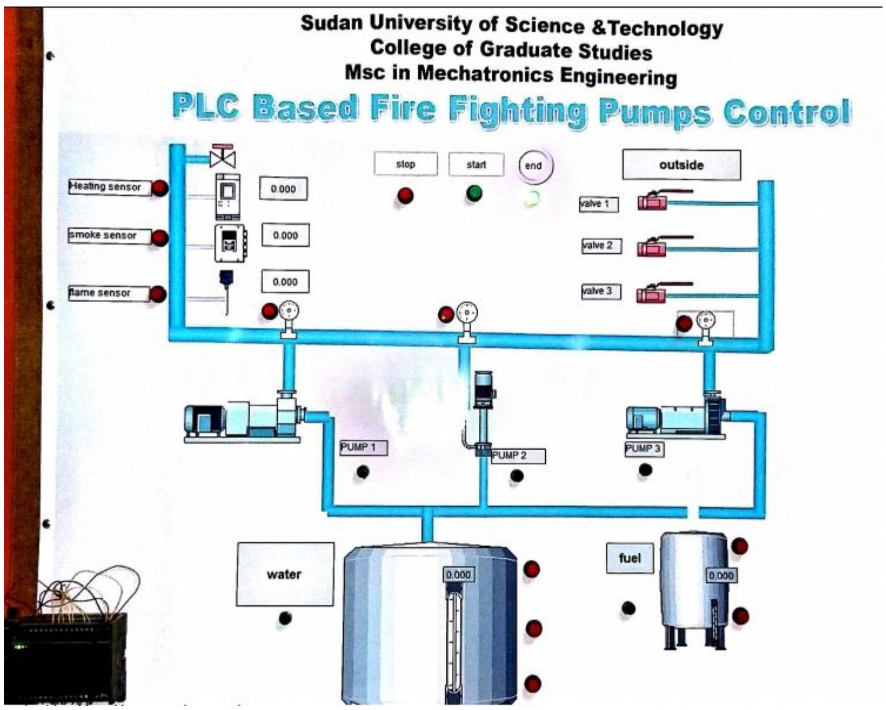


Figure 4.1: System Startup

Figure 4.1 shows the system startup. When startup push button is pressed, startup indicator shines, and PLC starts to check all system sensor statuses. Figure 4.2 shows system startup simulation.

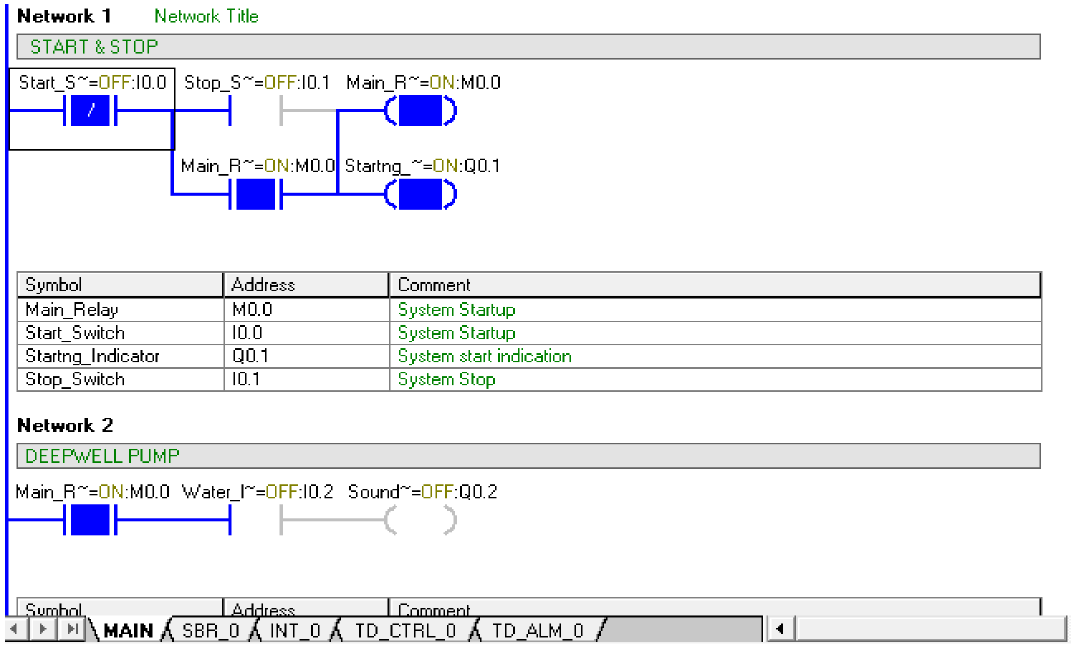


Figure 4.2: System Startup Simulation

4.3 Jockey Pump Operation Result

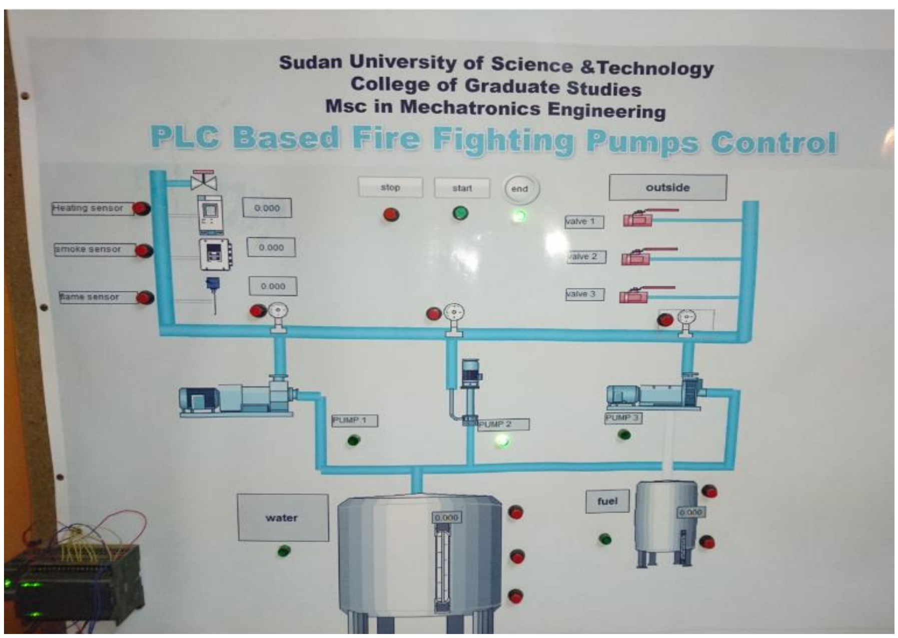
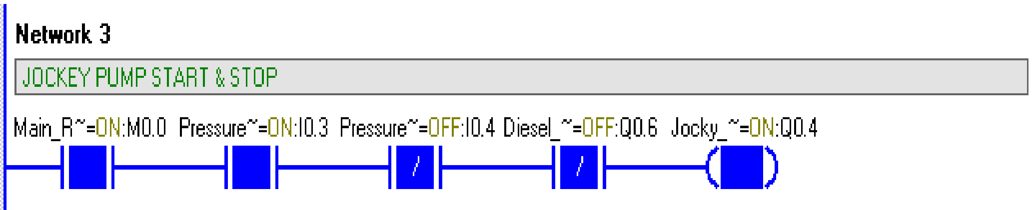


Figure 4.3: Jockey Pump Startup

Figure 4.3 shows the jockey pump operation. When the hydrant pressure goes below 8 bars, jockey pump starts to compensate the pressure dropped. Jockey pump is used to requite only minimal pressure downfall. Figure 4.4 shows jockey pump startup simulation.



Symbol	Address	Comment
Diesel_Pump	Q0.6	Diesel Pump
Jocky_Pump	Q0.4	Jockey pump
Main_Relay	M0.0	System Startup
Pressure_switch1	I0.3	8 bar
Pressure_switch2	I0.4	6 bar

Figure 4.4: Jockey Pump Startup Simulation

4.4 Electrical Pump Operation Result

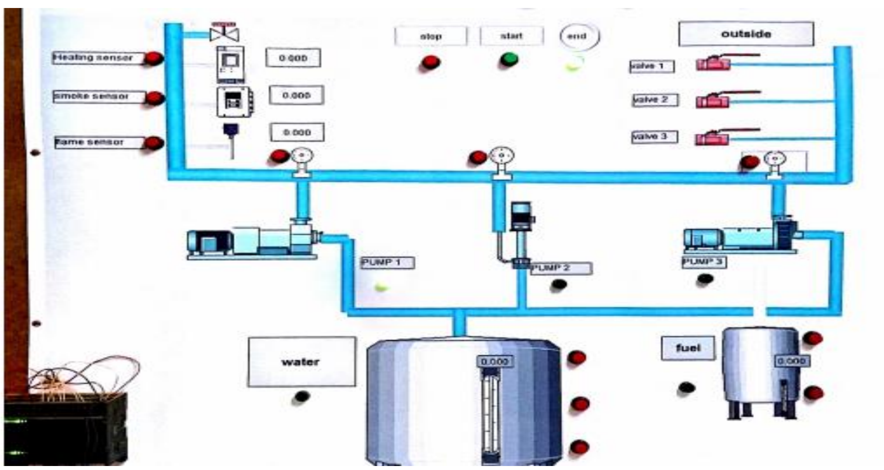


Figure 4.5: Electrical Pump Operation

Figure 4.5 shows the electrical pump operating status. When jockey pump unable to diminish the hydrant pressure drop and as soon as the pressure declines behind 6 bars, electrical pump will start. Figure 4.6 shows electrical pump startup simulation.

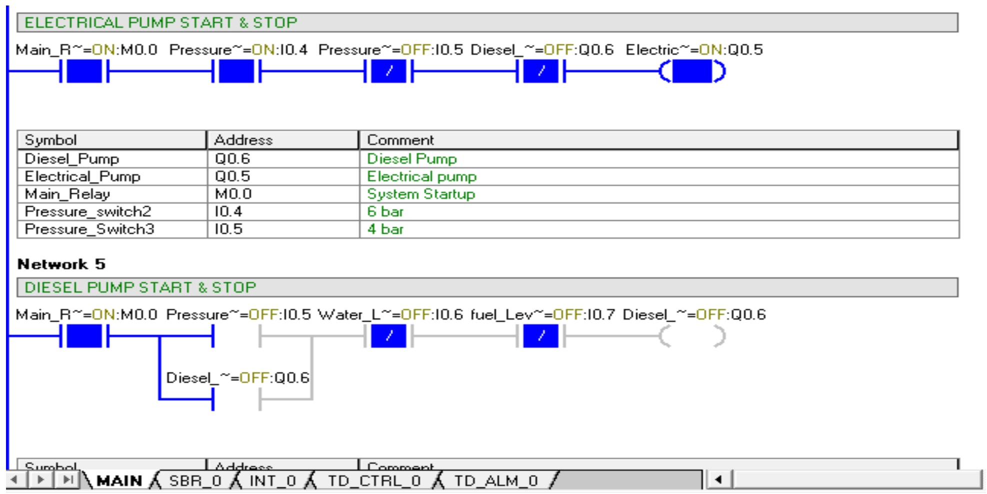


Figure 4.6: Electrical Pump Startup Simulation

4.5 Diesel Pump Operation Result

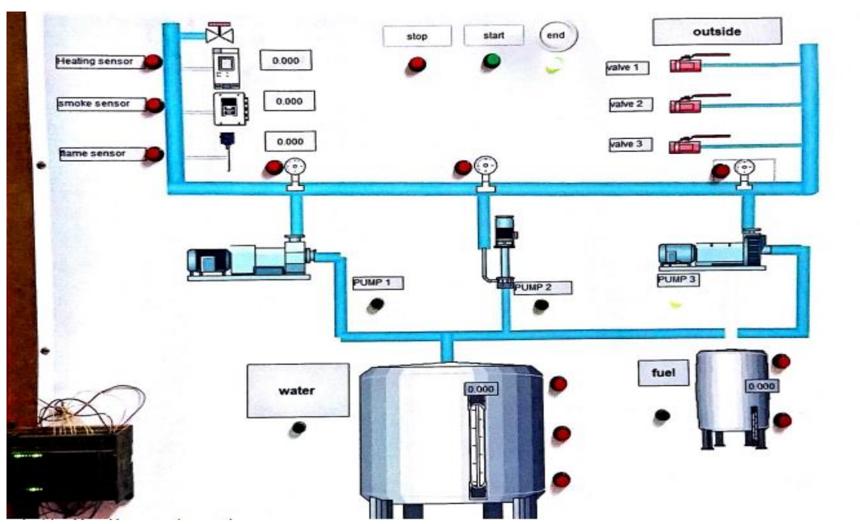


Figure 4.7: Diesel Pump Operation

Figure 4.7 shows the diesel pump operation status. Diesel pump is used to compensate excessive pressure drop. It will start immediately after hydrant pressure detracts below 4 bars. Moreover, diesel pump plays a significant role when an electrical power interruption occurs during the fire incident. Figure 4.8 shows diesel pump startup simulation.

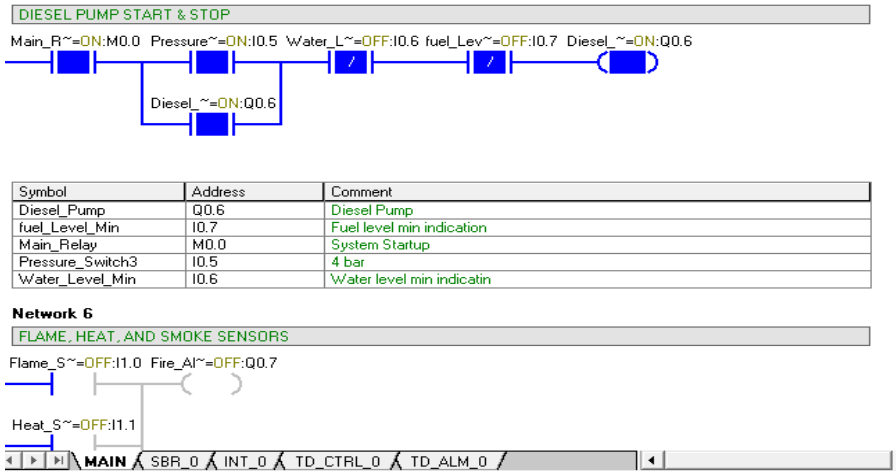


Figure 4.8: Diesel Pump Operation Simulation.

4.6 Water Pool and Fuel Level "Medium"

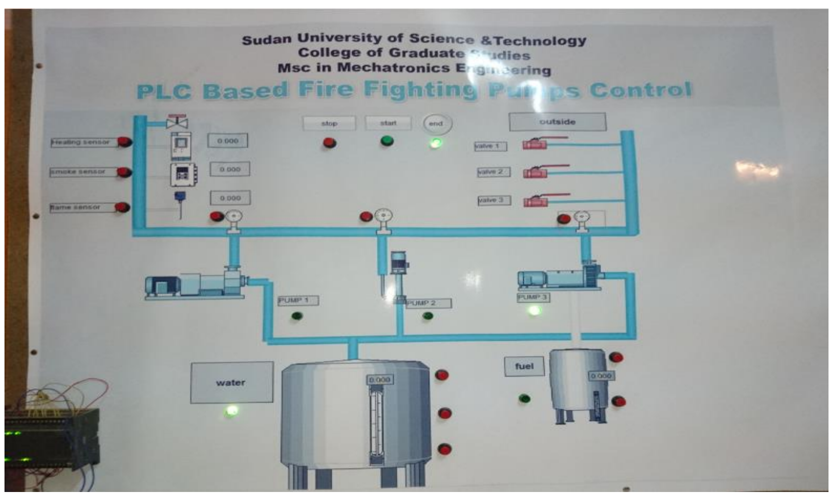


Figure 4.9: Water Level "Medium" Alarm.

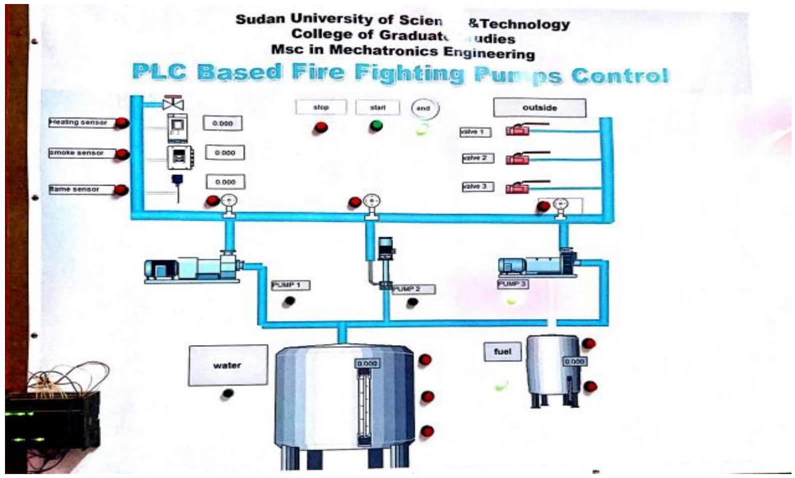


Figure 4.10: Fuel Level “Medium” Alarm.

Figure 4.9 and figure 4.10 show the water pool level fuel level alarm respectively. When the water level or fuel level elides to half, alarms warm-up safety officer. Figure 4.11 shows water pool and fuel level “medium” simulation.

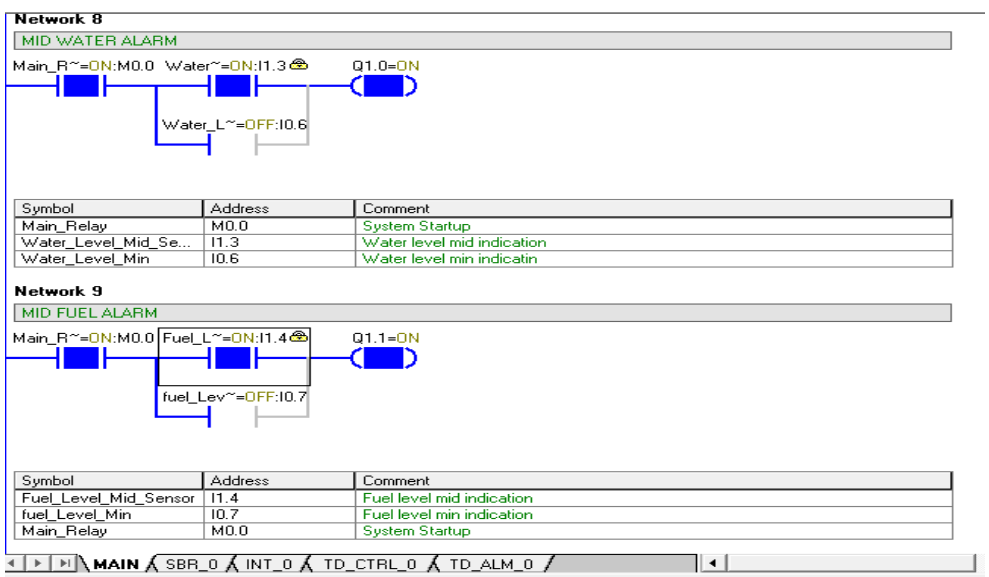


Figure 4.11: Water Pool and Fuel Level “Medium” Simulation

4.7 Water Pool and Fuel Level “Minimum”

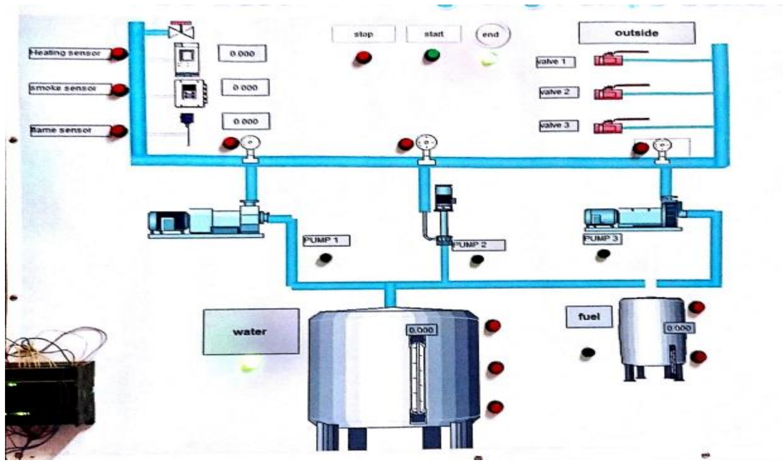


Figure 4.12: Water Pool Low Level Alarm

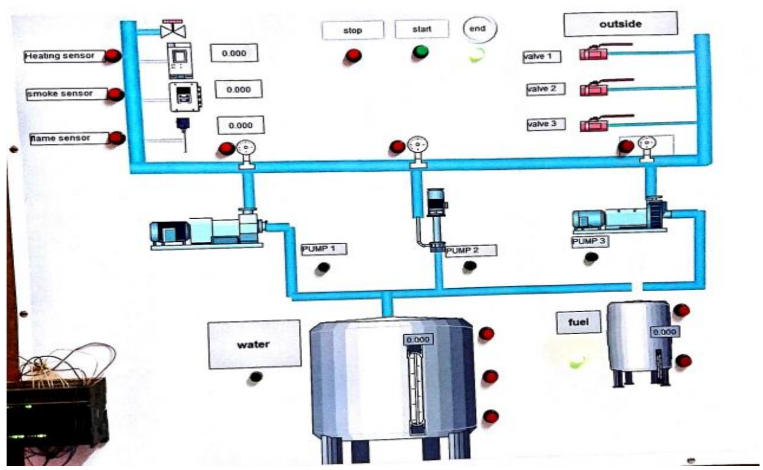
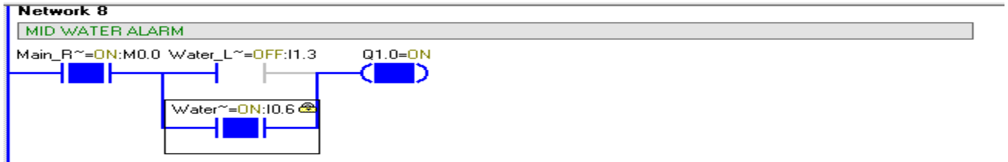
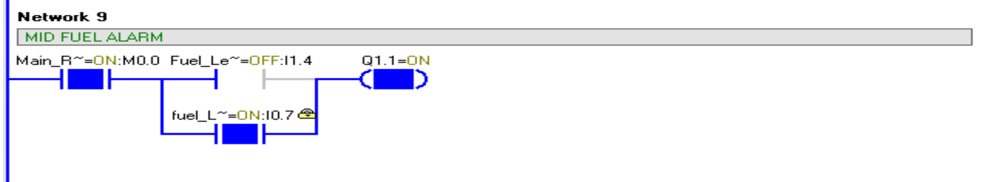


Figure 4.13: Fuel low level alarm.

Figure 4.12 and figure 4.13 show water pool low level and fuel low level respectively. When either water low level or fuel low level sensor is activated, indicators will shine and the diesel pump will stop accordingly. This action is taken to prevent the diesel pump from any malfunction or damage resulting from water or fuel mansions. Figure 4.14 shows water pool and fuel level “low” alarm simulation.



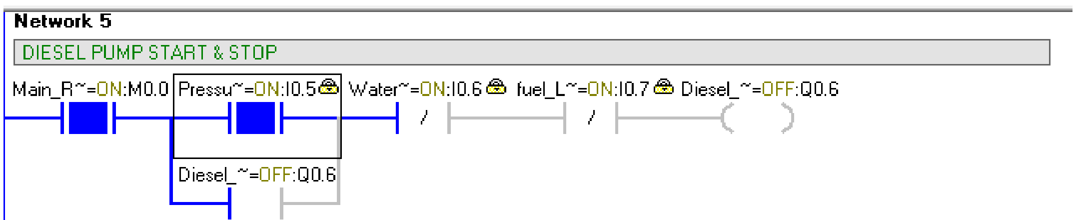
Symbol	Address	Comment
Main_Relay	M0.0	System Startup
Water_Level_Mid_Se...	I1.3	Water level mid indication
Water_Level_Min	I0.6	Water level min indicatin



Symbol	Address	Comment
Fuel_Level_Mid_Sensor	I1.4	Fuel level mid indication
fuel_Level_Min	I0.7	Fuel level min indication
Main_Relay	M0.0	System Startup

MAIN SBR_0 INT_0 TD_CTRL_0 TD_ALM_0

Figure 4.14: Water pool and fuel level “low” alarm simulation.



Symbol	Address	Comment
Diesel_Pump	Q0.6	Diesel Pump
fuel_Level_Min	I0.7	Fuel level min indication
Main_Relay	M0.0	System Startup
Pressure_Switch3	I0.5	4 bar
Water_Level_Min	I0.6	Water level min indicatin

Figure 4.15: water and fuel low level interlock simulation.

Figure 4.15 shows water and fuel low level interlock with diesel pump simulation. This interlock has been created to prevent the diesel pump from any defect. It can be clearly seen that, when either water low level or fuel low level alarm is activated; diesel pump will stop immediately.

4.8 Heat, Flame, and Smoke Sensors Result

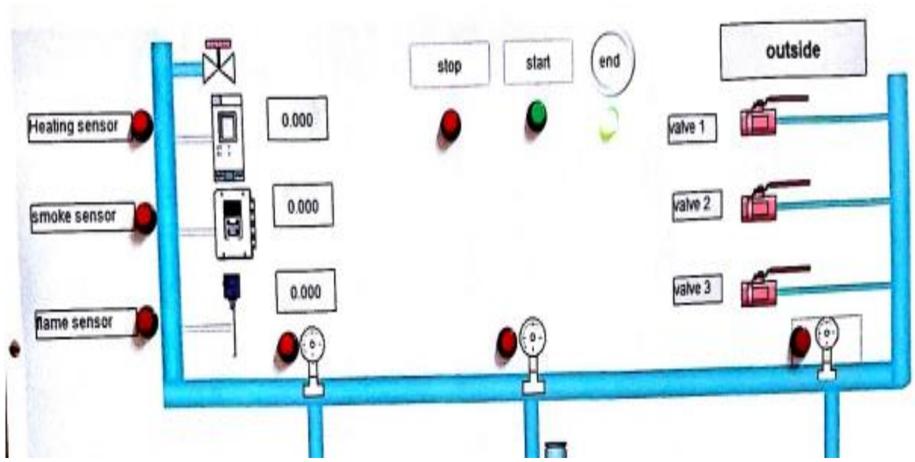
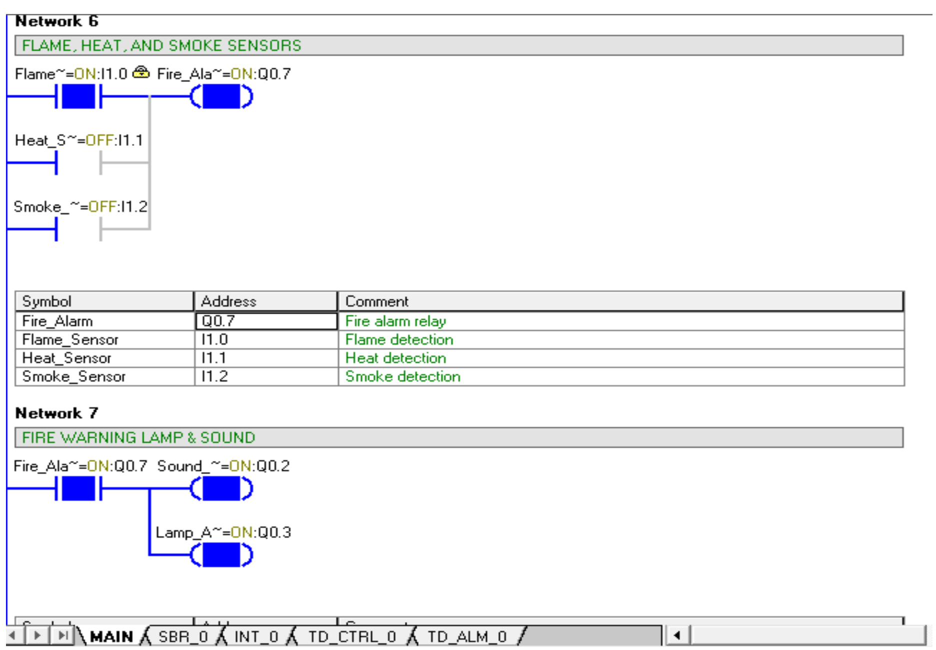


Figure 4.16: Heat, smoke, and flame sensors.

Figure 4.16 shows heat, smoke, and flame sensors. When either one sensor is detected by fire existence, sound and light alarms are activated.



Symbol	Address	Comment
Fire_Alarm	Q0.7	Fire alarm relay
Flame_Sensor	I1.0	Flame detection
Heat_Sensor	I1.1	Heat detection
Smoke_Sensor	I1.2	Smoke detection

Figure 4.17: Flame sensor detection simulation.

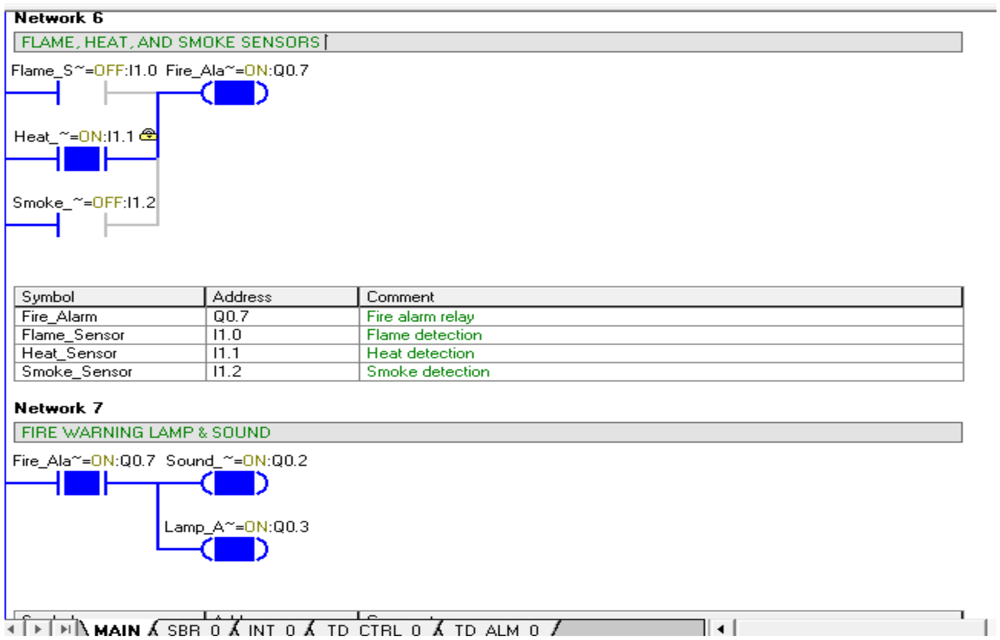


Figure 4.18: Heat sensor detection simulation.

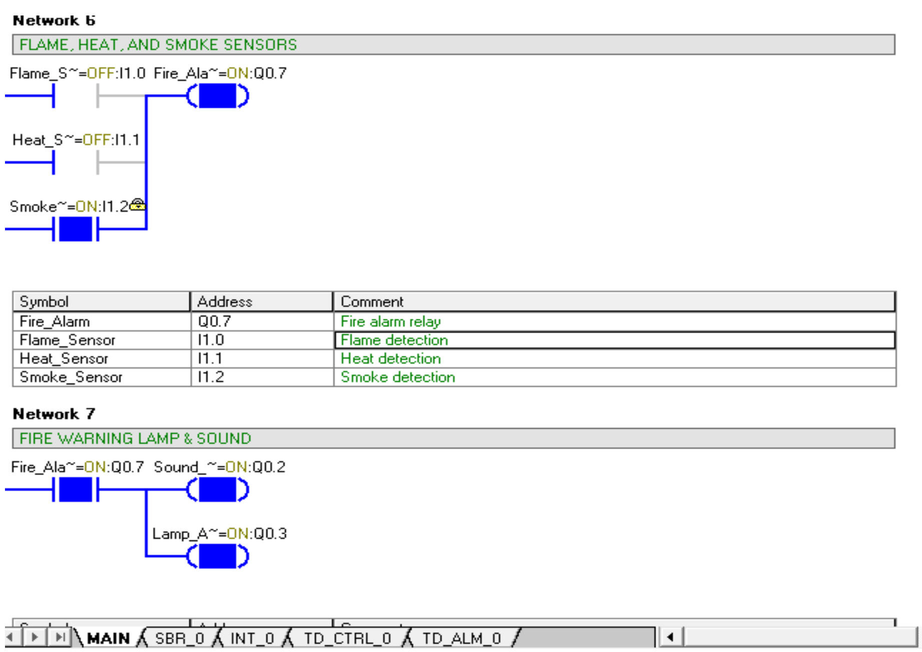


Figure 4.19: Smoke Sensor Detection Simulation

Figures 4.17, 4.18, 4.19 show flame, heat, and smoke sensors detection simulation. When either one sensor detects fire existence, sound and light alarm will be activated.

CHAPTER 5
CONCLUSION

5.1 Conclusion

This project has been motivated by the desire to design a system that can control fire pumps and intervention. The thesis has presented a unique vision of the concepts which are used in this particular field. It aims to promote technology innovation to achieve a reliable and efficient outcome from the various instruments. Experimental work has been carried out carefully. The result shows that higher efficiency is indeed achieved using the PLC. With a common digitalized platform, these latest instruments will enable increased flexibility in control, operation, and expansion; allow for embedded intelligence, essentially foster the resilience of the instruments; and eventually benefit the customers with improved services, reliability and increased convenience. This thesis also presents the major features and functions of the various concepts that could be used in this field in detail through various categories. Since this initial work cannot address everything within the proposed framework and vision, more research and development efforts are needed to fully implement the proposed framework through a joint effort of various entities.

5.2 Discussion

The objectives of this thesis project were mostly covered and achieved. This is done by developing a prototype of PLC based fire-fighting pumps control. Other than that, an application for this thesis project has been developed. It can be concluded that, the prototype model functions well. Hopefully, with the concept and information that had been developed in this system; it could contribute to the evolution in the fire fighting pumps control and its application.

5.2 Recommendations

1. Consider the deep well pump to automatically start to fill the water pool.
2. Design a solar power backup to avoid power interruption consequences during fire existence.
3. Design a graphical user interface 'GUI' for distance system operation.
4. Consider the detecting sensor and springs as a part of the system.