A Dissertation Report on

INDUSTRIAL FIRE FIGHTING SYSTEM USING PLC WITH SCADA

Submitted in partial fulfillment of the requirement for the award of the degree of

MASTER OF TECHNOLOGY

in

INSTRUMENTATION ENGINEERING

by

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CERTIFICATE

This is to certify that Mr. **SRINIVASAREDDY ALLAM** (Roll no.208506) student of final year M.Tech in Instrumentation Engineering of **National Institute of Technology, Kurukshetra** had satisfactorily completed his dissertation work entitled **"INDUSTRIAL FIRE FIGHTING SYSTEM USING PLC WITH SCADA"** as a part of the curriculum under my guidance at **Visakhapatnam Steel Plant, Visakhapatnam** from January 2010 to July 2010. During his tenure at our organizations, we found him to be sincere, hardworking and enthusiastic with a good grasp over fundamentals. He has displayed keen interest and put in efforts in realizing the task in time to our satisfaction.

This is an authentic work carried out by him under our supervision and guidance.

To the best of our knowledge, the matter embodied in the report has not been submitted to any other university / institute for the award of any degree or diploma.

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CANDIDATE'S DECLARATION

I, Srinivasareddy Allam hereby declare that the work which is being presented in the dissertation entitled **"INDUSTRIAL FIRE FIGHTING SYSTEM USING PLC WITH SCADA"** for the award of Master of Technology in Instrumentation submitted to National Institute of Technology, Kurukshetra, is an authentic record of my own work carried out under the supervision of Mr. Naga Prasad, AGM, Instrumentation Dept., Visakhapatnam Steel Plant and Dr. Ashavani Kumar, Associate Professor, NIT Kurukshetra. The matter presented in this thesis has not been submitted by me in any other University or Institute.

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ABSTRACT

Industrial safety is as much important as the processes carried out in any industry. So, sophisticated equipment is required to prevent loss caused by the fire accidents. Objective of the project is to design an industrial fire fighting system to prevent fire and to warn incase of fire accidents. This project is to design such equipment by using several proven technologies like PLC and SCADA software.

Presence of fire can be detected by using several detectors. Out of them heat and smoke detectors are the commonly used detectors. The detectors are connected in loops and each loop corresponds to a single zone. Depending on the size, the plant is divided into several zones. And each zone may have four to several detectors depending on the size of that particular zone. As the detectors are connected in loops, voltage and current variations will arise depending on number of detectors activated and by measuring those variations presence of fire can be sensed. Then preventive actions can be initiated. In some zones water can sprayed to stop fire and as well exhaust fans should be stopped. But in several zones, as there will be some critical equipment, water should not be used. For those zones, sounders are activated so that employees in that zone will take preventive actions.

Existing system is a microprocessor based system which is having some disadvantages and with my design I tried to rectify those. The modified system also serves the same purpose as microprocessor based system but this uses more sophisticated equipment. The major differences between the existing and modified systems are

- The way they measure the status of the detectors.
- Logic used to generate fault, alert and alarm signals.
- Size of the system.
- The way they visualize the alarm signals.

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Last but not least I am very thankful to the persons who have directly and indirectly helped me to complete the dissertation work.

A. Srinivasa Reddy
(SRINIVASAREDDY ALLAM)

INDEX

LIST OF FIGURES

LIST OF TABLES

This chapter gives introduction about my dissertation work entitled "Industrial Fire Fighting System Using PLC with SCADA".

1.1 Industrial Fire Safety [4]:

Industrial accidents and unsafe working conditions can result in temporary or permanent injury, illness, or even death. They also impact on reduced efficiency and loss of productivity. Making the work environment safer was less costly than paying compensation. Well-planned fire prevention activities can save millions of rupees by preventing the destructiveness of fire, as well as saving lives in industry and the public.

Adequate fire protection and detection systems must be determined and installed for the protection of the plant buildings, equipments and occupants. The type and amount of suitable fire protection equipment will depend upon the process and storage hazards found in the plant. Water supplies and distribution systems for firefighting are also considerations. The fire prevention authority must be responsible to see that all fire fighting systems and equipment are designed and installed to meet the fire protection needs of the plant.

1.2 Problem Background:

In Visakhapatnam steel plant on my first day of training I got to attend safety session for two hours. There I came to know the importance of safety in process industries. Later I went for mock drills conducted by fire safety professional of CISF (Central Industrial Security Force) Fire Wing to check condition of fire fighting system. At that time I observed that there some problems with existing system. And also I noticed that industries are paying less attention to the fire and gas safety. The existing system is a microprocessor based system which is having some limitations to the industrial environment. Frequent false alarms are very frequent and became very common. So employees in the control room started ignoring those alarms and later they will not believe even in actual instance of fire occurrence. This leads to fire accidents due to negligence.

The automating fire fighting system in the Visakhapatnam steel plant is kept in manual mode due to frequent false alarms. Due to this preventive actions will be delayed and this leads to loss.

The main disadvantages of the existing system are

- False alarms are more frequent
- No provision to store previous history of alarms
- It sends limited information to the CSIF Fire Wing
- To change the pumps priority rewiring should be done
- Difficult to change the program sequence written for microprocessor

1.3 Objectives:

Main objective of this project work is to design a system using reliable technologies to eliminate the problems noted as above associated with the existing system. To achieve this I divided my work into three segments. They are

- Fire detectors connected in loops are used for detection of fire. Here I should find out how to connect detector loops to be connected to programmable logic controller.
- Programming the PLC in such a way to monitor detector loops, generate status signals and initiating fire preventive actions.
- Generating visualization screens for status of fire and preventive actions by using SCADA (supervisory control and data acquisition system).

The proposed system is explained in the subsequent chapters.

This chapter introduces the theoretical concepts of the technologies useful for this project work.

2.1 Fire [3]:

Fire is the rapid oxidation of a material in the chemical process of combustion, releasing heat, light, and various reaction products.

Fire or combustion is a chemical reaction, and specifically it is an oxidation reaction. Oxidation is defined as the chemical combination of oxygen with any substance. In other words, whenever oxygen (and some other materials) combines chemically with a substance, that substance is said to have been oxidized. Rust is an example of oxidized iron. In this case, the chemical reaction is very slow. The very rapid oxidation of a substance is called combustion, or fire.

There are three basic theories that are used to describe the reaction known as fire. They are: the fire triangle, the tetrahedron of fire, and the life cycle of fire. Of the three, the first is the oldest and best known; the second is accepted as more fully explaining the chemistry of fire, while the third is a more detailed version of the fire triangle. Each is briefly described below.

The first of these theories, the fire triangle, is quite simplistic and provides a basic understanding of the three entities that are necessary for a fire. This theory states that there are three things necessary to have a fire: fuel, oxygen (or an oxidizer), and heat (or energy). It likens these three things to the three sides of a triangle, stating that as long as the triangle is not complete, that is, the legs are not touching each other to form the closed or completed triangle, combustion cannot take place.

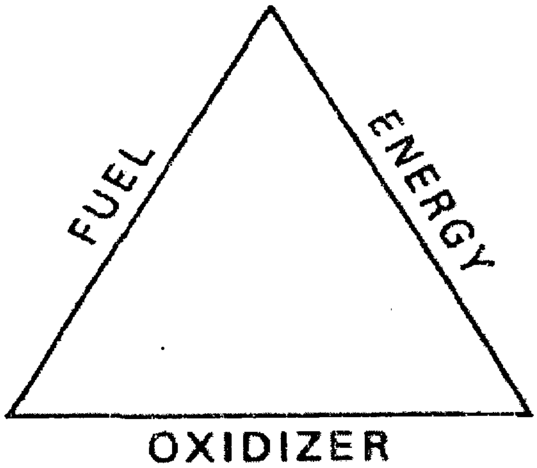


Figure 2.1: fire triangle

A fuel may be defined as anything that will burn. Fuels may be categorized into the following classes:

1. Elements (which include the metals and some non-metals such as carbon, sulphur, and phosphorus)
2. Hydrocarbons
3. Carbohydrates (including mixtures that are made up partially of cellulose, like wood and paper)
4. Many covalently bonded gases (including carbon monoxide, ammonia, and hydrogen cyanide)
5. All other organic compounds

The second leg of the fire triangle is oxygen, or the oxidizer leg. The oxidizer is the other reactive of the chemical reaction. In most cases, it is the ambient air, and in particular one of its components, Oxygen (O2).

The third leg of the fire triangle is heat, or the energy leg. This energy can be provided in one or more of several ways. The energy can be generated chemically, mechanically, electrically or by nuclear methods.

Once the energy - in many cases, heat - is generated, it must be transmitted to the fuel (the "touching" of the fuel and energy legs). This process is accomplished in three ways: conduction (the transfer of heat through a medium, such as a pan on a stove's heating element), convection (the transfer of heat with a medium, such as the heated air in a hot-air furnace), and radiation (the transfer of heat which is not dependent on any medium).

These three entities (fuel, oxidizer, energy) make up the three legs of the fire triangle. It is a physical fact, a law of nature that cannot be repealed, that when fuel, oxidizers, and energy are brought together in the proper amounts, a fire will occur. If the three are brought together slowly, and over a long period of time, the oxidation will occur slowly, as in the rusting of iron. If the three are of a particular combination, the resulting oxidation reaction might even be an explosion. Whatever forms the final release of energy takes, the thing that cannot be changed is that the chemical reaction will occur.

The second popular explanation of fire is the tetrahedron theory which is illustrated in the following figure.

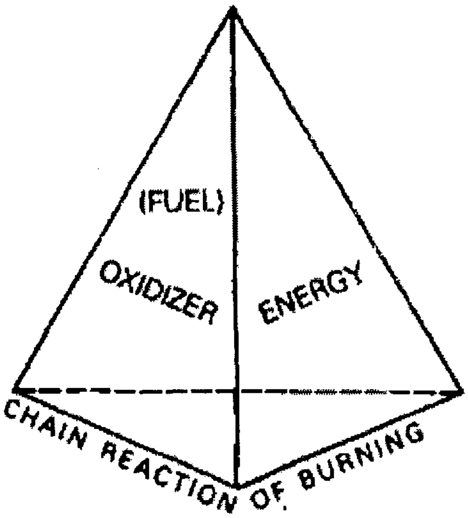


Figure 2.2: Fire tetrahedron

This theory encompasses the three concepts in the fire triangle theory but adds a fourth "side" to the triangle, making it a pyramid, or tetrahedron; this fourth side is called the "chain reaction of burning". This theory states that when energy is applied to a fuel like a hydrocarbon, some of the carbon-to-carbon bonds break, leaving an unpaired electron attached to one of the molecular fragments caused by the cleavage of the bond, thus creating a free radical. This molecular fragment with the unpaired electron, or "dangling" bond, is highly reactive and will therefore seek out some other material to react with in order to satisfy the octet rule. The same energy source that provided the necessary energy to break the carbon-to-carbon bond may have also broken some carbon-to- hydrogen bonds, creating more free radicals, and also broken some oxygen-to-oxygen bonds, creating oxide radicals. This mass breaking of bonds creates the free radicals in a particular space and in a number large enough to be near each other, so as to facilitate the recombining of these free radicals with whatever other radicals or functional groups may be nearby. The breaking of these bonds releases the energy stored in them, so that this subsequent release of energy becomes the energy source for more bond breakage, which in turn releases more energy. Thus the fire "feeds" upon itself by continuously creating and releasing more and more energy (the chain reaction)" until one of several things happens: either the fuel is consumed, the oxygen is depleted, the energy is absorbed by something other than the fuel, or this chain reaction is broken. Thus a fire usually begins as a very small amount of bond breakage by a relatively small energy (ignition) source and builds itself up higher and higher, until it becomes a raging inferno, limited only by the fuel present (a fuel-regulated fire) or the influx of oxygen (an oxygen-regulated fire). The earlier in the process that the reaction can be interrupted, the easier the extinguishment of the fire will be. This theory claims that the propagation of all hydrocarbon fires (or fires involving hydrocarbon derivatives) depends upon the formation of the hydroxyl (-OH) radical, which is found in great quantities in all such fires.

The third theory of fire is the life cycle theory, which is illustrated in Figure 2.3. According to this theory, the combustion process can be categorized by six steps, rather than the three of the fire triangle or the four of the tetrahedron of fire theory. Three of the steps in this theory are the same as the only three steps in the fire triangle theory.

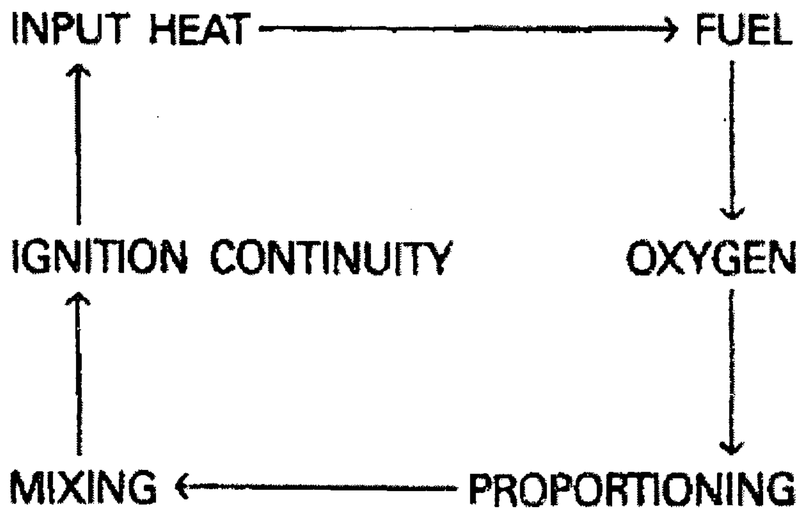


Figure 2.3: life cycle theory of fire

In the life cycle of fire theory, the first step is the input heat, which is defined as the amount of heat required to produce the evolution of vapors from the solid or liquid. The input heat will also be the ignition source and must be high enough to reach the ignition temperature of the fuel; it must be continuing and self-generating and must heat enough of the fuel to produce the vapors necessary to form an ignitable mixture with the air near the source of the fuel. The second part of the life cycle of fire theory is the fuel, essentially the same as the fuel in the tetrahedron of fire and the fire triangle.

It was assumed without so stating in the fire triangle theory, and is true in all three theories, that the fuel must be in the proper form to bum; that is, it must have vaporized, or, in the case of a metal, almost the entire piece must be raised to the proper temperature before it will begin to bum. The third part is oxygen in which the classical explanation of this theory only concems itself with atmospheric oxygen, because the theory centers around the diffusion flame, which is the flame produced by a spontaneous mixture (as opposed to a pre-mixed mixture) of fuel gases or vapors and air. This theory concems itself with air-regulated fires, so airflow is crucial to the theory; this is why only atmospheric oxygen is discussed. Ignoring oxygen and the halogens that are generated from oxidizing agents should be viewed as a flaw in this theory. The fourth part of the theory is proportioning, or the occurrence of intermolecular collisions between oxygen and the hydrocarbon molecule (the "touching" together of the oxidizer leg and the fuel leg of the fire triangle). The speed of the molecules and the number of collisions depend on the heat of the mixture of oxygen and fuel; the hotter the mixture, the higher the speed. A rule of thumb is used in chemistry that states the speed of any chemical reaction doubles for roughly every 180 F (10°C.) rise in temperature. The fifth step is mixing; that is, the ratio of fuel to oxygen must be right before ignition can occur (flammable range). Proper mixing after heat has been applied to the fuel to produce the vapors needed to burn is the reason for the "backdraft" explosion that occurs when a fresh supply of air is admitted to a room where a fire has been smoldering. The sixth step is ignition continuity, which is provided by the heat being radiated from the flame back to the surface of the fuel; this heat must be high enough to act as the input heat for the continuing cycle of fire. In a fire, chemical energy is converted to heat; if this heat is converted at a rate faster than the rate of heat loss from the fire, the heat of the fire increases; therefore, the reaction will proceed faster, producing more heat faster than it can be carried away from the fire, thus increasing the rate of reaction even more. When the rate of conversion of chemical energy falls below the rate of dissipation, the fire goes out. That is to say, the sixth step, ignition continuity, is also the first step of the next cycle, the input heat. If the rate of generation of heat is such that there is not enough energy to raise or maintain the heat of the reaction, the cycle will be broken, and the fire will go out. The life cycle of fire theory adds the concepts of flash point and ignition point (heat input) and flammable range (mixing).

2.2 Fire Extinguishment [10]

Fire can be extinguished by removing any one of the elements of the fire tetrahedron. Consider a natural gas flame, such as from a stovetop burner. The fire can be extinguished by any of the following:

- Turning off the gas supply, which removes the fuel source;
- Covering the flame completely, which smothers the flame as the combustion both uses the available oxidizer (the oxygen in the air) and displaces it from the area around the flame with CO_2;
- Application of water, which removes heat from the fire faster than the fire can produce it (similarly, blowing hard on a flame will displace the heat of the currently burning gas from its fuel source, to the same end), or
- Application of a retardant chemical such as Halon to the flame, which retards the chemical reaction itself until the rate of combustion is too slow to maintain the chain reaction.

Fire is an exothermic (heat-liberating) reaction. There must be a continuous feedback of energy (heat) to keep the reaction going. Also, heat is dissipated from the fire by one or more of the methods of transferring heat: conduction, convection, and radiation. Heat energy is also fed back to the fire by radiation from the flame, and this source of heat keeps the fire going. If we could devise a way to interrupt that feedback of heat to the fuel, the continuity of the fire would be broken, and the fire would go out. Hence, a fire-extinguishing agent is needed that siphons heat energy away from the fire, reduces the temperature of the material burning, and cools the surroundings below the ignition temperature of the fuel, so that there would not be a re-ignition of flammable vapors once the fire was extinguished.

Water is the most common extinguishing agent that performs this task. Water has many disadvantages, however. Some of the drawbacks to the use of water as an extinguishing agent include its propensity to conduct electricity (which, of course, is deadly if the water is applied incorrectly), its low viscosity (which allows it to run off a wall instead of sticking there), and a high surface tension (which prevents it from penetrating tightly arranged materials). Water also allows heat to be radiated through it, freezes at a relatively high temperature, splashes about, and displaces many flammable liquids, causing them to spread rapidly, while burning all the time. This list of problems also includes the fact that water itself will violently react with many of the hazardous materials it is supposed to control.

In addition to the fact that water is relatively inexpensive and is usually available in large quantities, there are two specific properties of water that make it invaluable. Those properties are its latent heat of vaporization and its specific heat. The latent heat of vaporization of a substance is defined as the amount of heat a material must absorb when it changes from a liquid to a vapor or gas. The specific heat of a substance is defined as the ratio between the amount of heat necessary to raise the temperature of a substance and the amount of heat necessary to raise the same weight of water by the same number of degrees.

Water, of course, does not work with all materials. There is a special class of materials that are water reactive, and hence water becomes an unacceptable extinguishing agent. For these classes of materials another approach to eliminating the fire is taken. Specifically, we must remove the oxidizer leg from the fire triangle; i.e. cut off the supply of oxygen which fuels the air to fuel mixture.

3.3 Fire Classes [3]

In firefighting, fires are identified according to one or more fire classes. Each class designates the fuel involved in the fire, and thus the most appropriate extinguishing agent. The classifications allow selection of extinguishing agents along lines of effectiveness at putting the type of fire out, as well as avoiding unwanted side-effects. For example, non-conductive extinguishing agents are rated for electrical fires, so to avoid electrocuting the firefighter. Multiple classification systems exist, with different designations for the various classes of fire.

The United States uses the NFPA (*National Fire Protection Association*) system. Europe and Australasia use another.

American	European/Australian/Asian	Fuel/Heat source
Class A	Class A	Ordinary combustibles
Class B	Class B	Flammable liquids
	Class C	Flammable gases
Class C	Class E	Electrical equipment
Class D	Class D	Combustible metals
Class K	Class F	Cooking oil or fat

Figure 2.4: Fire classes

- **Ordinary combustibles:**

"Ordinary combustible" fires are the most common type of fire, and are designated *Class A* under both systems. These occur when a solid, organic material such as wood, cloth, rubber, or some plastics become heated to their flash point and ignite. At this point the material undergoes combustion and will continue burning as long as the four components of the fire tetrahedron (heat, fuel, oxygen, and the sustaining chemical reaction) are available. This class of fire is commonly used in controlled circumstances, such as a campfire, match or wood-burning stove. To use the campfire as an example, it has a fire tetrahedron - the heat is provided by another fire (such as a match or lighter), the fuel is the wood, the oxygen is naturally available in the open-air environment of a forest, and the chemical reaction links the three other facets. This fire is not dangerous, because the fire is contained to the wood alone and is usually isolated from other flammable materials, for example by bare ground and rocks. However, when a class-A fire burns in a less-restricted environment the fire can quickly grow out of control and become a wildfire. This is the case when firefighting and fire control techniques are required. This class of fire is fairly simple to fight and contain - by simply removing the heat, oxygen, or fuel, or by suppressing the underlying chemical reaction, the fire tetrahedron collapses and the fire dies out. The most common way to do this is by removing heat by spraying the burning material with water; oxygen can be removed by smothering the fire with foam from a fire extinguisher; forest fires are often fought by removing fuel by backburning; and an ammonium phosphate dry chemical powder fire extinguisher (but not sodium bicarbonate or potassium bicarbonate both of which are rated for B-class fires) breaks the fire's underlying chemical reaction. As these fires are the most commonly encountered, most fire departments have equipment to handle them specifically. While this is acceptable for most ordinary conditions, most firefighters find themselves having to call for special equipment such as foam in the case of other fires.

- **Flammable liquid and gas:**

Flammable or combustible liquid or gaseous fuels: The US system designates all such fires "Class B". In the European/Australian system, flammable liquids are designated "Class B", while burning gases are separately designated "Class C". These fires follow the same basic fire tetrahedron (heat, fuel, oxygen, chemical reaction) as ordinary combustible fires, except that the fuel in question is a flammable liquid such as gasoline, or gas such as natural gas. A solid stream of water should never be used to extinguish this type because it can cause the fuel to scatter, spreading the flames. The most effective way to extinguish a liquid or gas fueled fire is by inhibiting the chemical chain reaction of the fire, which is done by dry chemical and Halon extinguishing agents, although smothering with CO_2 or, for liquids, foam is also effective. Halon has fallen out of favor in recent times because it is an ozone-depleting material; the Montreal Protocol declares that Halon should no longer be used. Chemicals such as FM-200 are now the recommended halogenated suppressant. Some newer clean agents designed to replace Halon work by cooling the liquid below its flash point, but these have limited class B effectiveness.

- **Electrical**

Electrical fires are fires involving potentially energized electrical equipment. The US system designates these "Class C"; the European/Australian system designates them "Class E". This sort of fire may be caused by, for example, short-circuiting machinery or overloaded electrical cables. These fires can be a severe hazard to firefighters using water or other conductive agents: Electricity may be conducted from the fire, through water, the firefighter's body, and then earth. Electrical shocks have caused many firefighter deaths. Electrical fire may be fought in the same way as an ordinary combustible fire, but water, foam, and other conductive agents are not to be used. While the fire is, or could possibly be electrically energized, it can be fought with any extinguishing agent rated for electrical fire. Carbon dioxide CO2, FM-200 and dry chemical powder extinguishers such as PKP and even baking soda are especially suited to extinguishing this sort of fire. This should be last resort solution to extinguishing the fire due to PKP's corrosive tendencies. Once electricity is shut off to the equipment involved, it will generally become an ordinary combustible fire.

- **Metal**

Certain metals are flammable or combustible. Fires involving such are designated "Class D" in both systems. Examples of such metals include sodium, titanium, magnesium, potassium, steel, uranium, lithium, plutonium, and calcium. Magnesium and titanium fires are common, and 2006-7 saw the recall of laptop computer models containing lithium batteries susceptible to spontaneous ignition. When one of these combustible metals ignites, it can easily and rapidly spread to surrounding ordinary combustible materials. With the exception of the metals that burn in contact with air or water (for example, sodium), masses of combustible metals do not represent unusual fire risks because they have the ability to conduct heat away from hot spots so efficiently that the heat of combustion cannot be maintained - this means that it will require a lot of heat to ignite a mass of combustible metal. Generally, metal fire risks exist when sawdust, machine shavings and other metal 'fines' are present. Generally, these fires can be ignited by the same types of ignition sources that would start other common fires. Water and other common firefighting materials can excite metal fires and make them worse. The NFPA recommends that metal fires be fought with 'dry powder' extinguishing agents. Dry Powder agents work by smothering and heat absorption. The most common of these agents are sodium chloride granules and graphite powder. In recent years powdered copper has also come into use. Some extinguishers are labeled as containing *dry chemical* extinguishing agents. This may be confused with *dry powder*. The two are not the same. Using one of these extinguishers in error, in place of dry powder, can be ineffective or actually increase the intensity of a metal fire. Metal fires represent a unique hazard because people are often not aware of the characteristics of these fires and are not properly prepared to fight them. Therefore, even a small metal fire can spread and become a larger fire in the surrounding ordinary combustible materials.

2.4 Fire Fighting System:

Firefighting is the act of extinguishing destructive fires. An automatic fire fighting system is used to detect the unwanted presence of fire by monitoring environmental changes associated with combustion. In general, a Fire Fighting System is either classified as automatically actuated, manually actuated, or both. Automatic fire alarm systems can be used to notify people to evacuate in the event of a fire or other emergency, to summon emergency services, and to prepare the structure and associated systems to control the spread of fire and smoke.

Design:

After the fire protection goals are established - usually by referencing the minimum levels of protection mandated by the appropriate model building code, insurance agencies, and other authorities - the fire fighting system designer undertakes to detail specific components, arrangements, and interfaces necessary to accomplish these goals. Equipment specifically manufactured for these purposes are selected and standardized installation methods are anticipated during the design. In most industries, NFPA 72, *The National Fire Alarm Code* is an established and widely used installation standard.

Generally any fire fighting system will have the following components:

- Fire alarm control panel: This component, the hub of the system, monitors inputs and system integrity, controls outputs and relays information.

- Primary Power supply: Commonly the non-switched 120 or 240 Volt Alternating Current source supplied from a commercial power utility. In non-residential applications, a branch circuit is dedicated to the fire alarm system and its constituents. "Dedicated branch circuits" should not be confused with "Individual branch circuits" which supply energy to a single appliance.

- Secondary (backup) Power supplies: This component, commonly consisting of sealed lead-acid storage batteries or other emergency sources including generators, is used to supply energy in the event of a primary power failure.

- Initiating Devices: This component acts as an input to the fire alarm control unit and are either manually or automatically actuated.

- Notification appliances: This component uses energy supplied from the fire alarm system or other stored energy source, to inform the proximate persons of the need to take action, usually to evacuate.
- A fire sprinkler system that discharges water when the effects of a fire have been detected.

- Safety Interfaces: This interface allows the fire fighting system to control aspects of the built environment and to prepare the building for fire and to control the spread of smoke fumes and fire by influencing air movement, lighting, process control, human transport and exit.

Fire alarm control panel:

A fire alarm control panel (FACP), or fire alarm control unit (FACU), is an electric panel that is the controlling component of a fire fighting system. The panel receives information from environmental sensors designed to detect changes associated with fire, monitors their operational integrity and provides for automatic control of equipment, and transmission of information necessary to prepare the facility for fire based on a predetermined sequence. The panel may also supply electrical energy to operate any associated sensor, control, transmitter, or relay.

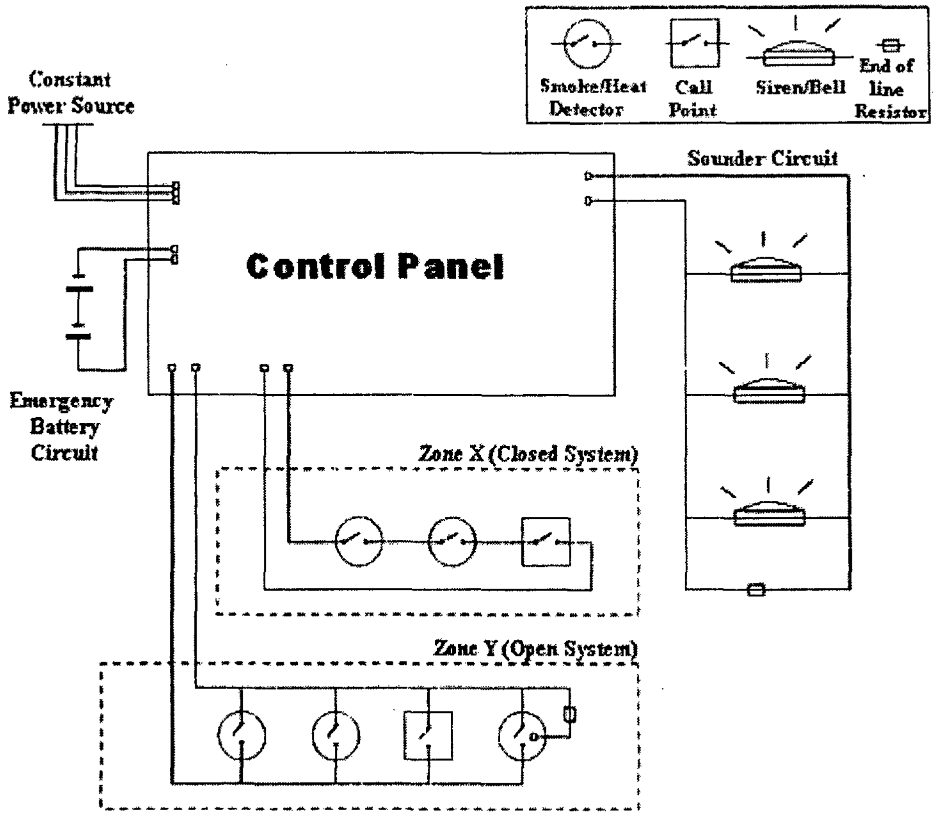


Figure 2.5: Fire alarm control panel

Various initiating devices and notification appliances are as follows:

Initiating devices

- Manually actuated devices; Break glass stations, Buttons and manual pull station are constructed to be readily located (near the exits), identified, and operated.
- Automatically actuated devices can take many forms intended to respond to any number of detectable physical changes associated with fire: emitted thermal energy; heat detector, products of combustion; smoke detector, radiant energy; flame detector, combustion gasses; carbon monoxide detector. The newest innovations can use cameras and computer algorithms to analyze the visible effects of fire and movement in applications inappropriate for or hostile to other detection methods.

Notification appliances:

- Audible, visible or tactile to alert the occupants. Audible or visible signals are the most common and may utilize speakers to deliver live or pre-recorded instructions to the occupants. In the United States, fire alarm evacuation signals are required to use a standardized interrupted four count temporal pattern to avoid confusion with other signals using similar sounding appliances.
- Other methods include: Audible textual appliances, which are employed as part of a fire alarm system that includes Emergency Voice Alarm Communications (EVAC) capabilities. High reliability speakers are used to notify the occupants of the need for action in connection with a fire or other emergency. These speakers are employed in large facilities where general undirected evacuation is considered impracticable or undesirable. The signals from the speakers are used to direct the occupant's response. The system may be controlled from one or more locations within the building known as Fire Wardens Stations, or from a single location designated as the building Fire Command Center. Speakers are automatically actuated by the fire alarm system in a fire event, and following a pre-alert tone, selected groups of speakers may transmit one or more prerecorded messages directing the occupants to safety. These messages may be repeated in one or more languages. Trained personnel activating and speaking into a dedicated microphone can suppress the replay of automated messages in order to initiate or relay real time voice instructions.

List of the input and output devices of a fire alarm control panel are given below.

Common input devices include:

- Smoke detectors
- Heat Detectors (Rate of Rise and Fixed Temperature)
- Manual call points or manual pull stations
- Notification appliances
- Responders
- Fire sprinkler system inputs
- Switches

- Flow control
- Pressure
- Isolate
- Standard switches

Output devices are known as relays and include:

- (Warning System/Bell) Relays
- Door Holder Relays
- Auxiliary (Control Function) Relays

Relays are used to control a variety of functions such as:

- Switching fans on or off
- Closing/opening fire dampers
- Activating fire suppression systems
- Activating notification appliances
- Shutting down industrial equipment
- Recalling elevators to a safe exit floor
- Activating another fire alarm panel or communicator

2.5 Fire Detectors:

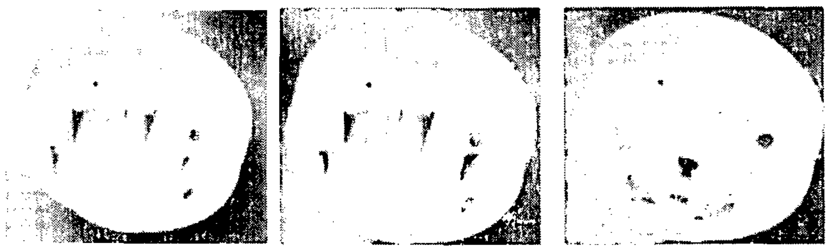


Figure 2.6 fire detectors

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 and/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. 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.

Optical Smoke Detector

Optical smoke detectors incorporate a pulsing LED located in a chamber within the housing of the detector. The chamber is designed to exclude light from any external source. At an angle to the LED is a photo-diode which normally does not register the column of light emitted by the LED. In the event of smoke from a fire entering the chamber, the light pulse from the LED will be scattered and hence registered by the photo-diode. If the photo-diode "sees" smoke on the two following pulses, the detector changes into the alarm state and the indicator LED lights up. The detector housing is identical to that of the ionization detector but has an indicator LED which is clear in quiescent state but produces red light in alarm.

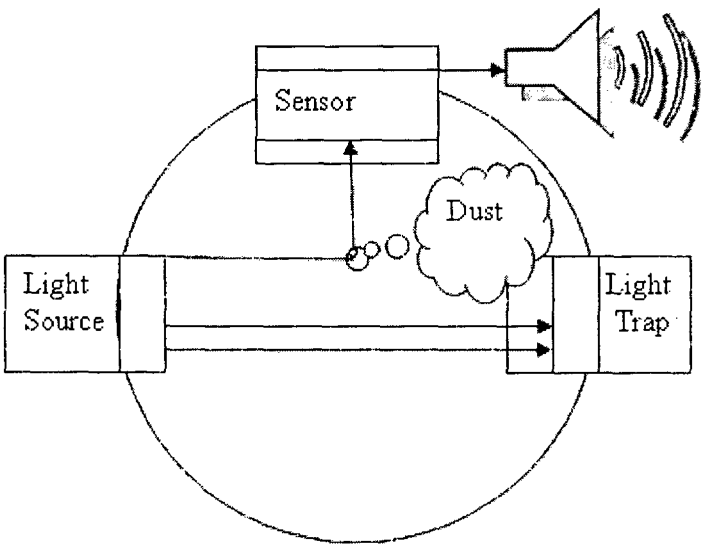


Figure 2.7: Optical smoke detector

Optical smoke detectors are quick in detecting particulate (smoke) generated by smoldering (cool, smoky) fires. Many independent tests indicate that optical smoke detectors typically detect particulates (smoke) from hot, flaming fires approximately 30 seconds later than ionization smoke alarms.

They are less sensitive to false alarms from steam or cooking fumes generated in kitchen or steam from the bathroom than are ionization smoke alarms. For the aforementioned reason, they are often referred to as 'toast proof' smoke alarms.

Ionization Smoke Detector

This type of detector is cheaper than the optical detector; however, it is sometimes rejected because it is more prone to false (nuisance) alarms than photoelectric smoke detectors. It can detect particles of smoke that are too small to be visible.

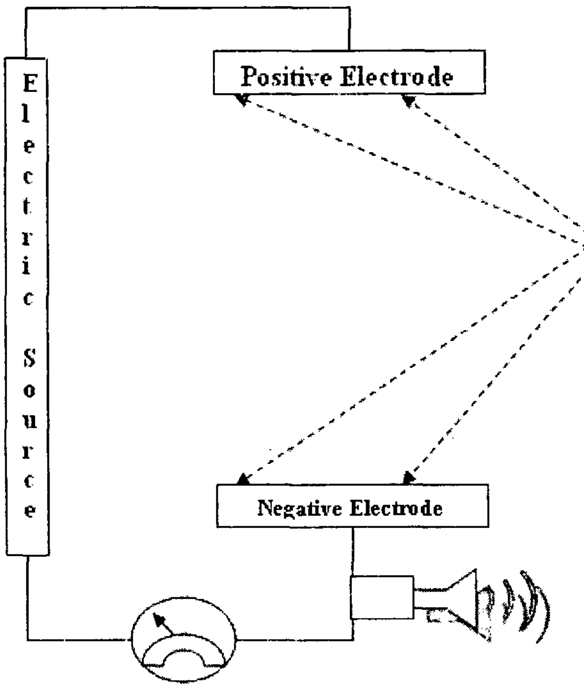


Figure 2.8: Ionization smoke detector

The sensing part of the detector consists of two chambers - an open, outer chamber and a semi-sealed reference chamber within. Mounted in the reference chamber is a low activity radioactive foil of Americium 241 which enables current to flow between the inner and outer chambers when the detector is powered up. As smoke enters the detector, it causes a reduction of the current flow in the outer chamber and hence an increase in voltage measured at the junction between the two chambers. The voltage increase is monitored by the electronic circuitry which triggers the detector into the alarm state at a preset threshold. An externally visible red LED lights up when the detector changes to alarm state. An integrating ionization detector, suitable for use in areas where transient levels of smoke may be expected, is also available.

^{241}Am, an alpha emitter, has a half-life of 432 years. This means that it does not have to be replaced during the useful life of the detector, and also makes it safe for people at home, since it is only slightly radioactive. Alpha radiation, as opposed to beta and gamma, is used for two additional reasons: Alpha particles have high ionization, so sufficient air particles will be ionized for the current to exist, and they have low penetrative power, meaning they will be stopped by the plastic of the smoke detector and/or the air. About one percent of the emitted radioactive energy of ^{241}Am is gamma radiation.

Heat Detector

A heat detector is a device that responds to changes in ambient temperature. Typically, if the ambient temperature rises above a predetermined threshold an alarm signal is triggered. Fixed temperature heat detectors and Rate-of-rise (ROR) heat detectors operate by using a matched pair of thermistors to sense heat. One thermistor is exposed to the ambient temperature, the other is sealed. In normal conditions the two thermistors register similar temperatures, but, on the development of a fire, the temperature recorded by the exposed thermistor will increase rapidly, resulting in an imbalance, causing the detector to change into the alarm state. Rate-of-rise detectors are designed to detect a fire as the temperature increases, but they also have a fixed upper limit at which the detector will go into alarm if the rate of temperature increase has been too slow to trigger the detector earlier. Externally, the heat detectors are distinguishable from the smoke detectors by having wide openings to the surrounding atmosphere to allow good movement of air around the external thermistor.

Heat Detector ideally suited to locations where high sensitivity is required for change in heat and where smoke detectors are found unsuitable for detection of fire. Generally, smoke detectors, do not work efficiently in the places where material stores and produces little smoke in the initial stage of out breaking of fire or where adverse environmental conditions are prevailing.

2.6 Programmable Logic Controller [5]

A programmable logic controller (PLC) is an industrially hardened computer-based unit that performs discrete or continuous control functions in a variety of processing plant and factory environments. Originally intended as relay replacement equipment for the automotive industry, the PLC is now used in virtually every industry imaginable. Though they were commonly referred to as PCs before 1980, PLC became the accepted abbreviation for programmable logic controllers, as the term "PC" became synonymous with personal computers in recent decades. PLCs are produced and sold worldwide as stand-alone equipment by several major control equipment manufacturers. In addition, a variety of more specialized companies produce PLCs for original equipment manufacturer (OEM) applications.

Typically, PLC vendors can supply large volumes of application notes for their products. Most major PLC vendors also publish detailed articles about applications in technical journals and prepare papers for engineering societies and industrial symposia on control, automation, and so forth. Each manufacturer's software package usually has its own application programming techniques. Vendors also are a valuable source of "how-to" information, providing training courses in their local office or at the factory as well as actual hands-on experience to help users gain familiarity with the PLC. Most vendors offer an applications or programming manual that provides insight on how to use available programming features. Of course, familiarity with one brand of PLC generally helps the engineer learn to use other brands quickly.

PLCs have been gaining popularity on the factory floor and will probably remain predominant for some time to come. Most of this is because of the advantages they offer.

- Cost effective for controlling complex systems.
- Flexible and can be reapplied to control other systems quickly and easily.
- Computational abilities allow more sophisticated control.
- Trouble shooting aids make programming easier and reduce downtime.
- Reliable components make these likely to operate for years before failure.

The following table gives a comparison between conventional Relay Systems, Solid-State control system, Microprocessor, Minicomputer and Programmable Logic Controllers.

	Relays	Solid-State Controls	Microprocessor	Minicomputer	PLCs
Hardware cost	Low	Equal	Low	High	High to low, depending on number of controls
Versatility	Low	Low	Yes	Yes	Yes
Usability	Yes	Yes	No	No	Yes
Troubleshooting maintainability	Yes	No	No	No	Yes
Computer-compatible	No	No	Yes	Yes	Yes
Arithmetic capability	No	No	Yes	Yes	Yes
Information gathering	No	No	Yes	Yes	Yes
Industrial environment	Yes	No	No	No	Yes
Programming cost	(Wiring) High	(Wiring) High	Very high	High	Low
Reusable	No	No	Yes	Yes	Yes
Space required	Largest	Large	Small	OK	Small

Table 2.1: Comparison between conventional Relay Systems, Solid-State control system, Microprocessor, Minicomputer and Programmable Logic Controllers

Hardware:

Many PLC configurations are available, even from a single vendor. But, in each of these there are common components and concepts. The most essential components are:

Power Supply - This can be built into the PLC or be an external unit. Common voltage levels required by the PLC (with and without the power supply) are 24Vdc, 120Vac, 220Vac.

CPU (Central Processing Unit) - This is a computer where ladder logic is stored and processed.

I/O (Input/output) - A number of input/output terminals must be provided so that the PLC can monitor the process and initiate actions.

Indicator lights - These indicate the status of the PLC including power on, program running, and a fault. These are essential when diagnosing problems.

Block diagram of a Programmable Logic Controller:

The block diagram of a PLC is as shown in the following figure and explanation for each block is as given below.

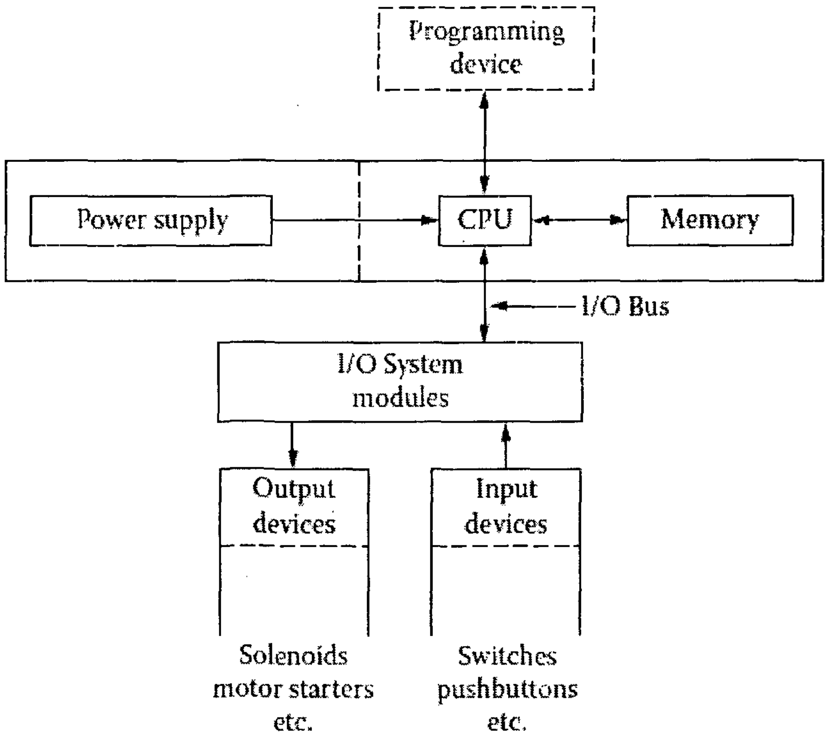


Figure 2.9: Block diagram of a PLC

CPU:

- The processor unit houses the microprocessor, memory module and the communication circuitry necessary for the processor to operate and communicate with the I/O and other peripheral equipment
- The CPU is the decision maker that controls the operation of the equipment to which it is connected. It controls the operating devices and the program that has been entered into memory.

- The scan rate is determined by the microprocessor clock rate and the program size and is in the order of 1 to 10 ms per kilobyte of program.
- The differences in CPUs (and PLCs) are typically dependent on number of I/O they can processes, amount of memory, number and type of instructions, and speed of the CPU.

Program memory:

- This memory is either battery backed CMOS random access during program development or some form of Read-Only-Memory that does not lose its content on losing power.
- In this area the program steps are stored. It is important that this area is non-volatile since in the event of a power failure it would be very inconvenient to have to re-enter the program steps.

Work memory:

- In many cases, this area of CMOS random access memory will at least be partially battery backed to prevent loss of its content in the event of power loss.
- This area stores auxiliary relay states, timer/counter states, various I/O states and arithmetic logic calculations result. This section that holds auxiliary relay states will usually be battery backed.

Inputs and Outputs Modules:

Inputs to, and outputs from, a PLC is necessary to monitor and control a process. Both inputs and outputs can be categorized into two basic types: logical or continuous. Consider the example of a light bulb. If it can only be turned on or off, it is logical control. If the light can be dimmed to different levels, it is continuous. Continuous values seem more intuitive, but logical values are preferred because they allow more certainty, and simplify control. As a result most controls applications (and PLCs) use logical inputs and outputs for most applications.

Outputs to actuators allow a PLC to cause something to happen in a process. A short list of popular actuators is given below in order of relative popularity.

- Solenoid Valves: logical outputs that can switch a hydraulic or pneumatic flow.
- Lights: logical outputs that can often be powered directly from PLC output boards.
- Motor Starters: Motors often draw a large amount of current when started, so they require motor starters, which are basically large relays.

- Servo Motors: A continuous output from the PLC can command a variable speed or position.

Outputs from PLCs are often relays, but they can also be solid state electronics such as transistors for DC outputs or Triacs for AC outputs. Continuous outputs require special output cards with digital to analog converters.

Inputs come from sensors that translate physical phenomena into electrical signals. Typical examples of sensors are listed below in relative order of popularity.

- Proximity Switches: Uses inductance, capacitance or light to detect an object logically.
- Switches: Mechanical mechanisms will open or close electrical contacts for a logical signal.
- Potentiometer: Measures angular positions continuously using resistance.
- LVDT (linear variable differential transformer): Measures linear displacement continuously using magnetic coupling.

Inputs for a PLC come in a few basic varieties, the simplest are AC and DC inputs. Sourcing and sinking inputs are also popular. This output method dictates that a device does not supply any power. Instead, the device only switches current on or off, like a simple switch.

- Sinking: When active the output allows current to flow to a common ground. This is best selected when different voltages are supplied.
- Sourcing: When active, current flows from a supply, through the output device and to ground. This method is best used when all devices use a single supply voltage. This is also referred to as NPN (sinking) and PNP (sourcing). PNP is more popular.

In smaller PLCs the inputs and outputs are normally built in and are specified when purchasing the PLC. For larger PLCs the inputs and outputs are purchased as modules, or cards, with 8 or 16 inputs of the same type on each card. The I/O modules are designed for both analog and digital inputs and outputs for different voltage and current ranges.

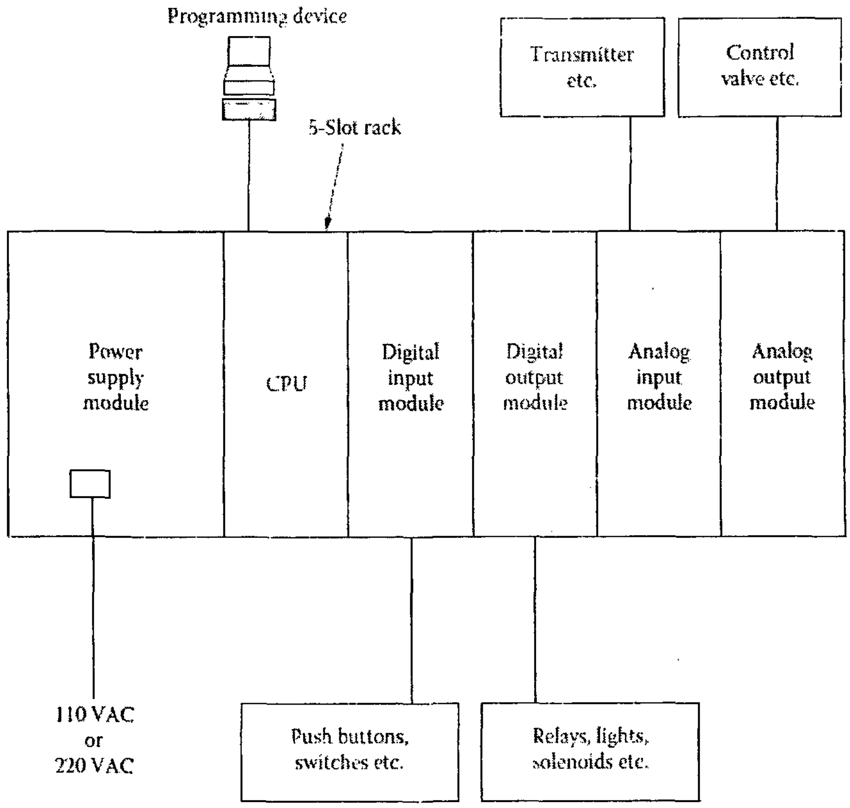


Figure 2.10: PLC I/O modules

PLC input cards rarely supply power, this means that an external power supply is needed to supply power for the inputs and sensors.

Programming device:

- A programming device is needed to enter, modify, and troubleshoot the plc program, or to check the condition of the processor.
- Once program has been entered and the plc is running, the programming device may be disconnected.
- It is not necessary for the programming device to be connected for the plc to operate, but it is used to monitor the plc program while program is running.
- They come in three types
    - Dedicated Desktop Programmer
    - Hand Held Programmer
    - Computer Programmer

Power Supply Unit:

- The PLCs internal power supply provides a clean DC supply to all the internal logic and microprocessor circuitry.
- There may also be battery backup of useful auxiliary relay contacts, timer/counter values and, most important of all, program memory where this is in volatile RAM.
- The power supply is intended to power the cards that plug into the rack and not for powering the sensors and actuators.
- The power for sensors and actuators should be powered using a separate, isolated power source.
- The PLC power supplies are isolated to minimize noise and other problems and therefore two separate and different power sources are preferred.

Operation Sequence:

All PLCs have four basic stages of operations that are repeated many times per second. Initially when turned on the first time it will check its own hardware and software for faults. If there are no problems it will copy all the input and copy their values into memory, this is called the input scan. Using only the memory copy of the inputs the ladder logic program will be solved once, this is called the logic scan. While solving the ladder logic the output values are only changed in temporary memory. When the ladder scan is done the outputs will updated using the temporary values in memory, this is called the output scan. The PLC now restarts the process by starting a self check for faults. This process typically repeats 10 to 100 times per second as is shown in the following figure.

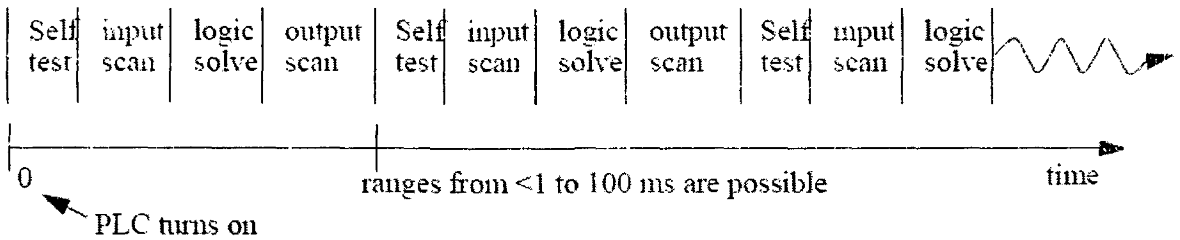


Figure 2.11: PLC Scan Cycle

SELF TEST - Checks to see if all cards error free, reset watch-dog timer, etc. (A watchdog timer will cause an error, and shut down the PLC if not reset within a short period of time - this would indicate that the ladder logic is not being scanned normally).

INPUT SCAN - Reads input values from the chips in the input cards, and copies their values to memory. This makes the PLC operation faster, and avoids cases where an input changes from the start to the end of the program (e.g., an emergency stop). There are special PLC functions that read the inputs directly, and avoid the input tables.

LOGIC SOLVE/SCAN - Based on the input table in memory, the program is executed 1 step at a time, and outputs are updated. This is the focus of the later sections.

OUTPUT SCAN - The output table is copied from memory to the output chips. These chips then drive the output devices.

The input scan takes a *snapshot* of the inputs, and solves the logic. This prevents potential problems that might occur if an input that is used in multiple places in the ladder logic program changed while half ways through a ladder scan, Thus changing the behaviors of half of the ladder logic program. This problem could have severe effects on complex programs that are developed later in the book. One side effect of the input scan is that if a change in input is too short in duration, it might fall between input scans and be missed. When the PLC is initially turned on the normal outputs will be turned off. This does not affect the values of the inputs.

PLC Programming:

Plc manufacturers have their own programming editors. There are five programming languages to program a plc. They are

- Instruction List(IL)
- Structured Text(ST)
- Ladder Diagrams(LD)
- Function Block Diagram(FBD)
- Sequential Function Chart(SFC)

Out of all ladder logic is the most commonly used programming language in many industrial applications. Its syntax for the instructions is similar to a relay ladder logic diagram: Ladder allows us to track the power flow between power rails as it passes through various contacts, complex elements, and output coils. The logical connections between the binary signal states are represented by a serial or parallel arrangement of contacts. Each rung in the ladder ends in a coil. Complex functions are represented by boxes. The following list gives the instructions available for programming Siemens S7 series PLCs.

Instructions [9]:

- **Bit Logic Instructions**

Bit logic instructions work with two digits, 1 and 0. These two digits form the base of a number system called the binary system. The two digits 1 and 0 are called binary digits or bits. In the world of contacts and coils, a 1 indicates activated or energized, and a 0 indicates not activated or not energized. The bit logic instructions interpret signal states of 1 and 0 and combine them according to Boolean logic. These combinations produce a result of 1 or 0 that is called the "result of logic operation" (RLO). The logic operations that are triggered by the bit logic instructions perform a variety of functions.

There are bit logic instructions to perform the following functions:

- ---| |--- Normally Open Contact (Address)
- ---| / |--- Normally Closed Contact (Address)
- --- (SAVE) Save RLO into BR Memory
- XOR Bit Exclusive OR
- --- ( ) Output Coil
- --- (#) --- Midline Output
- ---|NOT|--- Invert Power Flow

The following instructions react to an RLO of 1:

- ---(S) Set Coil
- ---(R) Reset Coil
- SR Set-Reset Flip Flop
- RS Reset-Set Flip Flop

Other instructions react to a positive or negative edge transition to perform the following functions:

- --- (N) --- Negative RLO Edge Detection
- --- (P) --- Positive RLO Edge Detection

• NEG Address Negative Edge Detection

• POS Address Positive Edge Detection

• Immediate Read

• Immediate Write

- **Comparison Instructions**

IN1 and IN2 are compared according to the type of comparison choosed:

== IN1 is equal to IN2

<> IN1 is not equal to IN2

> IN1 is greater than IN2

< IN1 is less than IN2

>= IN1 is greater than or equal to IN2

<= IN1 is less than or equal to IN2

If the comparison is true, the RLO of the function is "1". It is linked to the RLO of a rung network by AND if the compare element is used in series, or by OR if the box is used in parallel. The following comparison instructions are available:

• CMP? I Compare Integer

• CMP? D Compare Double Integer

• CMP? R Compare Real

- **Conversion Instructions**

The conversion instructions read the contents of the parameters IN and convert these or change the sign. The result can be queried at the parameter OUT.

The following conversion instructions are available:

• BCD_I BCD to Integer

• I_BCD Integer to BCD

• BCD_ DI BCD to Double Integer

• I_DINT Integer to Double Integer

• DI_BCD Double Integer to BCD

• DI_REAL Double Integer to Floating-Point

• INV_I Ones Complement Integer

• INV_DI Ones Complement Double Integer

• NEG_I Twos Complement Integer

- NEG_DI Twos Complement Double Integer
- NEG_R Negate Floating-Point Number
- ROUND Round to Double Integer
- TRUNC Truncate Double Integer Part
- CEIL Ceiling
- FLOOR Floor

- **Counter Instructions**

Area in Memory

Counters have an area reserved for them in the memory of the CPU. This memory area reserves one 16-bit word for each counter address. The ladder logic instruction set supports 256 counters. The counter instructions are the only functions that have access to the counter memory area.

Count Value

Bits 0 through 9 of the counter word contain the count value in binary code. The count value is moved to the counter word when a counter is set. The range of the count value is 0 to 999.

We can vary the count value within this range by using the following counter instructions:

- S_CUD Up-Down Counter
- S_CD down Counter
- S_CU up Counter
- --- (SC) Set Counter Coil
- --- (CU) Up Counter Coil
- --- (CD) Down Counter Coil

- **Logic Control Instructions**

We can use logic control instructions in all logic blocks: organization blocks (OBs), function blocks (FBs), and functions (FCs).

There are logic control instructions to perform the following functions:

- --- (JMP) --- Unconditional Jump
- --- (JMP) --- Conditional Jump
- --- (JMPN) --- Jump-If-Not

- **Integer Math Instructions**

Using integer math, we can carry out the following operations with **two integer numbers** (16 and 32 bits):

- ADD_I Add Integer
- SUB_I Subtract Integer
- MUL_I Multiply Integer
- DIV_I Divide Integer
- ADD_DI Add Double Integer
- SUB_DI Subtract Double Integer
- MUL_DI Multiply Double Integer
- DIV_DI Divide Double Integer
- MOD_DI Return Fraction Double Integer

- **Program Control Instructions**

The following program control instructions are available:

- --- (CALL) Call FC SFC from Coil (without Parameters)
- CALL_FB Call FB from Box
- CALL_FC Call FC from Box
- CALL_SFB Call System FB from Box
- CALL_SFC Call System FC from Box
- Call Multiple Instance
- Call Block from a Library
- Important Notes on Using MCR Functions
- --- (MCR<) Master Control Relay On
- --- (MCR>) Master Control Relay Off
- --- (MCRA) Master Control Relay Activate
- --- (MCRD) Master Control Relay Deactivate
- RET Return

- **Shift instructions**

The following shift instructions are available:

- SHR_I Shift Right Integer
- SHR_DI Shift Right Double Integer
- SHL_W Shift Left Word
- SHR_W Shift Right Word
- SHL_DW Shift Left Double Word

• SHR_DW Shift Right Double Word

- **Timer Instructions**

The following timer instructions are available:

• S_PULSE Pulse S5 Timer

• S_PEXT Extended Pulse S5 Timer

• S_ODT On-Delay S5 Timer

• S_ODTS Retentive On-Delay S5 Timer

• S_OFFDT Off-Delay S5 Timer

• --- (SP) Pulse Timer Coil

• --- (SE) Extended Pulse Timer Coil

• --- (SD) On-Delay Timer Coil

• --- (SS) Retentive On-Delay Timer Coil

• --- (SA) Off-Delay Timer Coil

- **Word logic instructions**

Word logic instructions compare pairs of words (16 bits) and double words (32 bits) bit by bit, according to Boolean logic. If the result at output OUT does not equal 0, bit CC 1 of the status word is set to "1". If the result at output OUT does equal 0, bit CC 1 of the status word is set to "0".

The following word logic instructions are available:

• WAND_W (Word) AND Word

• WOR_W (Word) OR Word

• WXOR_W (Word) Exclusive OR Word

• WAND_DW (Word) AND Double Word

• WOR_DW (Word) OR Double Word

• WXOR_DW (Word) Exclusive OR Double Word

Comparison between the relay logic and ladder logic:

Relays are used to let one power source close a switch for another (often high current) power source, while keeping them isolated. An example of a relay in a simple control application is shown in the following figure. In this system the first relay on the left is used as normally closed, and will allow current to flow until a voltage is applied to the input A. The second relay is normally open and will not allow current to flow until a voltage is applied to the input B. If current is flowing through the first two relays then current will flow through the coil in the third relay, and close the switch for output C.

This circuit would normally be drawn in the ladder logic form. This can be read logically as C will be on if A is off and B is on.

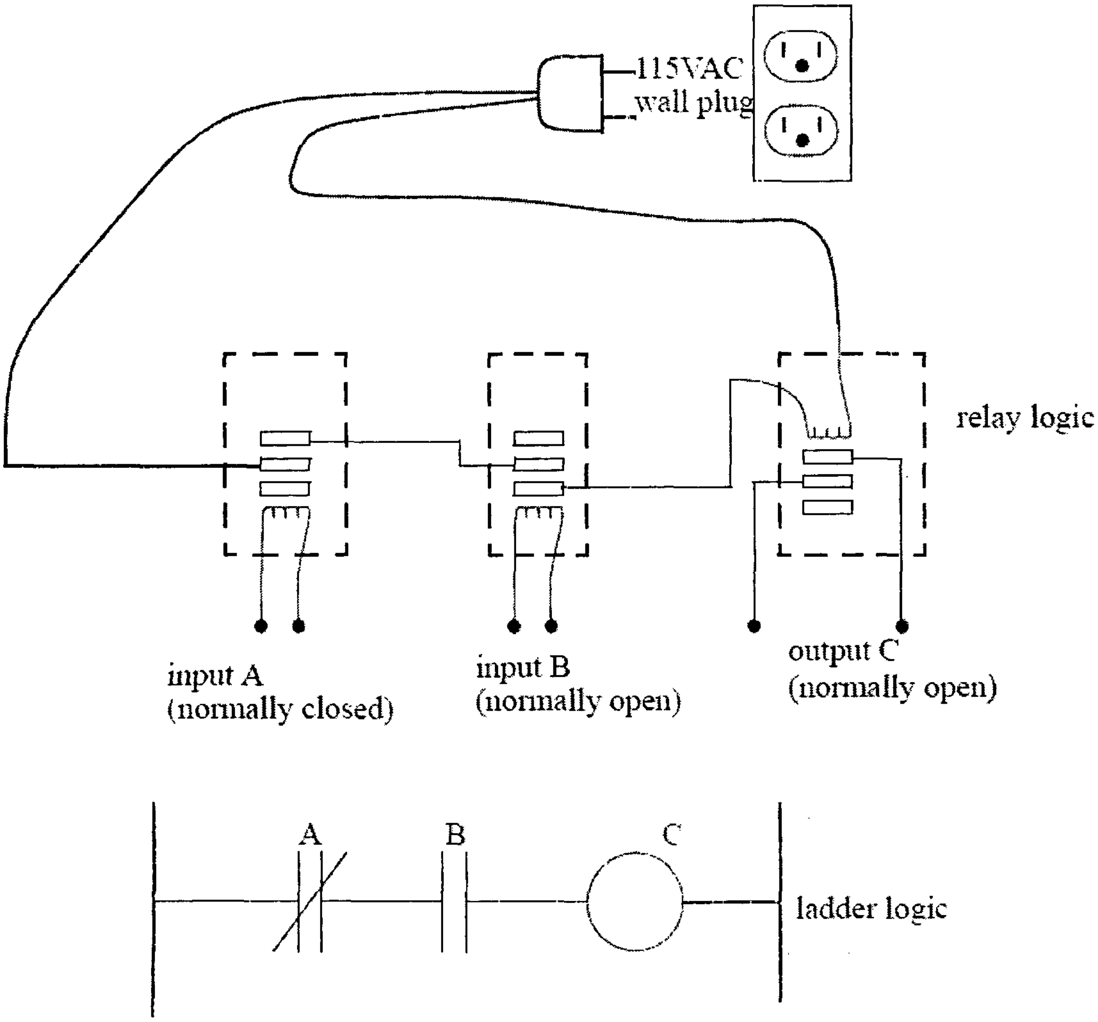


Figure 2.12: Comparison between Relay logic and Ladder logic

The following diagram explains how inputs and outputs interact with PLC using Ladder program.

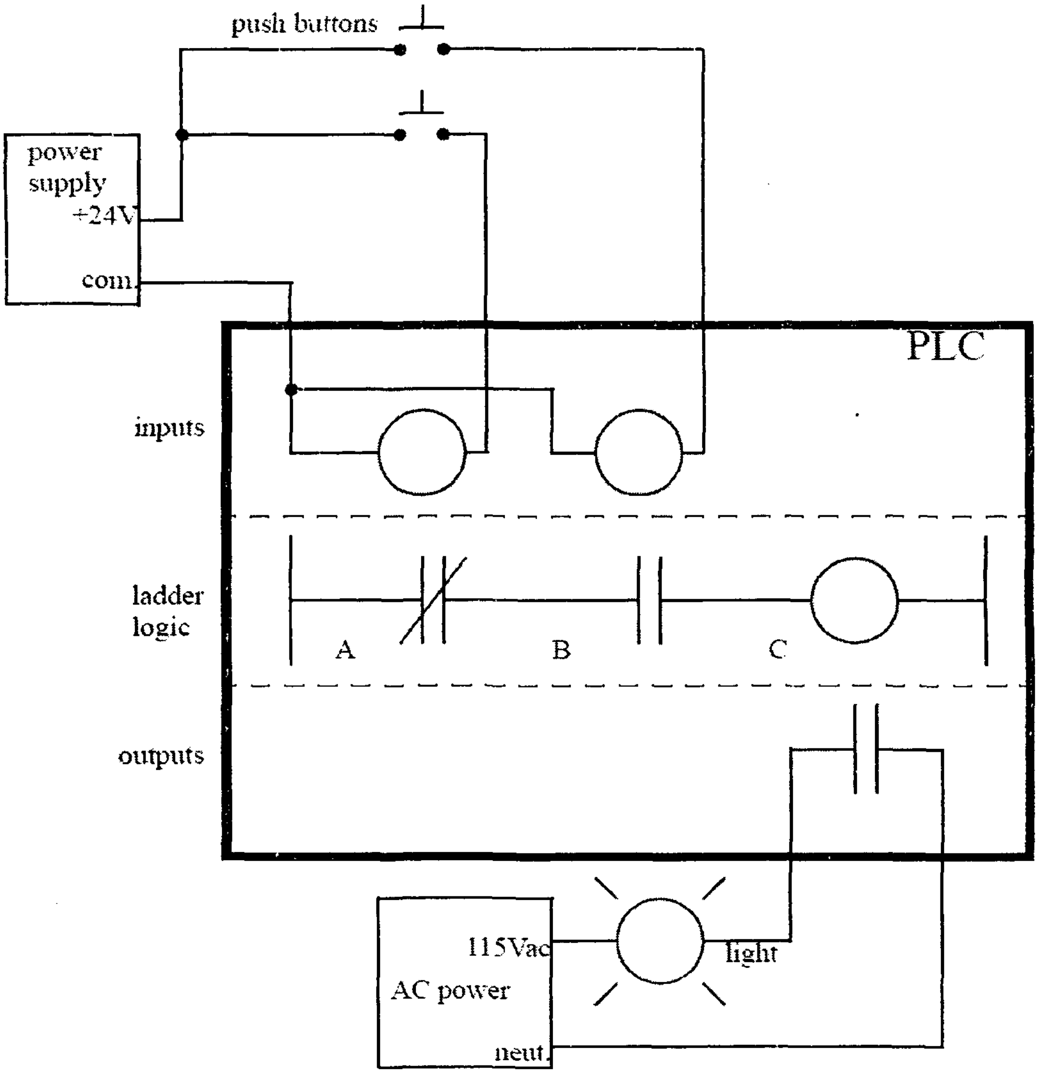


Figure 2.13: Interaction of inputs and outputs with PLC

Partial List of PLC Suppliers:

- ABB (Elsag-Bailey Controls)
- Allen-Bradley/Rockwell Automation
- Automation Direct
- Danaher (Eagle Signal Controls)
- Eaton (Cutler-Hammer)
- Emerson (Westinghouse)
- Fuji Electric Corp.
- G.E. Fanuc Automation
- Giddings & Lewis
- Idec Corp.

2.7 SCADA [1,2]

SCADA (supervisory control and data acquisition) has been around as long as there have been control systems. The first 'SCADA' systems utilized data acquisition by means of panels of meters, lights and strip chart recorders. The operator manually operating various control knobs exercised supervisory control. These devices were and still are used to do supervisory control and data acquisition on plants, factories and power generating facilities. The following figure shows a sensor to panel system.

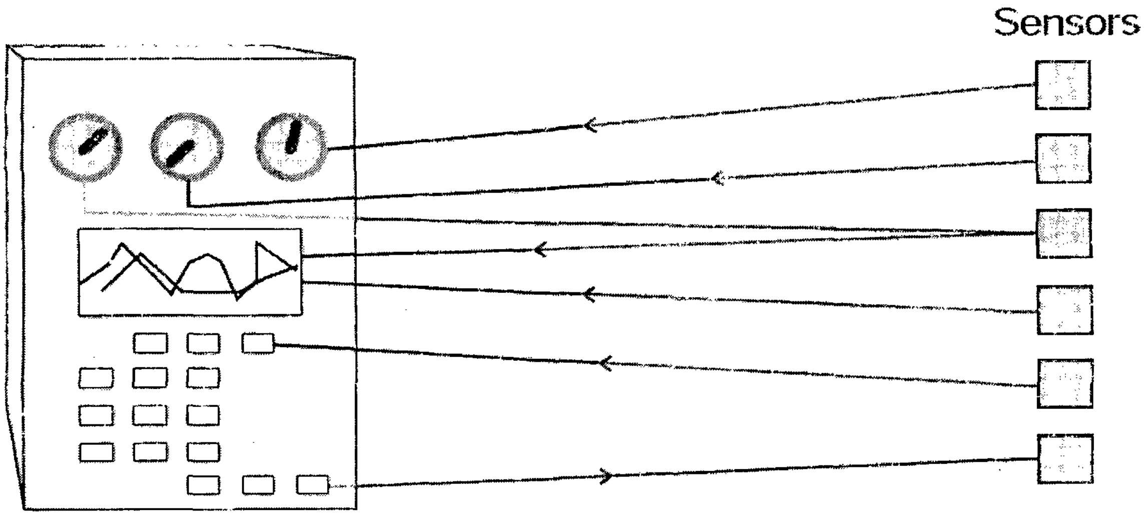


Figure 2.14: Sensor to panel system

The sensor to panel type of SCADA system has the following advantages:

- It is simple, no CPUs, RAM, ROM or software programming needed
- The sensors are connected directly to the meters, switches and lights on the panel
- It could be (in most circumstances) easy and cheap to add a simple device like a switch or indicator

The disadvantages of a direct panel to sensor system are:

- The amount of wire becomes unmanageable after the installation of hundreds of sensors
- The quantity and type of data are minimal and rudimentary
- Installation of additional sensors becomes progressively harder as the system grows
- Re-configuration of the system becomes extremely difficult
- Simulation using real data is not possible
- Storage of data is minimal and difficult to manage
- No off site monitoring of data or alarms

• Someone has to watch the dials and meters 24 hours a day

In modern manufacturing and industrial processes, mining industries, public and private utilities, leisure and security industries telemetry is often needed to connect equipment and systems separated by large distances. This can range from a few meters to thousands of kilometers. Telemetry is used to send commands, programs and receives monitoring information from these remote locations.

SCADA refers to the combination of telemetry and data acquisition. SCADA encompasses the collecting of the information, transferring it back to the central site, carrying out any necessary analysis and control and then displaying that information on a number of operator screens or displays. The required control actions are then conveyed back to the process.

In the early days of data acquisition, relay logic was used to control production and plant systems. With the advent of the CPU and other electronic devices, manufacturers incorporated digital electronics into relay logic equipment. The PLC or programmable logic controller is still one of the most widely used control systems in industry. As need to monitor and control more devices in the plant grew, the PLCs were distributed and the systems became more intelligent and smaller in size. PLCs and DCS (distributed control systems) are used as shown below.

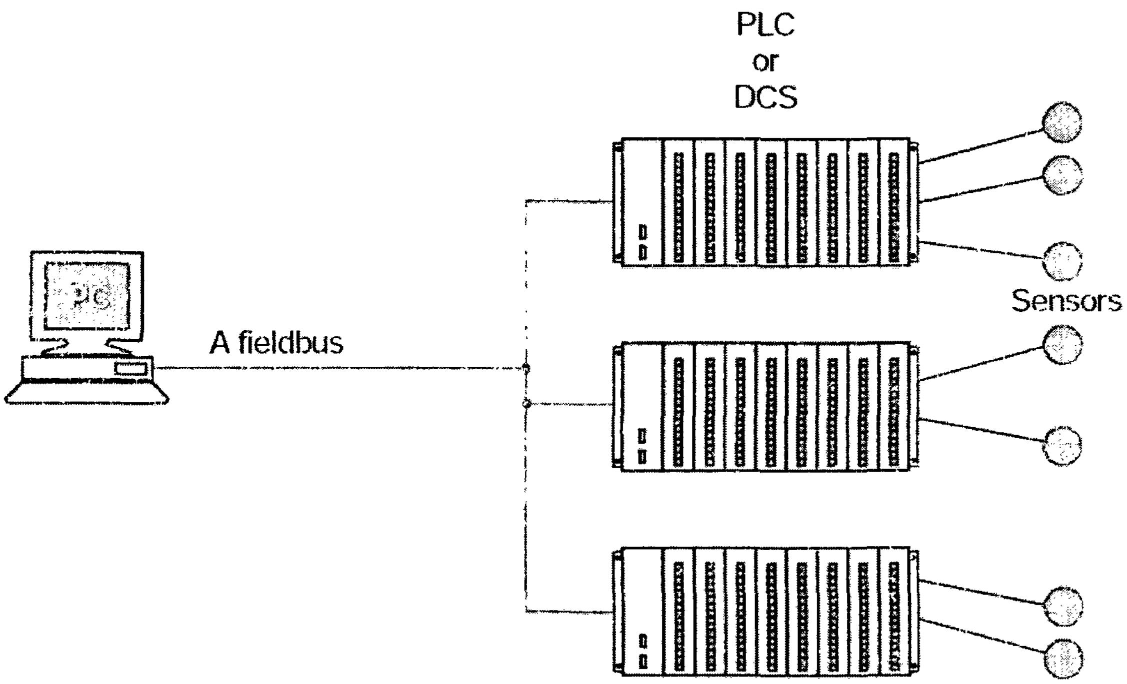


Figure 2.15. PLC / DCS SCADA

The advantages of the PLC / DCS SCADA system are:

- The computer can record and store a very large amount of data
- The data can be displayed in any way the user requires
- Thousands of sensors over a wide area can be connected to the system
- The operator can incorporate real data simulations into the system
- Many types of data can be collected from the RTUs
- The data can be viewed from anywhere, not just on site

The disadvantages are:

- The system is more complicated than the sensor to panel type
- Different operating skills are required, such as system analysts and programmer
- With thousands of sensors there is still a lot of wire to deal with
- The operator can see only as far as the PLC

SCADA HARDWARE:

A SCADA system consists of a number of remote terminal units (RTUs) collecting field data and sending that data back to a master station, via a communication system. The master station displays the acquired data and allows the operator to perform remote control tasks.

The accurate and timely data allows for optimization of the plant operation and process. Other benefits include more efficient, reliable and most importantly, safer operations. These results in a lower cost of operation compared to earlier non-automated systems.

On a more complex SCADA system there are essentially five levels or hierarchies:

- Field level instrumentation and control devices
- Marshalling terminals and RTUs
- Communications system
- The master station(s)
- The commercial data processing department computer system

The RTU provides an interface to the field analog and digital sensors situated at each remote site.

The communications system provides the pathway for communication between the master station and the remote sites. This communication system can be wire, fiber optic, radio, telephone line, microwave and possibly even satellite. Specific protocols and error detection philosophies are used for efficient and optimum transfer of data.

The master station (or sub-masters) gather data from the various RTUs and generally provide an operator interface for display of information and control of the remote sites. In large telemetry systems, sub-master sites gather information from remote sites and act as a relay back to the control master station.

SCADA software

SCADA software can be divided into two types, proprietary or open. Companies develop proprietary software to communicate to their hardware. These systems are sold as 'turn key' solutions. The main problem with this system is the overwhelming reliance on the supplier of the system. Open software systems have gained popularity because of the interoperability they bring to the system. Interoperability is the ability to mix different manufacturers' equipment on the same system.

Key features of SCADA software are:

- User interface
- Graphics displays
- Alarms
- Trends
- RTU (and PLC) interfaces
- Scalability
- Access to data
- Database
- Networking
- Fault tolerance and redundancy
- Client/server distributed processing

The typical components of a SCADA system are indicated in the next diagram.

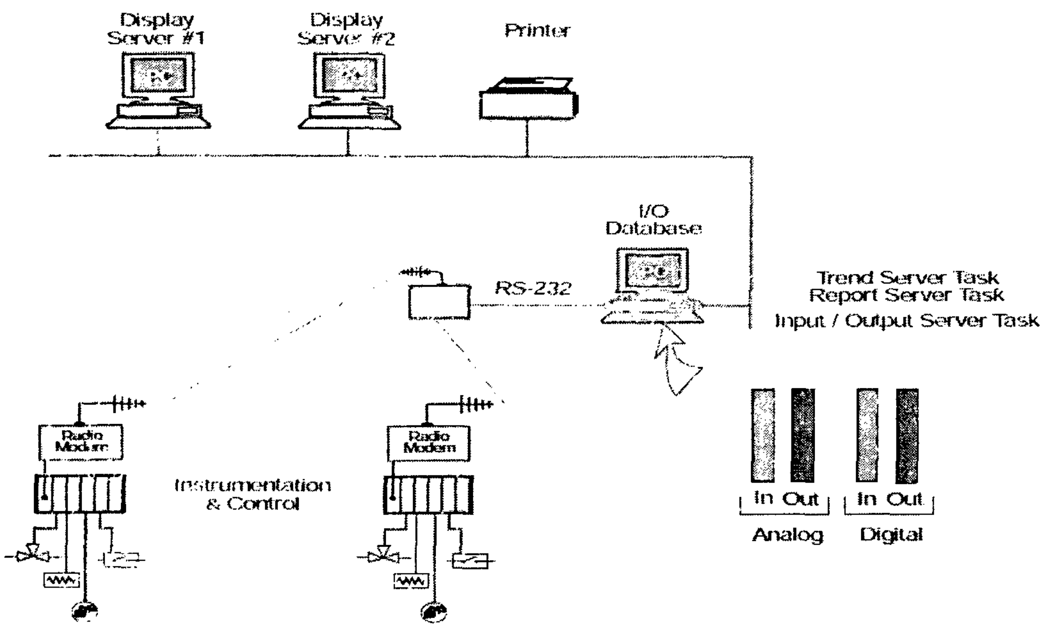


Figure 2.16: components of a SCADA system

SCADA System

In a SCADA system, a group of tasks are running on the PC, each of them performing specific functions. The database stores the tag numbers of devices and loops, which are exchanged for the various tasks. Because many of these tags are mapped onto the corresponding PLC variables by one or more of the tasks, the handling of the plants or machines may be implemented by means of read/write actions on the relevant tags.

The following figure illustrates how the SCADA system notifies a human operator through a PC of an alarm condition that was detected by the PLC. The alarm condition is detected by a sensor, which is located in the field. The field device sends the alarm to the PLC through its input boards. This initiates a suitable alarm handling procedure in the PLC, which results in the transmission of an alarm event, via the PC–PLC connection, to the PC. Such an event is handled by a PLC task (action) of the SCADA and results in associating the event with the tag number of the alarm, which resides in the SCADA database. Then, the alarm handling task of the SCADA notifies the human operator of the existence of the alarm condition by sending a suitable text message to the screen of the PC. If necessary, an audible signal can also be initiated.

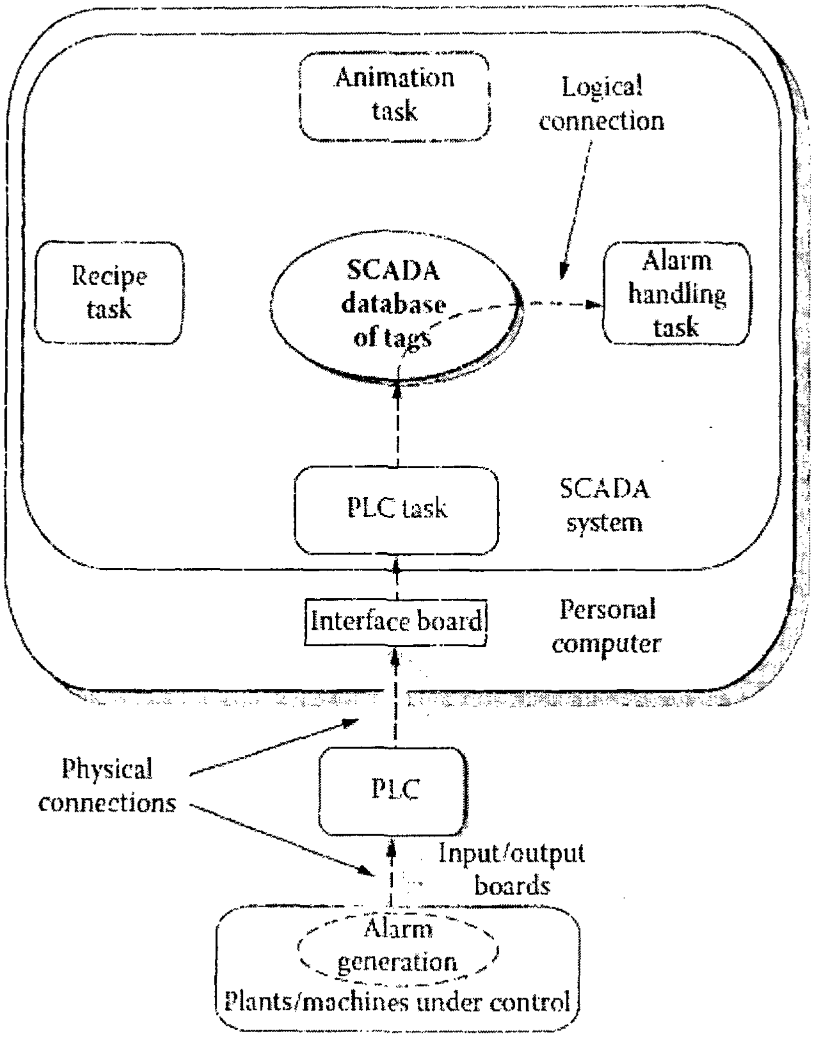


Figure 2.17: interaction of SCADA with PLC

A software package that is developed to serve only the monitoring and supervision of a PLC is usually simpler than a complete SCADA system and can be implemented using one of the high-level programming languages.

3.1 Block diagram:

Simplified Block diagram of the existing safety system in the blast furnace of Visakhapatnam steel plant is as shown below. This system is constructed around microprocessor and there are input cards per each zone so that the detector loops can be connected to it. The input card compares the voltage variations and generates several signals like fault, alert and alarm. By checking status of these signals microprocessor activates LEDS on the front panel of the system to indicate status of each zone, pump to supply water to the zones and sounders to give audio alert. The system can work in both auto and manual modes.

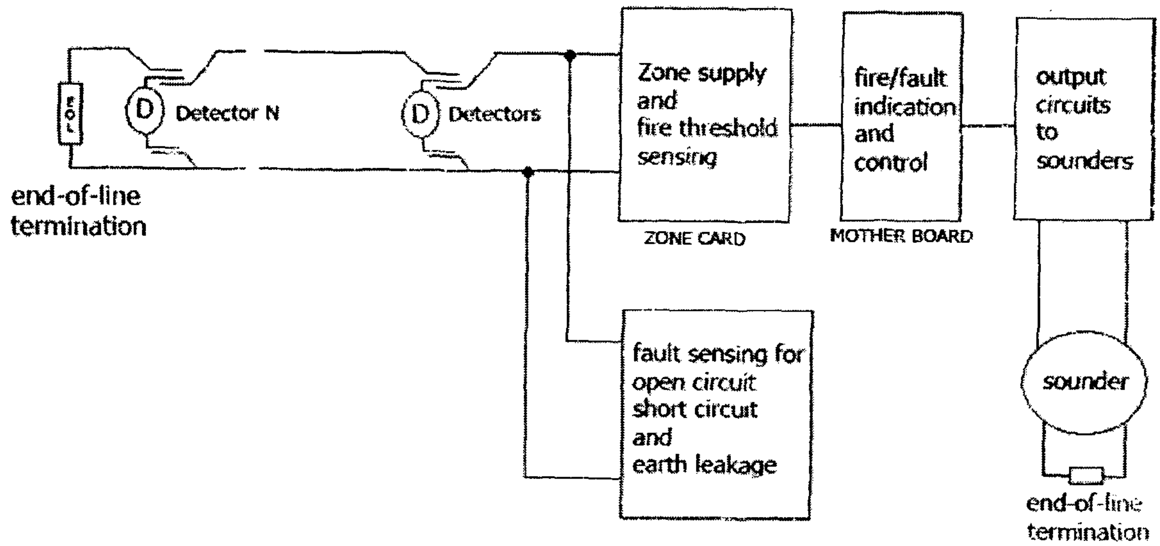


Figure 3.1: Block diagram of existing fire fighting system

The more detailed Block diagram of the microprocessor based fire fighting system is shown in the following figure. It includes the different outputs to be activated in case of fire.

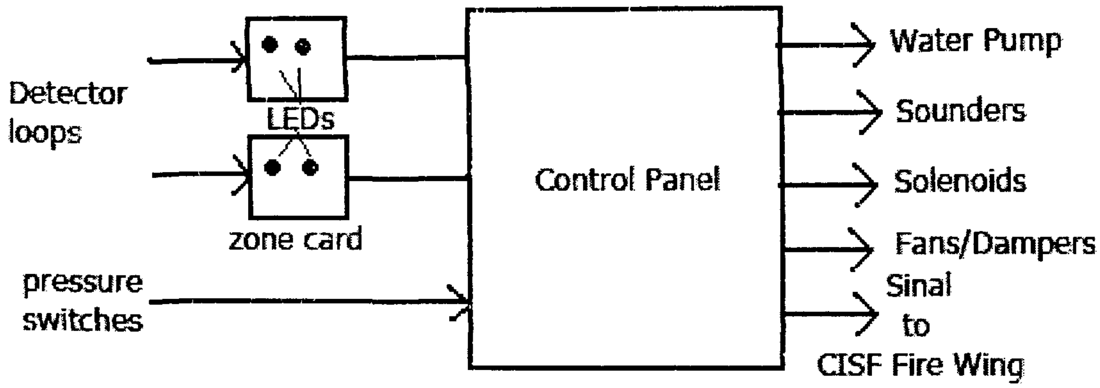


Figure 3.2: Block diagram of existing fire fighting system with I/OS

3.2 Detector circuit:

Generally fire detectors are connected in two-wire loops along with Manual call points (MCP) and one end-on-line termination resistor. The connection diagram of the detectors to the zone card is as shown in below. The zone card supplies 24 V DC to the detector loops. This DC power is current limited. With the end-on-line resistor, a small current is circulated through the loop and it is being continuously monitored.

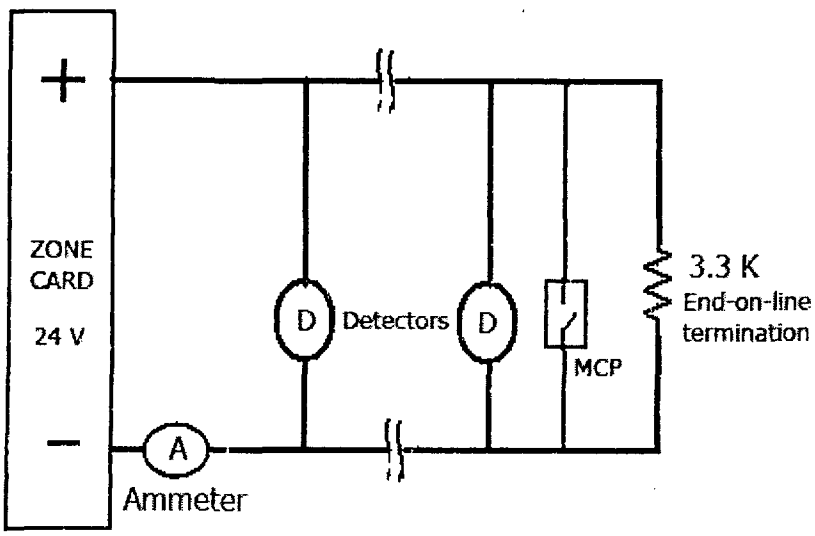


Figure 3.3: Detector loop

The fire detector acts like a resistor with infinite resistance when not activated (i.e. No fire) and with few ohms resistance when activated (i.e. in case of fire). The variation of the loop current changes based on the fire and fault status and is being sensed by the zone card and respective LEDs are lit.

Variations in the loop current and voltage are tabulated as follows for zone 83 in the blast furnace 1 of Visakhapatnam steel plant.

Condition	**Loop Voltage** (V)	**Loop Current** (mA)
Open circuit	20.2	–
Healthy	18.5	6
Alert	12.3	28.73
Alarm	8.49	43.5

Table 3.1: Variations in the loop current and voltage

The following figures show the fire alarm control panel and arrangement of detectors and water sprinkling nozzles in one of the zones of blast furnace 1 of Visakhapatnam steel plant.

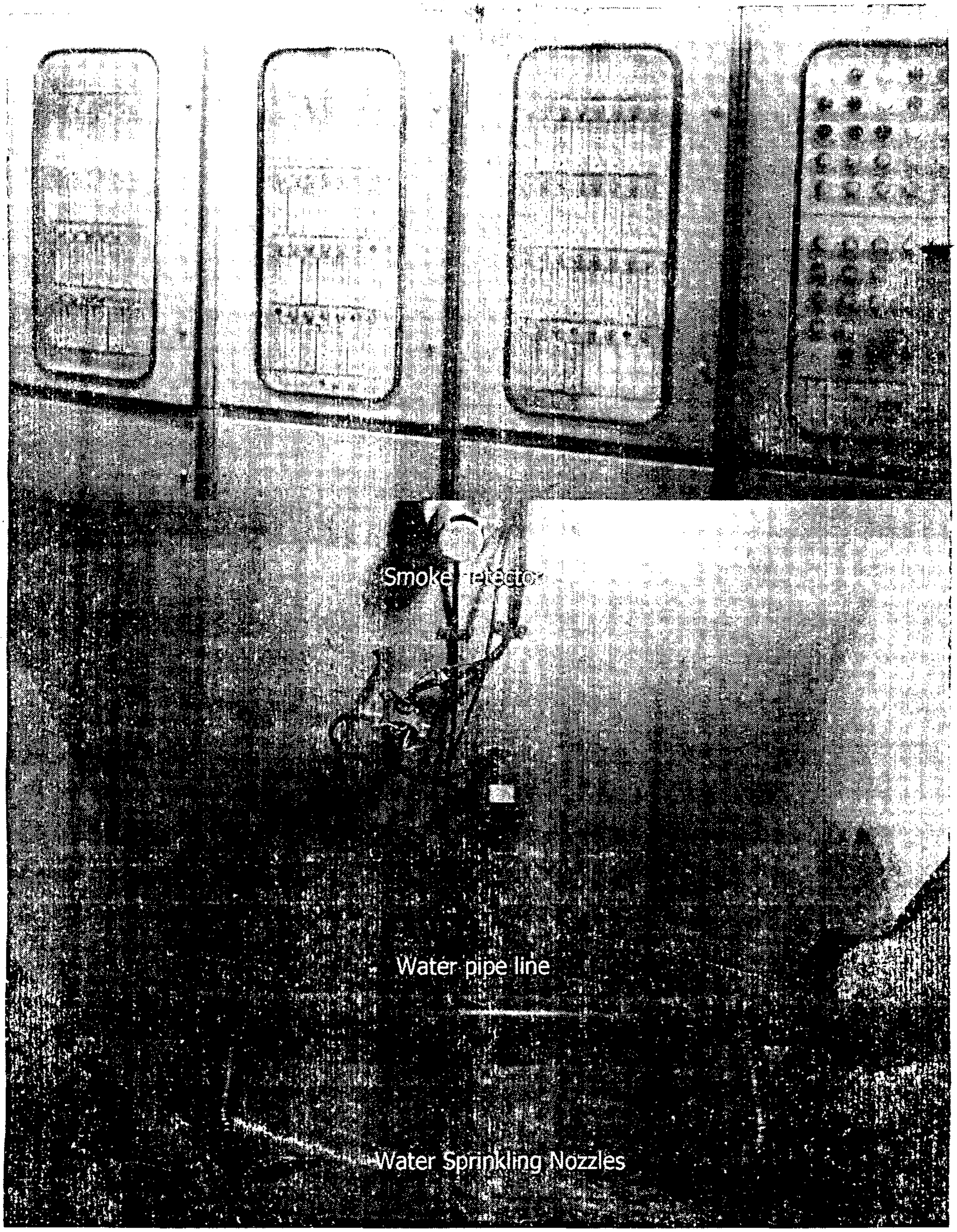


Figure 3.4: Fire Alarm control panel and Arrangement of detectors and water sprinkling nozzles

3.3 Disadvantages:

- False alarms are more frequent
- No provision to store previous history of alarms
- It sends limited information to the CSIF Fire Wing
- To change the pumps priority rewiring should be done
- Difficult to change the program sequence written for microprocessor

Even with these disadvantages industries are still using these and some industries using even older systems. Probably the most important reason for this is that fire detection systems are 'safety systems' and are covered by one or more strict sets of regulations to comply with the necessary standard for the insurance companies or fire officers. This has tended to make the fire detection industry very conservative and cautious in the introduction of new technology. Another reason is that the industries really do not want to invest money on safety systems.

There are many reasons for these unwanted or false alarms, including poor maintenance of the system and bad initial fire engineering in the sitting of the detectors.

4.1 Modified detector loop:

To connect the detectors to the PLC we need to change the loops of the detectors by adding resistors. The modified circuit diagram of the loop is as shown in the following figure. With introduction of the 2.2k resistor in series with the detector limits the current. The current values flowing in the loop with no detector activated-Healthy, one detector activated-Alert and two detectors activated-Alarm are tabulated in the following table.

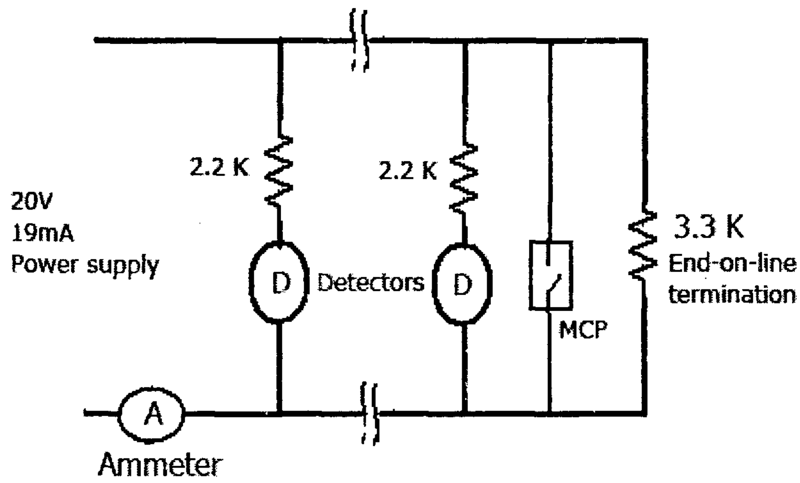


Figure 4.1: Modified detector loop

Condition	Loop Current Theoretical (mA)	Loop Current Practical (mA)
Healthy	6	6.5
Alert	13.46	12.1
Alarm	21	17.6

Table 4.1: Variations in the loop current

By observing the current values we can conclude that the loop gives 0 to 20 mA depending upon the number of detectors activated. So this loop can be connected to the 0-20 mA analog input card of a PLC. Now PLC has to program in such a way that it will generate various status signals by comparing the input current from the detector loops of various zones. 0-20 mA current is subdivided into several ranges to indicate various conditions of the loop. The same is tabulated as follows.

Loop Current (mA)	**Loop status**
0	Fault
4 to 8	Healthy
9 to 14	Alert
Greater than 14	Alarm

Table 4.2: Current ranges for status signals

4.2 Block diagram

Block diagram of the plc based fire fighting system is as shown in the following figure.

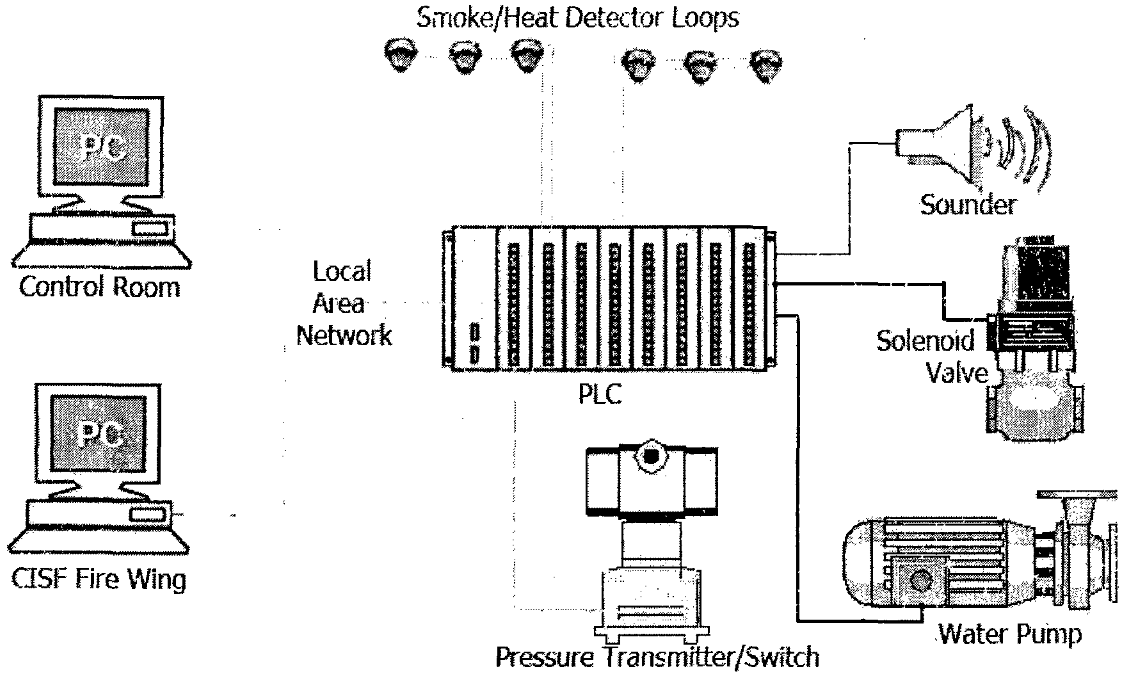


Figure 4.2: Block Diagram of proposed system

For the normal zones PLC will activate sounders and for water fighting zones it has to switch ON pump in order to supply water through pipes. So depending on the requirement PLC has to program to handle several activities. For this purpose I have used STEP 7 software for programming PLC and S7-PLCSIM for simulation from Siemens. PLC I programmed in ladder logic which explained as follows.

4.3 Programming with STEP7:

The STEP 7 standard tool is the keystone of the Totally Integrated Automation concept, with its uniform configuration and programming, data management and data transmission. We can use step 7 to configure the SIMATIC components, assign parameters to them and program them. SIMATIC manager in STEP 7 is the central tool for managing the automation data and necessary software tools. It keeps all the data for an automation project in a project folder with a hierarchic structure and stores standard software and re-usable user software in libraries.

The main activities performed with STEP 7 are:

- Configuring the hardware, that is arranging modules in racks, assigning addresses to them and setting the module properties
- Configuring communication connections, that is defining the communication partners and connection properties
- Writing the user program for the PLC in the programming languages Ladder Logic (LAD), Function Block Diagram (FBD), or Statement List (STL), and testing the program online on the controller

Using the STEP 7 software, we can create S7 program within a project. The S7 programmable controller consists of a power supply unit, a CPU, and input and output modules (I/O modules). The programmable logic controller (PLC) monitors and controls outputs with the S7 program. The I/O modules are addressed in the S7 program via the addresses.

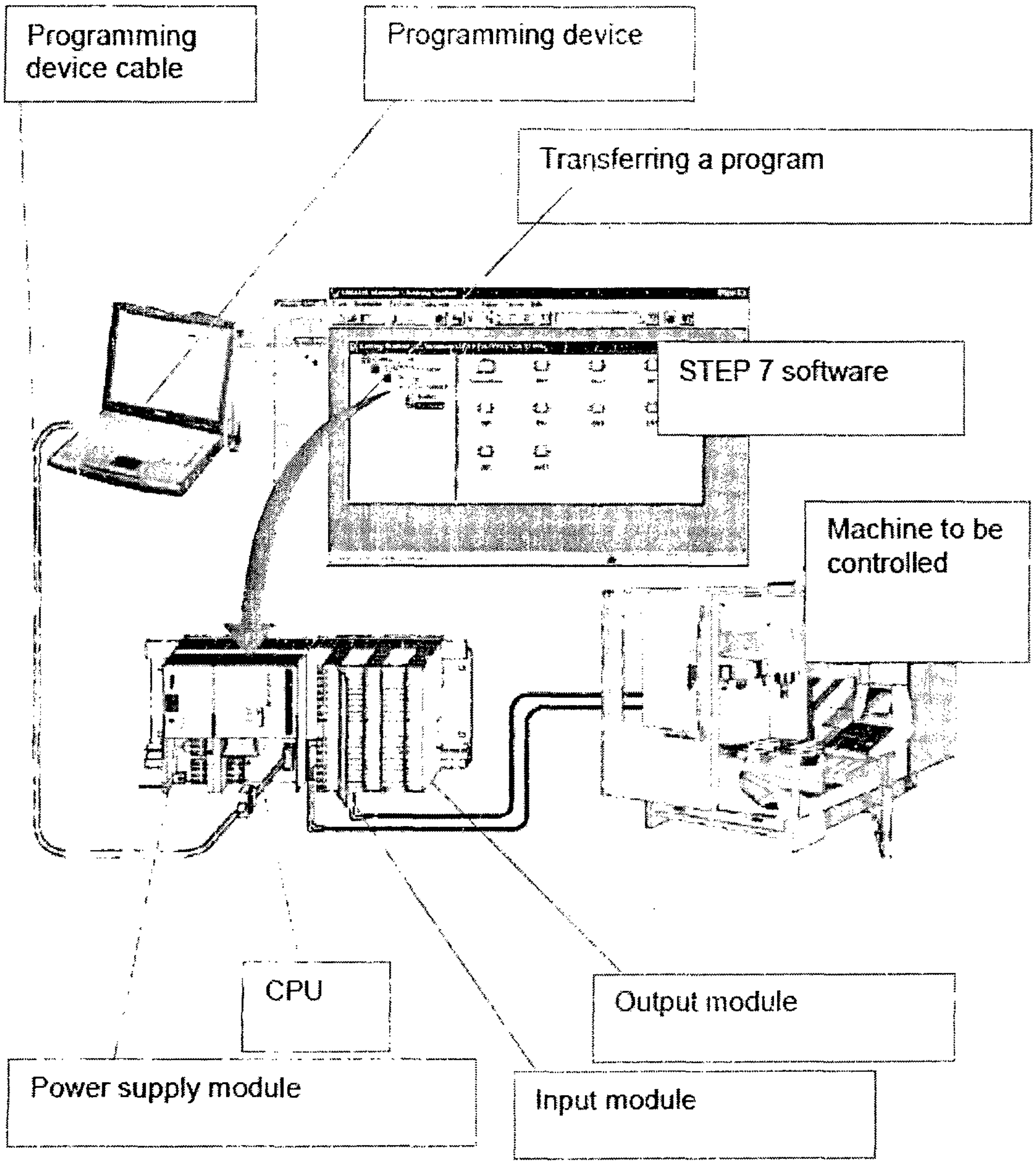


Figure 4.3: PLC Interfacing

Every input and output has an absolute address predefined by the hardware configuration. This address is specified directly; that is, absolutely. The absolute address can be replaced by any symbolic name we choose.

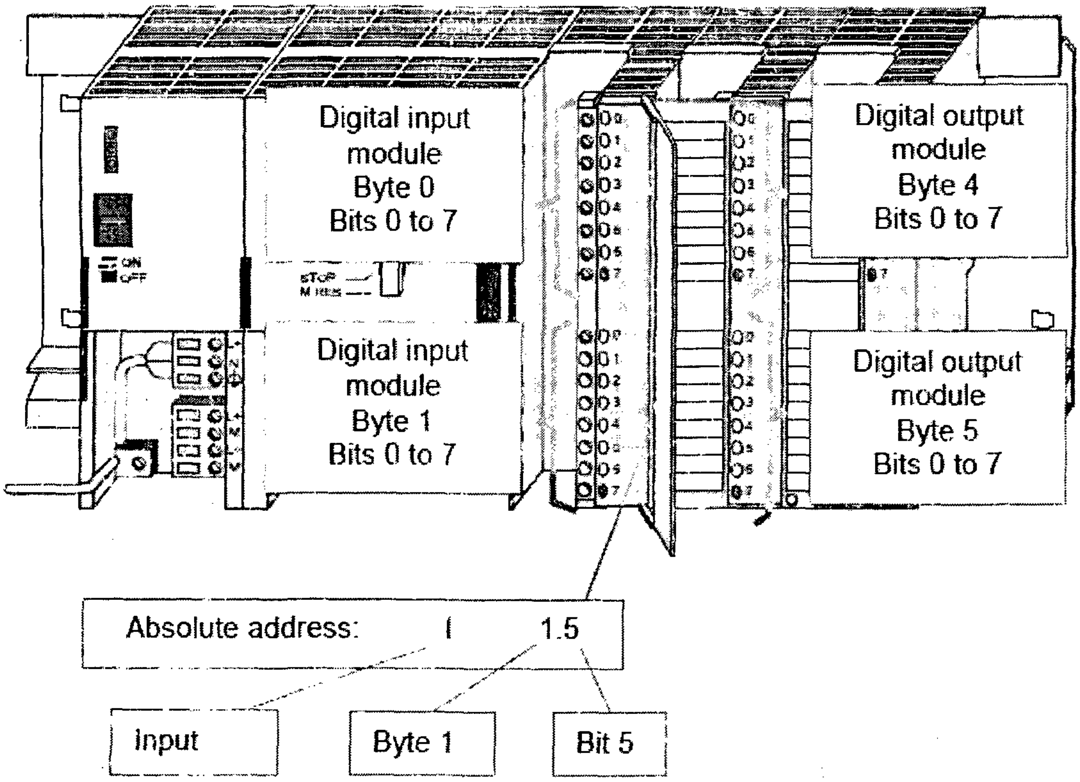


Figure 4.4: PLC Addressing

The following discussion gives explanation about the instructions I have used for programming the PLC for Firefighting system.

---| |--- Normally Open Contact (Address)

Symbol

<Address>
---| |---

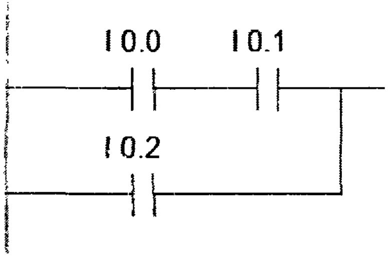
Parameter	Data Type	Memory Area	Description
<address>	BOOL	I, Q, M, L, D, T, C	Checked bit

Description

---| |--- (Normally Open Contact) is closed when the bit value stored at the specified **<address>** is equal to "1". When the contact is closed, ladder rail power flows across the contact and the result of logic operation (RLO) = "1". Otherwise, if the signal state at the specified **<address>** is "0", the contact is open. When the contact is open, power does not flow across the contact and the result of logic operation (RLO) = "0". When used in series, ---| |--- is linked to the RLO bit by AND logic. When used in parallel, it is linked to the RLO by OR logic.

Status word:

	BR	CC 1	CC 0	OV	OS	OR	STA	RLO	/FC
writes:	-	-	-	-	-	X	X	X	1



Power flows if one of the following conditions exists:

The signal state is "1" at inputs I0.0 and I0.1

Or the signal state is "1" at input I0.2

---| / |--- Normally Closed Contact (Address)

Symbol

<Address>
---| / |---

Parameter	Data Type	Memory Area	Description
<address>	BOOL	I, Q, M, L, D, T, C	Checked bit

Description

---| / |--- (Normally Closed Contact) is closed when the bit value stored at the specified **<address>** is equal to "0". When the contact is closed, ladder rail power flows across the contact and the result of logic operation (RLO) = "1".

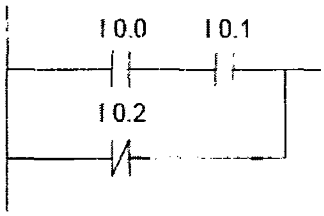
Otherwise, if the signal state at the specified **<address>** is "1", the contact is opened. When the contact is opened, power does not flow across the contact and the result of logic operation (RLO) = "0".

When used in series, ---| / |--- is linked to the RLO bit by AND logic. When used in parallel, it is linked to the RLO by OR logic.

Status word

	BR	CC 1	CC 0	OV	OS	OR	STA	RLO	/FC
writes:	-	-	-	-	-	X	X	X	1

Example



Power flows if one of the following conditions exists:

The signal state is "1" at inputs I0.0 and I0.1

Or the signal state is "1" at input I0.2

--- ( ) Output Coil

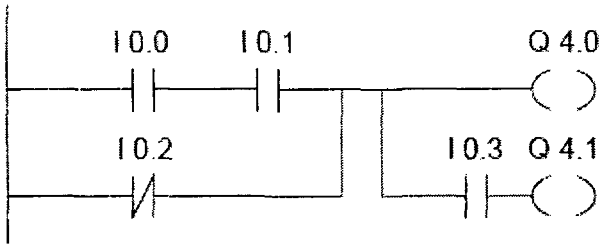
Symbol

<Address>
---( )

Description

--- ( ) (Output Coil) works like a coil in a relay logic diagram. If there is power flow to the coil (RLO = 1), the bit at location **<address>** is set to "1". If there is no power flow to the coil (RLO = 0), the bit at location **<address>** is set to "0". An output coil can only be placed at the right end of a ladder rung. Multiple output elements (max. 16) are possible (see example). A negated output can be created by using the ---|NOT|--- (invert power flow) element.

Example



The signal state of output Q4.0 is "1" if one of the following conditions exists:

The signal state is "1" at inputs I0.0 AND I0.1

OR the signal state is "0" at input I0.2.

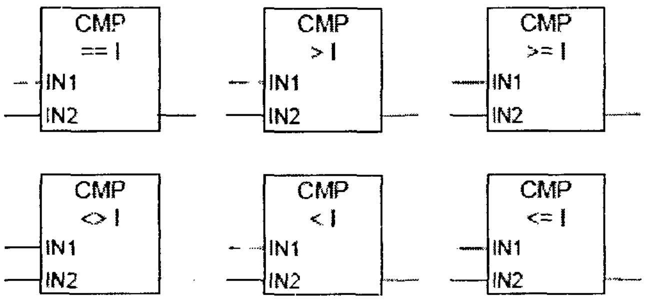
The signal state of output Q4.1 is "1" if one of the following conditions exists:

The signal state is "1" at inputs I0.0 AND I0.1

OR the signal state is "0" at input I0.2 AND "1" at input I0.3

CMP ? I Compare Integer

Symbols



Parameter	Data Type	Memory Area	Description
box input	BOOL	I, Q, M, L, D	Result of the previous logic operation
box output	BOOL	I, Q, M, L, D	Result of the comparison, is only processed further if the RLO at the box input = 1
IN1	INT	I, Q, M, L, D or constant	First value to compare
IN2	INT	I, Q, M, L, D or constant	Second value to compare

Description

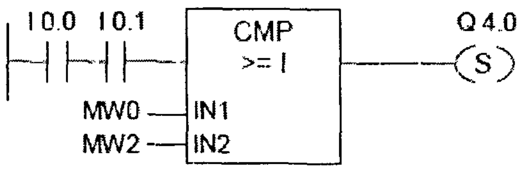
CMP ? I (Compare Integer) can be used like a normal contact. It can be located at any position where a normal contact could be placed. IN1 and IN2 are compared according to the type of comparison chosen.

If the comparison is true, the RLO of the function is "1". It is linked to the RLO of the whole rung by AND if the box is used in series, or by OR if the box is used in parallel.

Status word

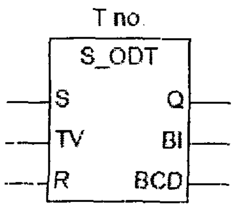
	BR	CC 1	CC 0	OV	OS	OR	STA	RLO	/FC
writes:	x	x	x	0	-	0	x	x	1

Example



S_ODT On-Delay S5 Timer

Symbol

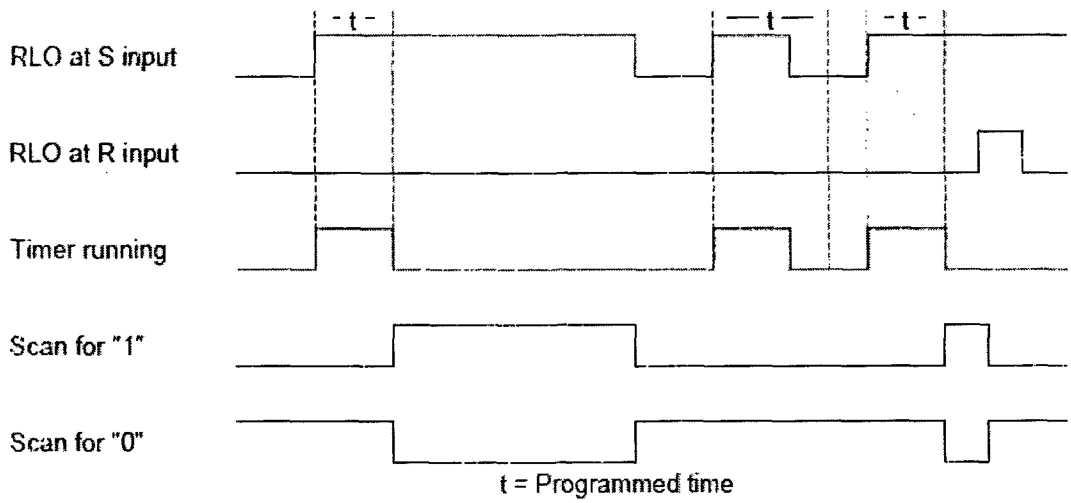


Description

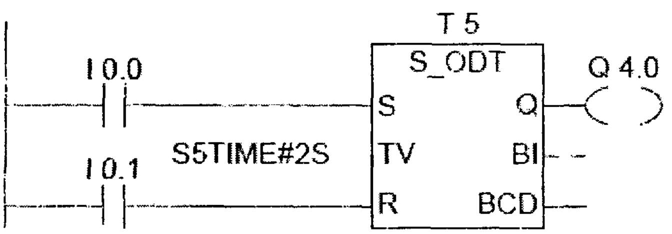
S_ODT (On-Delay S5 Timer) starts the specified timer if there is a positive edge at the start (S) input. A signal change is always necessary in order to enable a timer. The timer runs for the time interval specified at input TV as long as the signal state at input S is positive. The signal state at output Q is "1" when the timer has elapsed without error and the signal state at the S input is still "1". When the signal state at input S changes from "1" to "0" while the timer is running, the timer is stopped. In this case the signal state of output Q is "0". The timer is reset if

the reset I input changes from "0" to "1" while the timer is running. The current time and the time base are set to zero. The signal state at output Q is then "0". The timer is also reset if there is logic "1" at the R input while the timer is not running and the RLO at input S is "1".
The current time value can be scanned at the outputs BI and BCD. The time value at BI is binary coded, at BCD is BCD coded. The current time value is the initial TV value minus the time elapsed since the timer was started.

On-Delay timer characteristics:



Example:

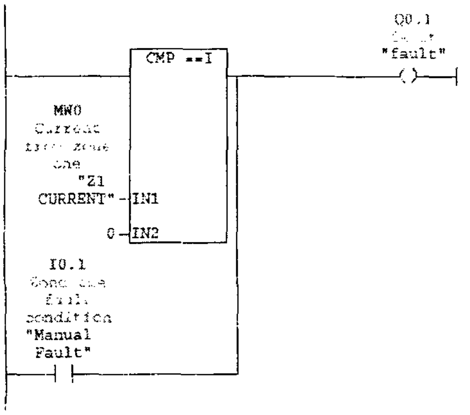


If the signal state of I0.0 changes from "0" to "1" (positive edge in RLO), the timer T5 will be started. If the time of two seconds elapses and the signal state at input I0.0 is still "1", the output Q4.0 will be "1". If the signal state of I0.0 changes from "1" to "0", the timer is stopped and Q4.0 will be "0" (if the signal state of I0.1 changes from "0" to "1", the time is reset regardless of whether the timer is running or not).

4.4 PLC program for single zone:

Block: FC1	**FIRE FIGHTING SYSTEM**
LADDER PROGRAM TO CHECK THE STATUS OF THE DETECTORS AND TO ACTIVATE SOUNDERS AND PUMP IN THE EVENT OF SEVERE FIRE	

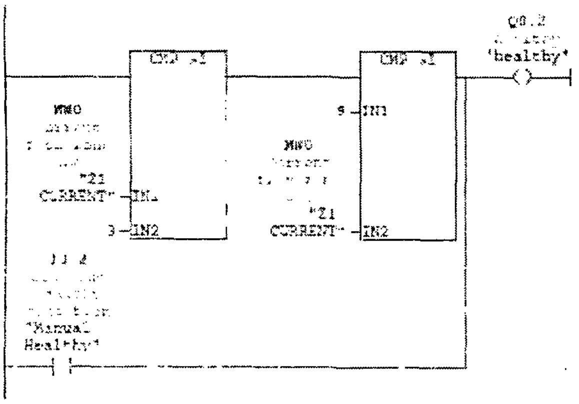
Network: 1	FAULT CONDITION 1
WHEN INPUT CURRENT IS ZERO THIS BECOMES ACTIVE	



Symbol information

MW0	Z1 CURRENT	Current from zone one
I0.1	Manual Fault	Zone one fault condition
Q0.1	fault	fault

Network: 2	HEALTHY CONDITION 1
WHEN INPUT CURRENT IS IN HEALTHY RANGE OUTPUT OF THIS NETWORK IS ACTIVE	

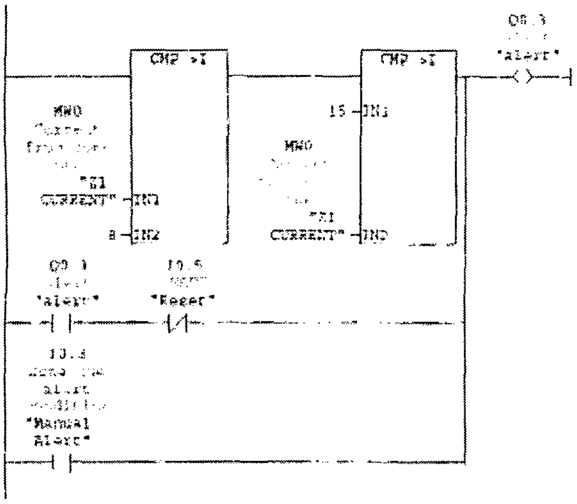


Symbol information

MW0	Z1 CURRENT	Current from zone one
I0.2	Manual healthy	Zone one healthy condition
Q0.2	healthy	healthy

Network: 3	ALERT 1

IF ANY ONE DETECTOR IS ACTIVATED LOOP CURRENT WILL IN ALERT RANGE AND THE OUTPUT
BECOMES ACTIVE

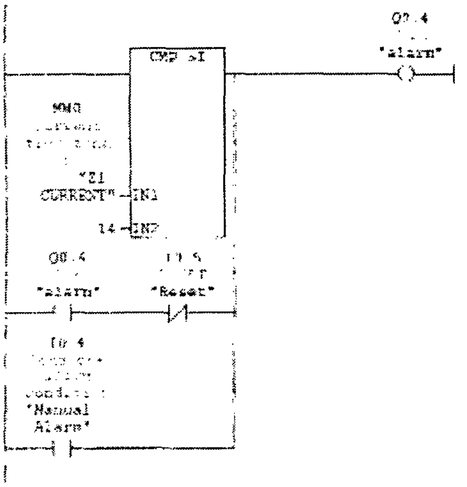


Symbol information

MW0	Z1 CURRENT	Current from zone one
Q0.3	alert	alert
I0.5	Reset	RESET
I0.3	Manual Alert	Zone one alert condition

Network: 4	ALARM 1

IF TWO OR MORE DETECTORS ARE ACTIVATED LOOP CURRENT WILL IN ALARM RANGE AND THE
OUTPUT BECOMES ACTIVE

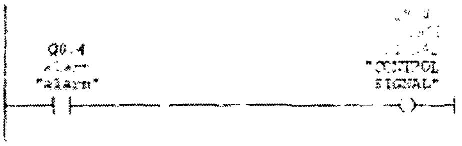


Symbol information

MW0	Z1 CURRENT	Current from zone one
Q0.4	alarm	alarm
I0.5	Reset	RESET
I0.4	Manual Alarm	Zone one alarm condition

Network: 5 CONTROL SIGNAL

ALARM SIGNAL ACTIVATES A CONTROL SIGNAL SO THAT SPRINKLERS, PUMP OR BOTH CAN BE ACTIVATED IN CASE OF FIRE

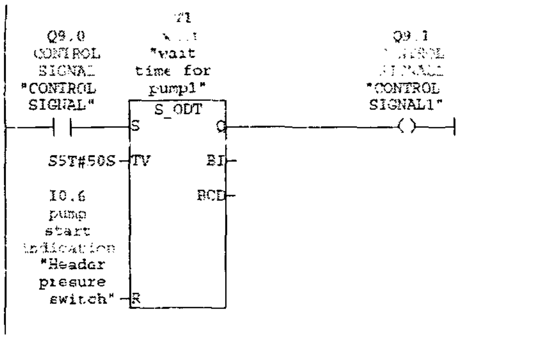


Symbol information

Q0.4	alarm	alarm
Q9.0	CONTROL SIGNAL	CONTROL SIGNAL

Network: 6 CHECKING WEATHER PUMP1 IS ON OR NOT

TO CHECK WEATHER PUMP1 IS ON OR NOT IN EVENT OF FIRE

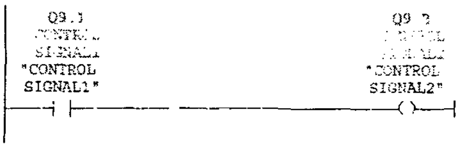


Symbol information

Q9.0	CONTROL SIGNAL	CONTROL SIGNAL
T1	wait time for pump1	wait
I0.6	Header presure switch	pump start indication
Q9.1	CONTROL SIGNAL1	CONTROL SIGNAL1

Network: 7 SWITHING ON THE SECOND PUMP

IF PUMP1 IS NOT ON THEN PUMP2 HAS TO BE SWITCHED ON IN ORDER TO SUPPLY WATER FOR THE SPRINKLING SYSTEM



Symbol information

Q9.1	CONTROL SIGNAL1	CONTROL SIGNAL1
Q9.2	CONTROL SIGNAL2	CONTROL SIGNAL2

Testing programs offline with S7-PLCSIM

The S7-PLCSIM enables us to test the user program offline without additional hardware. S7-PLCSIM simulates a plc on the programming device. When we start s7-plcsim, the programming device is online to an imaginary CPU. Now we can download the user program to the user memory of the CPU by clicking the menu commands PLC → DOWNLOAD. Then by clicking run or run-p in the CPU pane, s7-plcsim processes the downloaded user program like a real CPU of a plc.

4.5 Visualization Using SCADA

Alarm statuses for each zone can be visualized by using the SCADA software. In the actual practice SCADA reads the PLC inputs and outputs with the addresses given in the form of tags.

WinCC flexible from Siemens is the SCADA software I have used in my project work.

SIMATIC WinCC flexible

WinCC flexible is designed on a non-industry specific basis and it offers Engineering Software for SIMATIC HMI operator control and monitoring devices from the smallest Micro Panel up to PCs. We can transfer projects to different HMI platforms and run them there without needing to convert the projects. SIMATIC WinCC flexible is available on a graduated price and performance basis that can be tailored to our specific operator control and monitoring devices in an optimum way. Upward compatibility is always ensured within the WinCC flexible offering.

For more complex PC-based applications in plant construction, the SIMATIC WinCC process visualization system is available. WinCC offers complete SCADA (Supervisory Control and Data Acquisition) functionality under Windows for all sectors. The range of applications extends single-user down to distributed multi-user systems with redundant servers and crosslocation solutions with web clients. With the integrated process database (MS SQL server), WinCC forms the information hub for company-wide, vertical integration.

WinCC flexible is ideal for use as a Human Machine Interface (HMI) in any machine or process-level application in plant, machine and series-machine construction. WinCC flexible is designed for all sectors of industry and offers engineering software for all SIMATIC HMI operator panels, from the smallest Micro Panel to the Multi Panel, as well as runtime visualization software for PC-based single-user systems running under Windows Vista / XP. The projects can be transferred to different HMI platforms where they can be executed without the need for conversion.

The HMI system represents the interface between man (operator) and process (machine/plant). The PLC is the actual unit which controls the process. Hence, there is an interface between the operator and WinCC flexible (at the HMI device) and an interface between WinCC flexible and the PLC. An HMI system assumes the following tasks:

- Process visualization

  The process is visualized on the HMI device. The screen on the HMI device is dynamically updated. This is based on process transitions.

- Operator control of the process

  The operator can control the process by means of the GUI. For example, the operator can preset reference values for the controls or start a motor.

- Displaying alarms

  Critical process states automatically trigger an alarm, for example, when the setpoint value is exceeded.

- Archiving process values and alarms

  The HMI system can log alarms and process values. This feature allows us to log process sequences and to retrieve previous production data.

- Process values and alarms logging

  The HMI system can output alarms and process value reports. This allows us to print out production data at the end of a shift, for example.

- Process and machine parameter management

The HMI system can store the parameters of processes and machines in recipes. For example, we can download these parameters in one pass from the HMI device to the PLC to change over the product version for production.

The WinCC flexible workbench opens on the screen of our programming computer when we create a new or open an existing project in WinCC flexible. The project structure is visualized and the project managed in the "Project View." The following screen shot gives an idea how SCADA software windows are organized.

By using WicCC flexible software several screens are developed to indicate status of the detector loops, pumps, solenoids and sounders.

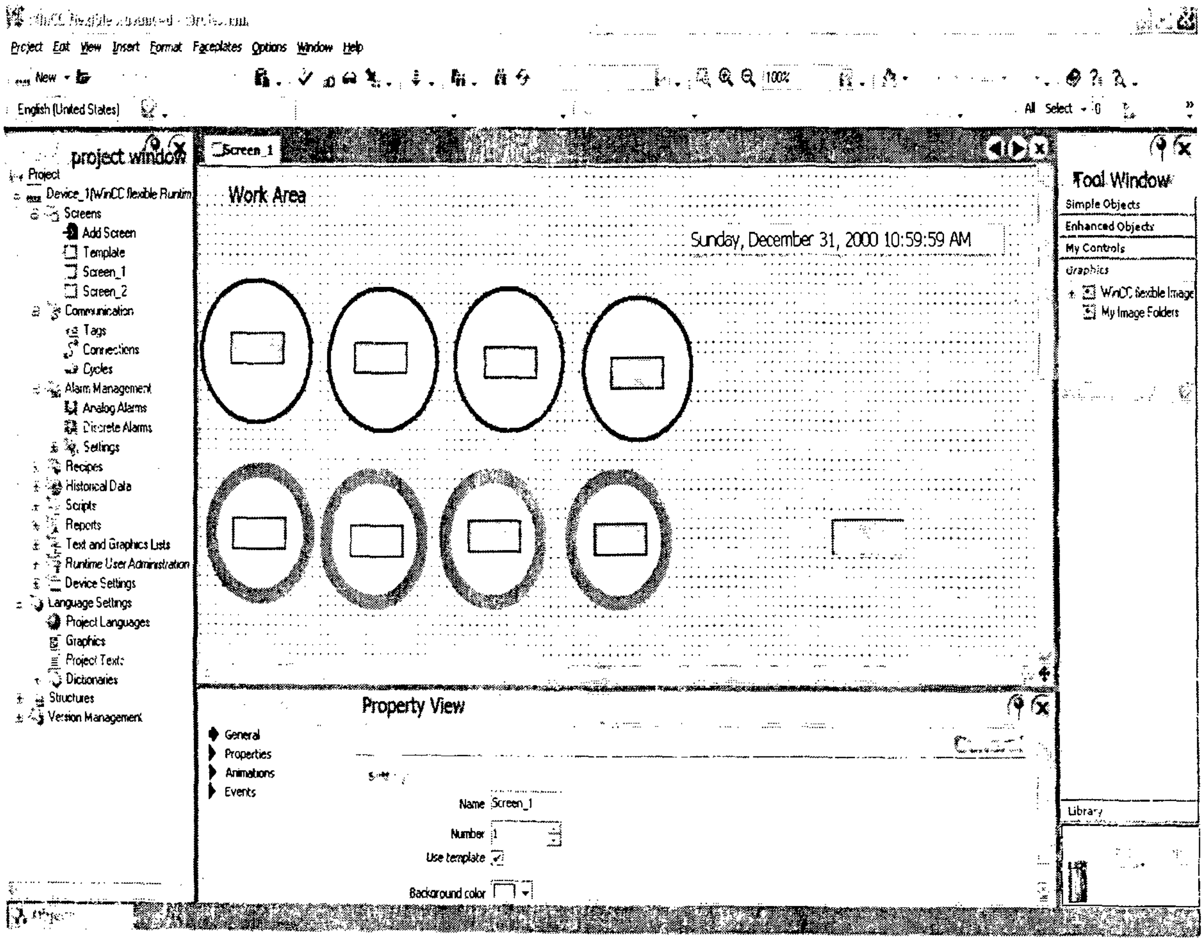


Figure 4.5: WinCC flexible screenshot

At first existing system's one loop is tested and the resulting current and voltage values are as tabulated as follows.

Condition	Loop Voltage (V)	Loop Current (mA)
Open circuit	20.2	–
Healthy	18.5	6
Alert	12.3	28.73
Alarm	8.49	43.5

Table 3.1: Variations in the loop current and voltage

Then by changing the circuit arrangement the detector loop is made to give 0-20 mA current depending on the no. of detectors activated due to fire. Those values are tabulated as follows.

Condition	Loop Current Theoretical (mA)	Loop Current Practical (mA)
Healthy	6	6.5
Alert	13.46	12.1
Alarm	21	17.6

Table 4 1: Variations in the Loop Current

With these results 0-20 mA current is subdivided to indicate various conditions and are shown as follows. Depending on these ranges only PLC will compare the current values of each loop and generates signals correspondingly.

Loop Current (mA)	**Loop status**
0	Fault
4 to 8	Healthy
9 to 14	Alert
Greater than 14	Alarm

Table 4.2: Current Ranges for Status Signals

After programming the PLC by using STEP 7 software it is tested by using **S7-PLCSIM** and the simulation result window is as shown below.

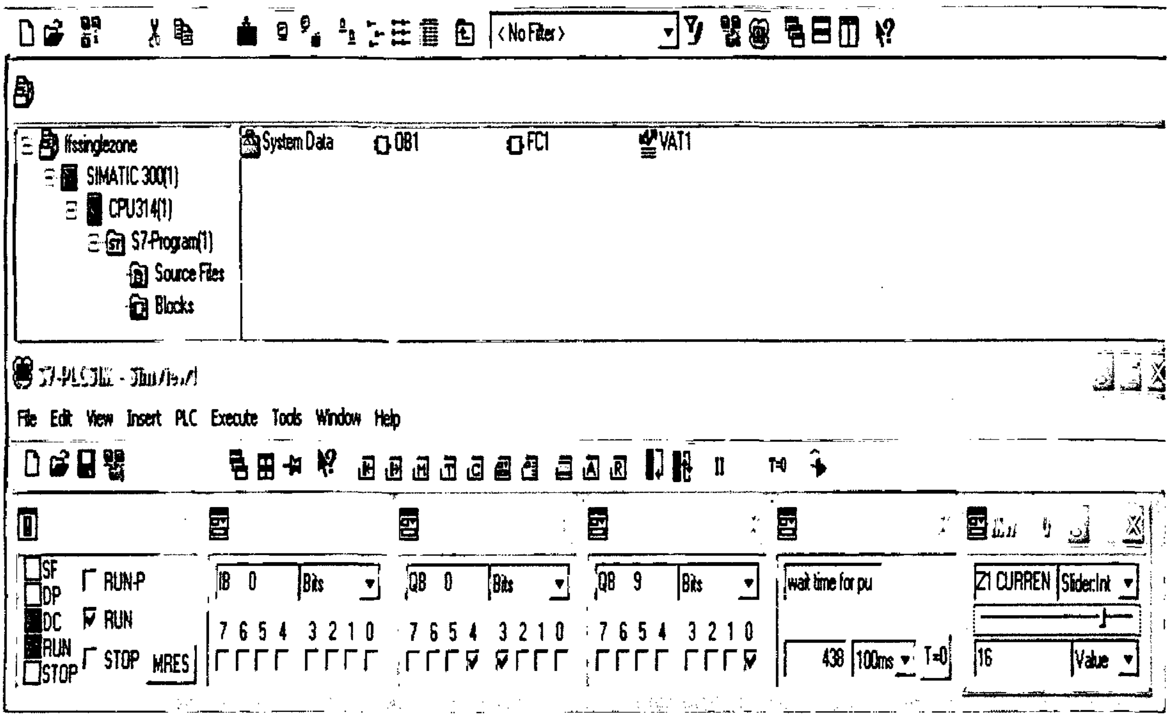


Figure 5.1: STEP7 screenshot

The SCADA screens can simulated by giving values manually, which PLC has to pass to SCADA. The following screens are the simulation results of zone status indication screen and pump house status indication screen.

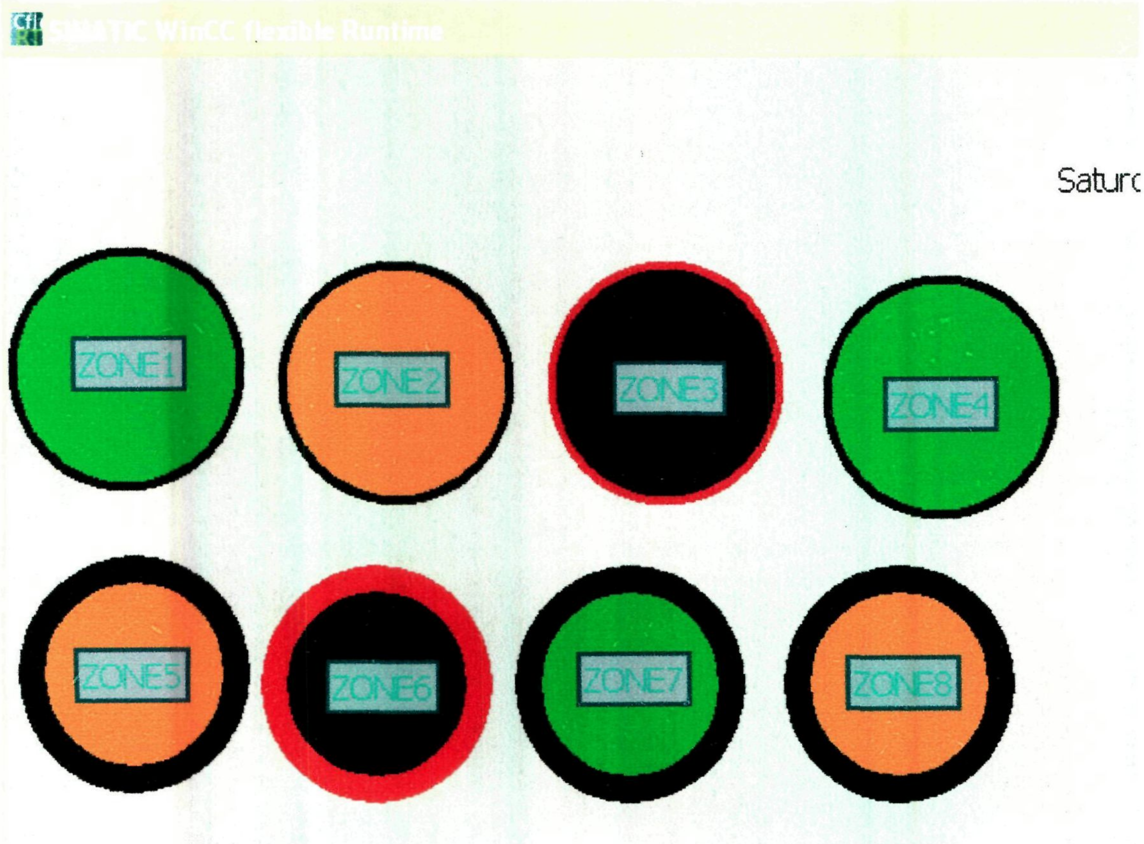


Figure 5.2: WinCC Flexible Runtime screenshot with zones

As shown in the figure for a particular zone color varies depending on the status of the fire detectors.

- Green: Zone In Healthy Condition
- Orange: Zone In Alert Condition
- Red: Zone In Alarm Condition

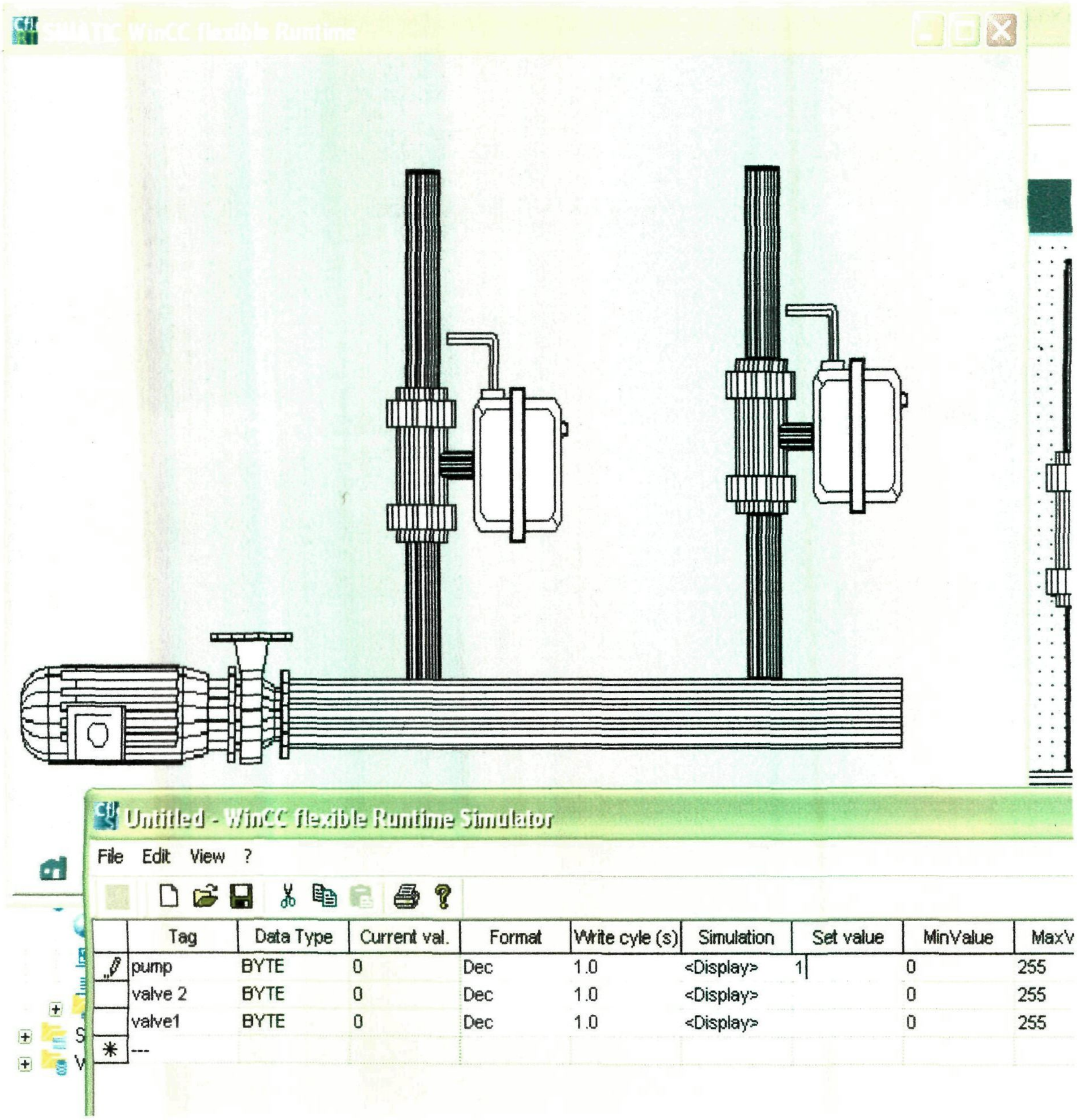


Figure 5.3: WinCC Flexible Runtime screenshot with pump in not activated condition

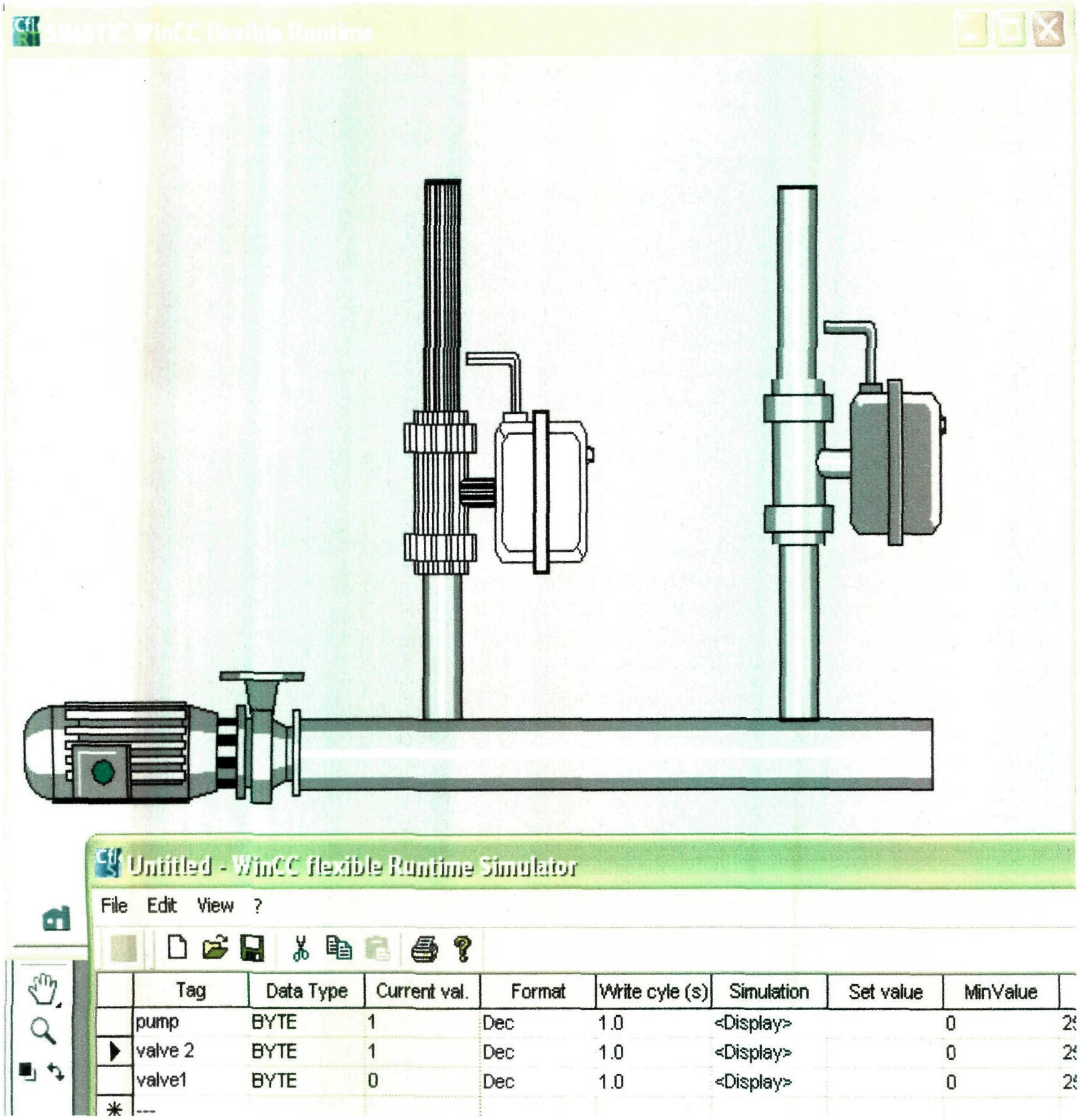


Figure 5.4: Screenshot indicating Pump and one Solenoid activated to supply water to one Zone

CONCLUSIONS AND FUTURE SCOPE

- Detector circuits are modified and are giving satisfying results
- The PLC program is tested on the simulator and is working properly and giving satisfactory results.
- SCADA screens created for visualization of alarm statuses of each zones and are tested with simulator.

In this project only fire safety was considered. But in the industry gas safety is as much important as fire safety. So this project can be extended for gas safety by adding gas detectors.

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