BACHELOR THESIS & COLLOQUIUM – ME 141502

DESIGN OF SHIP'S AUTOMATIC FIRE FIGHTING SYSTEM USING PROGRAMMABLE LOGIC CONTROLLER (PLC)

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Surabaya
2018

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APPROVAL FORM

Design Of Ship's Automatic Fire Fighting System Using Programmable Logic Controller (PLC)

BACHELOR THESIS & COLLOQUIUM
Asked to fulfill one of the requirements of obtaining a Double Degree of Bachelor Engineering
In
Study Field Marine Electrical and Automation System (MEAS)
S-1 Double Degree Study Program Department of Marine Engineering
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ABSTRACT

Safety aspect always the main focus when using the mass transportation. Not least on the ship. Crew and passenger safety should be taken seriously in order to avoid material loss and loss of life. Trend of ship accidents in Indonesia every year increased. The biggest cause of those accidents is fire or explode (Database KNKT 2016). Currently the fire handling still uses manualy operations by the crew and it will be needs more time to handle a fire. Automatic firefighting system based on PLC (Programmable Logic Controller) made for not replace of human work but help the human especially crew for faster to handle a fire. This automatic system depend on several detector such as smoke detector, flame detector and heat detector on each room to trigger supporting equipments of firefighting such as hazard alarm and pump. Detector on each room will be processed by PLC before controlled equipments for handle the fire with spraying water or CO2. Processing will be done depend on need of treatment in every potency of wildfire. PLC used is Omron CPM2A 30 IO with CX Programmer to make ladder diagram. Fire handling with spraying water average take times around 2,1 seconds and fire handling use CO2 average take times around 1,9 seconds. So by using controller in the form of PLC, warning hazard and firefighting can operated automatically and faster.

Keywords: ship accident, firefighting, PLC, automatic.

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Desain Sistem Pemadam Kebakaran Kapal Otomatis Menggunakan Programmable Logic Controller (PLC)

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ABSTRAK

Aspek keselamatan selalu menjadi fokus utama ketika menggunakan transportasi masal. Tidak terkecuali pada kapala. Keselamatan awak kapal dan penumpang harus diperhatikan untuk menghindari kerugian materi dan kehilangan nyawa. Tren kecelakaan kapal di perairan Indonesia setiap tahun selalu bertambah. Penyebab paling besar dari kecelakaan tersebut adalah kaal terbakar atau meledak (Database KNKT 2016). Saat ini penanganan kebakaran masih menggunakan operasi manual oleh awak kapal dan itu akan membutuhkan waktu yang lebih lama untuk mengatasi kebakaran. Sistem pemadam kebakaran otomatis berdasarkan PLC (*Programmable Logic Controller*) dibuat bukan untuk mengantikan tugas manusia namun untuk membantu pekerjaan khususnya awak kapal agar lebih cepat mengatasi kebakaran. Sistem otomatis ini mengandalkan beberapa sensor seperti sensor asap, sensor panas dan sensor api di setiap ruangan untuk memicu peralatan penunjang dalam sistem pemadam kebakaran seperti Sirine dan pompa.sensor pada setiap ruangan akan diproses oleh PLC sebelum peralatan di kontrol untuk memadamkan api dengan menyeprotkan air atau CO2. Pengolahan dilakukan berdasarkan kebutuhan terhadap potensi adanya kebakaran. PLC yang digunakan adalah Omron CPM2A yang memiliki 30 IO dengan CX Programmer untuk membuat *ladder diagram*. Pemadaman api dengan menyemprotkan air rata-rata membutuhkan sekitar 2,1 detik dan pemadaman api dengan menggunakan CO2 membutuhkan waktu sekitar 1,9 detik. Sehingga dengan menggunakan sebuah alat kontrol yaitu PLC, peringatan bahya dan proses pemadaman api dapat dilakukan secara otomatis dan lebih cepat.

Kata kunci: kecelakaan kapal, pemadam kebakarab, PLC, otomatis.

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PREFACE

All Praise and gratitude author said to the presence of God Almighty, Allah SWT, who has given pleasure, opportunities and guidance so that I can completely done the bachelor thesis report. In the procces of making this bachelor thesis report, the author would like to thank those who have helped to complete this final project report, including :

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Finally, I hope this bachelor thesis report can be useful for the readers and for me to finish my bachelor degree. My apologize for all readers if there is any mistake in thesis. In the further I will always improve myself and I hope we all become a person who is always blessed and give many benefits to the others.

Surabaya, July 2018

Ahmad Rizal Saputra

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CHAPTER I
INTRODUCTION

1.1 Background

In this millennium era, ships have become a very common marine transportation used to deliver a cargo from one place to another or to passenger services. Because very often the ship operates this causes ship accidents also can not be avoided. Based on Table 1.1 and Figure 1.1 shown the ship accidents in Indonesia and percentage of ship accidents type in Indonesia. The data states that from 2010-2016 cruise accidents in Indonesian sea are increasing every year. This is very necessary to be noticed because the accident is also related to the life of human body.

Table 1. 1 Cruise Accident Investigation Data, KNKT 2010-2016

No	Year	Total Accidents	Type of Accident					Victim		Recomendation
			Sink	Explode / Burning	Collision	Aground	Etc	Dead / Lost	Injury	
1	2010	5	1	1	3	0	0	15	85	45
2	2011	6	1	3	2	0	0	86	346	82
3	2012	4	0	2	2	0	0	13	10	28
4	2013	6	2	2	2	0	0	65	9	47
5	2014	7	2	3	2	0	0	22	4	25
6	2015	11	3	4	3	1	0	85	2	11
7	2016	15	4	4	3	2	2	51	18	35
Total		54	13	19	17	3	2	337	474	273

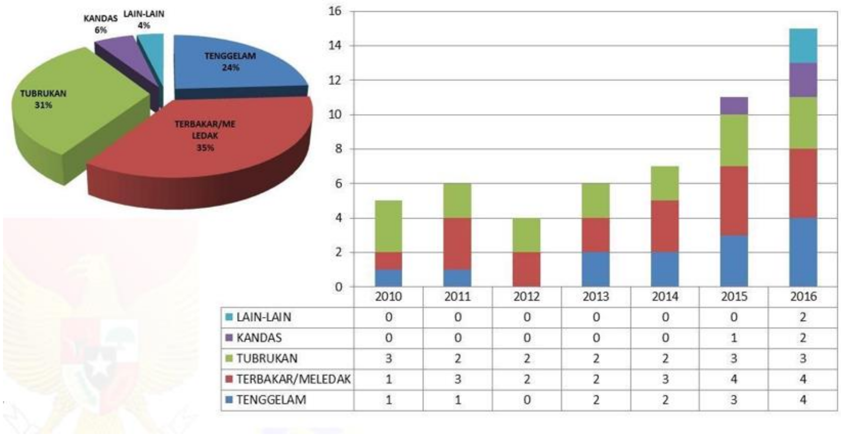


Figure 1. 1 The Percentage of Types Cruise Accidents

(source : KNKT 2016)

As a mass transportation, the ship must always ensure safety aspects for crew and passengers that using the ship's services. One of the things that need to be considered in the safety aspect is the firefighting system on board. In SOLAS chapter II-2 has been set about fire protection, fire detection and fire handling. SOLAS 74 gives 8 basic principles of fire protection on board ships in more details in Chapter II-

2, Regulation 2. These principles are as following: division of ship into main zones by thermal and structural border; separation of accommodation room of the ship by thermal and structural border; restricted use of combustible materials; detection of any fire in the zone of origin etc. Although SOLAS has regulated all matters relating to firefighting system on ship, the case of ship fires still happens and increases every year. The cause of the ship accident was 37% human error, 23% technical error, 38% due to environment and 2% for other causes (Traffic Accident Trend Analysis Report 2003-2003). From these data human error still has the highest presentation in the cause of ship accident followed by technical error and environment factor.

In this modern era of technology is growing very rapidly. All work that was woked by humans began to be replaced by machines. Analog devices are starting to shift with digital devices, and devices that are controlled manually are also being replaced with devices that can be controlled automatically. In this final project the author will make an automation of firefighting system by using PLC (Programmable Logic Controller) OMRON CPM2A. This system will take an action automatically if there is potential of fire. Action given is spraying water and open CO2 valve automatically to handle the fire.

1.2 Research Problem

Based on background mentioned above, it can be concluded some problems of this final project are:

1. How the design of automatic ship firefighting system based on PLC?

1.3 Research Limitation

This final project can be focused and organized, with limitations on problem which is :

a. The ship’s firefighting system using unscale model or laboratory scale

1.4 Research Objectives

Based on problems mention above, the objectives of this research are:

1. To design the automatic ship firefighting system based on PLC.

1.5 Research Benefit

The benefits of writing this final task in general is to understand the effectiveness of the operation of firefighting system on ship manually compared with firefighting system on ship automatically based on PLC. This comparison will be a recommendation to shipowners, shipyard, government, and related parties in developing firefighting system automation.

CHAPTER II
LITERATURE STUDY

2.1 Wildfire

Wildfire hazard is a danger posed by potential threats and degrees of fire emitted from the beginning of the fire to the smoke-generating fire (Permen PU No.26/PRT/M/2008). Wildfire may occur wherever, inhabitants, forests, buildings and even on boats that have the potential to cause material and life losses. Wildfire may occur because of potential fire.

Figure 2. 1 Fire Triangle

The definition of fire according to National Fire Protection Association (NFPA) 101, 2002 is a mass of glowing substances produced in a rapidly oxidizing chemical process and accompanied by the release of energy or heat. The emergence of this fire itself is caused by the source of heat derived from various forms of energy that can be a source of ignition in a fire triangle. The fire triangle is the 3 elements that can cause fire that fuel is a solid fuel, liquid or gas element that can burn, heat is enough energy to ignite the mixture between fuel and oxygen from air and oxygen contained in air.

2.2 Classification of Fire

Fire has a classification to distinguish how to handle the fire easier to extinguish. Basically to extinguish the fire that needs to be done is to remove one or more elements of the fire triangle. However, the handling must be in accordance with the existing fire classification, because a blazing fire device can not use the same extinguisher. The fire classification are:

1. Class A Fires— Fire comes from solid materials such as paper, wood and plastic. This type of fire is suitable to be extinguished using water which act mainly as smothering or chain-breaking agents, may also be used.
2. Class B Fires—Fires comes from flammable liquids such as grease, gas, oil and other substances give off large amounts of flammable vapors and require smothering agents to do the job. This type of fire is suitable to be extinguished using foam and carbon dioxide (CO2).
3. Class C Fires—For fires come from electrical equipment, conductors or appliances, non-conducting extinguishing agents must be used such as carbon dioxide, halon and dry chemical.

4. Class D Fires— This fire comes from chemicals such as zinc, magnesium, titanium and aluminum. They burn on the metal surface at very high temperature, often with a brilliant flame. (Shangchun Zhang, 2000)

2.3 Firefighting System on Ship

Each ship is required to have fire extinguishers based on their type and size (PP No. 51 th 2002 about shipping). This system is very important on the ship because the potential for fire on the ship is also very high. Installation and use of this system must also be appropriate to ensure the safety of any crew or passengers. In every part of the ship has different potential levels. Currently the system used is to use sprinklers with pressurized tanks where pressure should be checked periodically to avoid under pressure Hose mounted on the ship should be able to reach every part of the ship. Fire extinguiser should also be placed on the part that is easy to reach for handling can be done quickly. In the vessel accommodation space should be installed smoke detector and water sprinkle to detect the smoke that could be a potential fire and spray the water to the fire. The evacuation route should also be set up clearly to help everyone on board can save themselves when a fire occurs. The local fire department should be feasible for effective firefighting in an area. Working steps that can be done automatically or manually as well as possible do not affect the operation of other equipment. Automatic and abrupt usage should not damage other components. When the apparatus is manual, it can be mounted on the engine control room or in a place that provides adequate protection. (Volume III BKI 1996 section 12)

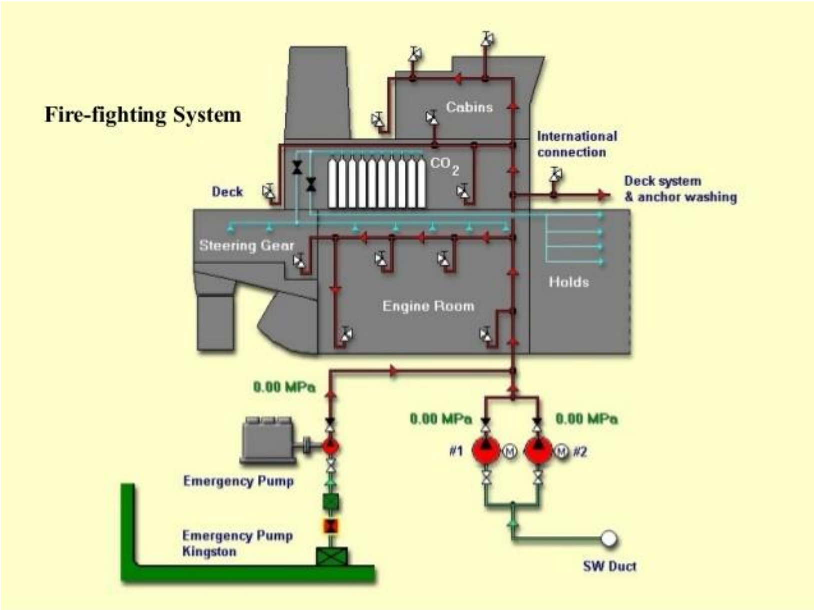


Figure 2. 2 Scheme of Ships Firefighting System
(source : kmsu, 2013)

Fire fighting system devided into three groups. First is fire main system. Seawater as fire extinguishing medium. At least two fire pumps and are located in two different compartments. An international shore connection is provided at port and starboard for external water supply. System is tested with at least streams of water directed from one fire pump. Pressure relief valve is fitted to mains to protect sudden over-pressure. Second is carbon dioxide system. This part is dry fire protection. This protection used in compartments that have potential for fire such as engine room, emergency generator room, paint locker and galley. System is equipped with audio and visual alarm to alert crew to evacuate. Prior to CO2 release, ventilation fans and fire damper to be shut. Third is sprinkle system. This is include into wet fire protection mainly for accommodation area. System is filled with fresh water and pressurized by compressed air. Subsequently, water is supplied from fire main. Sprinkle and fire main systems are separated by an alarm check valve. When the pressure in the sprinkle drops below the fire main fire pressure, the fire main pressure will overcome the internal pressure of the valve lift and automatically push open to accommodate the fire main.

2.3.1. Rules of Ship Firefighting System

Every sprinkler, fire detector, and fire alarm system needs to be capable of producing at any time. Each part of the sprinkler should include a means for automatically assigning the visual and sound alarm signal to one or more units indicating whenever the sprinkler is working. Sprinklers should be divided into separate parts, each of which should contain no more than 200 sprinklers. Each part of the sprinkler will not serve more than two decks. Sprinkler should be able to operate at a temperature between 68°C to 79°C. At least 6 spare sprinkler heads shall be provided for each section.

Each fire detection device must be operated automatically and manually at all times. Activation of any manually operated detector or call point should initiate a visual and audible fire signal at the control panel and show the unit. If the signal has not received attention within 2 minutes, the audible alarm should be automatically audible throughout the crew's accommodation and service room, control station, and engine room. The sound alarm system does not need to be an integral part of the detection system. All control panels must be on the navigation or bridge deck or on the main control station.

Smoke detectors must be installed in all stairs, corridors and escape routes in the accommodation room. Detectors shall be located for optimum performance. In general, detectors which are located on the overhead shall be a minimum distance of 0.5 metres away from bulkheads.

Table 2. 1 Maximum spacing of detectors

Type of detector	Maximum floor area per detector (m2)	Maximum distance apart between centres (m)	Maximum distance away from bulkheads (m)
Heat	37	9	4,5
Smoke	74	11	5,5

Smoke detectors are installed in stairwells, corridors and escape routes 12.5% obscuration per meter, but not until the smoke density exceeds 2% obscuration per meter. The heat detector must be certified to operate before the temperature exceeds 78 ° C but not until the temperature exceeds 54 ° C, when the temperature is raised to a limit of less than 1 ° C per minute. At a higher temperature rise rate, the heat detector must operate within limits for the sensitivity of detector sensitivity or excessive sensitivity. (SOLAS Chapter II)

2.4 Fire Safety in Smart Home

Smart home system is a system of buildings or homes that work automatically programmed using a computer device that will provide comfort, safety to its users. Programmable Logic Controller as one of the mainstay automatic control system in the field of industry provides another alternative in the arrangement of the intelligent home components. Fire detection system in smart home based on PLC aims to detect the room from fire hazard. Smoke detectors, relays and motors will be controlled by the PLC to provide the appropriate action that has been in the program. Results obtained by heat detector in the form of temperature comparison ≥ 37.8 ° C with a voltage ≤ 9V, smoke detector in the form of the ratio of smoke particles into the ionization region with strong currents and the system output conditions when the detector is on and off (Baiquny, 2012)

2.5 Firefighting System on Aircraft

Fire protection system on aircraft divided into 2 ie portable and fixed (non-portable). complete fire protection systems on modern aircraft, and on many older aircraft, including fire detection systems and fire fighting systems. A typical zone on an aircraft that has a fixed fire and / or fire extinguisher detection system are:

1. Engines and auxiliary power unit (APU)
2. Cargo and baggage compartments
3. Lavatories on transport aircraft
4. Electronic bays
5. Wheel wells
6. Bleed air ducts

   (Federal Aviation Administration)

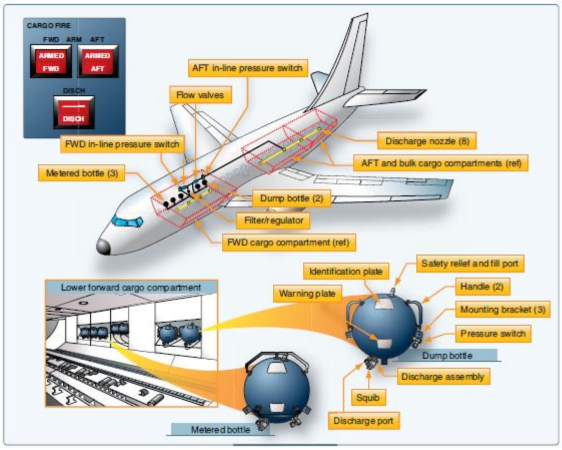


Figure 2. 3 Cargo and Baggage Compartment Extinguishing System.
(source : www.faa.gov/regulations_policies/handbooks_manuals)

2.6 Firefighting System on Shore/Building

Fire protection on shore or on building is complex. Because every activities in the room ot its building must be guaranteed for the safety aspec so the people can do all their activities with no anxious. Fire protection on building is not only for the equipment but also how people can save their life if any dangerous in the building. Two or more storey buildings and one floor building will be different for the fire protection system.

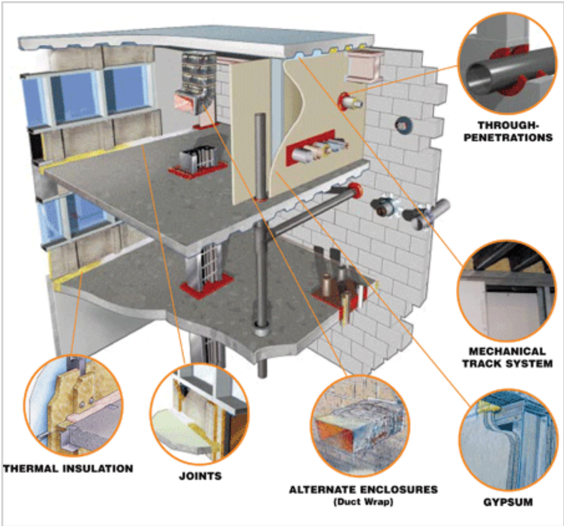


Figure 2. 4 The Basics of Passive Fire Protection
(source : www.buildings.com)

According to Chris Jelenewicz, engineering program manager at the Bethesda, MD-based Society of Fire Protection Engineers (SFPE), there are four main areas of passive fire protection.

a. Structural protection against fire. Structural fire protection protects important structural components (such as structural steel and connection systems) from fire effects.
b. Compartment Fire barriers, firewalls, fire partitions and smoke barriers are included in the compartmentalization. Fire retardants include walls, floors and ceilings made of fire (often made of concrete, combination of wood, plaster or stone).
c. Opening protection. Fire doors and windows are installed in an opening in a fire barrier to maintain fire resistance. McHugh explains: "The doors, the hardware of the builders and the frames work together to form an effective barrier against smoke and fire."
d. Firestopping materials. These materials are used to limit fire spread through penetrations in a fire barrier.

2.7 Basic of Control System

Every system alway use a cycle to achieving the goals. In control system there are two type of cycle. The first one is open loop control system and the scond one is close loop control system. Every cycle was made depend on the need of the system. Choosing the right cycle will make the system efective

2.7.1. Open Loop Control system

Open loop control system is control system that the output will no effect or will not give feedback to the input.In a physical system there is no automatic correction of the variation in its output. That is, in this type of system, sensing of the actual output and comparing of this output (through feedback) with the desired input doesnot take place. The system on its own is not in a position to give the desired output and it cannot take into account the disturbances. In these systems, the changes in output can be corrected only by changing the input manually.

Figure 2. 5 Open Loop Control System

These systems are simple in construction, stable and cost cheap. But these systems are inaccurate and unreliable. Moreover these systems donot take account of external disurbances that affect the output and they donot initiate corrective actions automatically.

2.7.2. Close Loop Control System

A closed loop control system is a system where the output has an effect upon the input quantity in such a manner as to maintain the desired output value. An open loop control system becomes a closed loop control system by including a feedback.

This feedback will automatically correct the change in output due to disturbances. This is why a closed loop control system is called as an automatic control system.

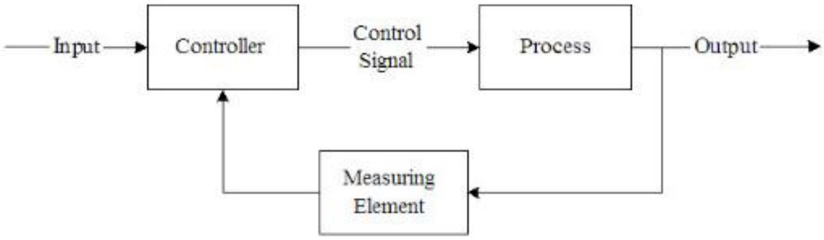


Figure 2. 6 Close Loop Control System

In a closed loop control system, the controlled variable (output) of the system is sensed at every instant of time, feedback and compared with the desired input resulting in an error signal. This error signal directs the control elements in the system to do the necessary corrective action such that the output of the system is obtained as desired.

2.8 PLC (Programmable Logic Controller)

PLC is an electronic system that operates digitally and is designed for industrial use, where it uses programmable memory for internal storage of instructions that implements specific functions such as logic, sequence, timing, enumeration and arithmetic operations to control machines or processes through digital or analog I / O modules (Capiel, 1982). Historically, PLC was first designed by General Motors (GM) around 1968 to replace the relay controls in sequential processes that were perceived as inflexible and high-cost. In the 1980s an attempt was made to standardize communications with General Motor's Manufacture Automation Protocol (MAP) automation protocol. It is also a time to minimize PLC size and programming software development through symbolic programming with PC computers rather than programmable terminals or use of handled programmers.

Figure 2. 7 PLC
(source : www.omron.co.id/products/family/36/)

PLC basically has 3 main function that is process (run instruction logic program); memory (saving process results); input / output (receiving data from outside and output process). PLC consists of two main parts there are CPU (processor) and I / O unit devices. This controlled process can be a continuous variable regulation such as servo systems or it only involves control of two states (On / Off) only but done repeatedly such as on drilling machines, conveyor systems, and so on.

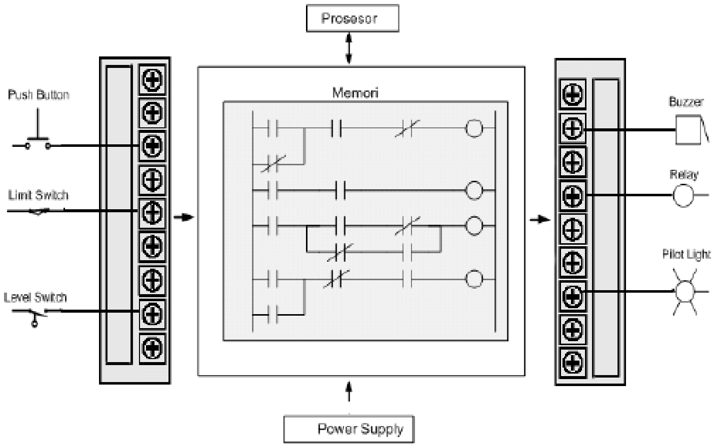


Figure 2. 8 Working Principle of PLC
(source : Programmable Logic Controller Dan Teknik Perancangan Sistem Kontrol, 2006)

Based on figure 2.5, the working principle of PLC is to process input from various sources such as push button, limit switch or switch level and give output to relay buzzer or pilot light. Ouput provided in accordance with the program in the form of ladder diagrams that have been made and transferred to the PLC.

2.8.1. Type of PLC

As mentioned, PLC have two main categories: modular and compact. Both have the same basic functions. A PLC is much like a personal computer. It consists of a central processing unit (CPU) and an input/output (I/O) interface system. The difference between a PC and PLC is that PLC handle multiple configurations and carry out control functions. All I/O systems consist of message or information carriers - inputs - and controllable devices - outputs. Any switches, sensors or other similar devices are physically linked to the main I/O system and all of the activity throughout the entire system is controlled by the CPU.

- Compact PLC are typically designed to perform basic functions. They are small and consist of a power supply and the CPU and I/O systems, which are all housed in one entity. The proper functioning of all processes largely depends on the flawless execution of every component.

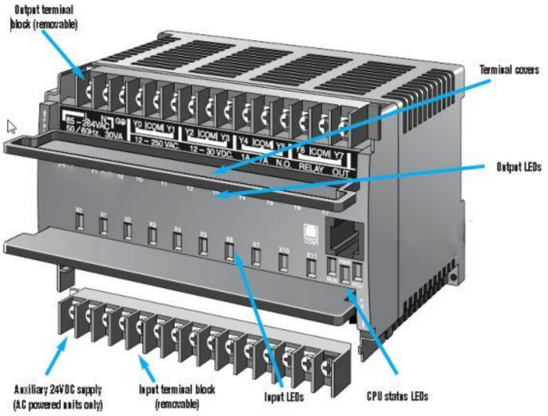


Figure 2. 9 Compact PLC
(source : http://www.plcedge.com)

- Modullar PLC also known as rack-mounted units, consist of bases allowing for many independent components, such as the installation of numerous I/O modules. These are easier to repair.

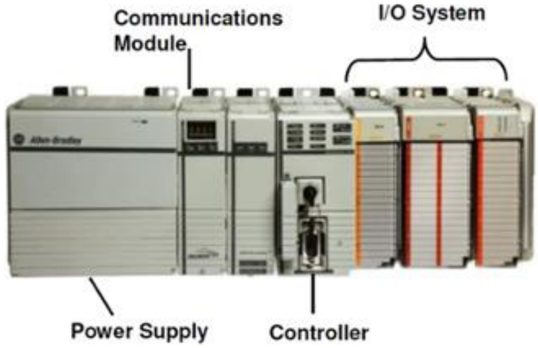


Figure 2. 10 Modullar PLC
(source : http://www.plcedge.com)

2.9 Ladder Diagram

Ladder diagram is diagram used for programming PLC. The ladder diagram or electrical schematic or elementary diagram can be divided into two distinct portions. The first is the power portion and the second is the control. Showing flow of power to a motor or other device in a factory environment is the primary focus of the power portion. Showing control of that motor is the focus of the control portion. While power flow is important, the focus is to dissect the control portion. Items such as fuses and disconnect devices may appear in both power and control circuits. The use of symbols is important for both power and control.

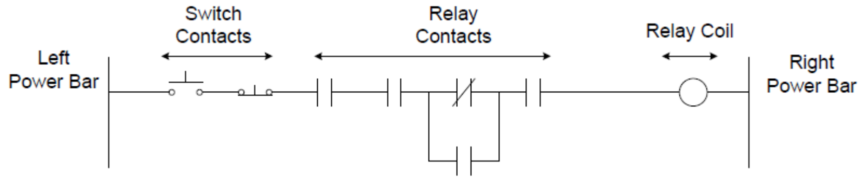


Figure 2. 11 Ladder Diagram singe rung
(source : www.eng.utoledo.edu/~wevans)

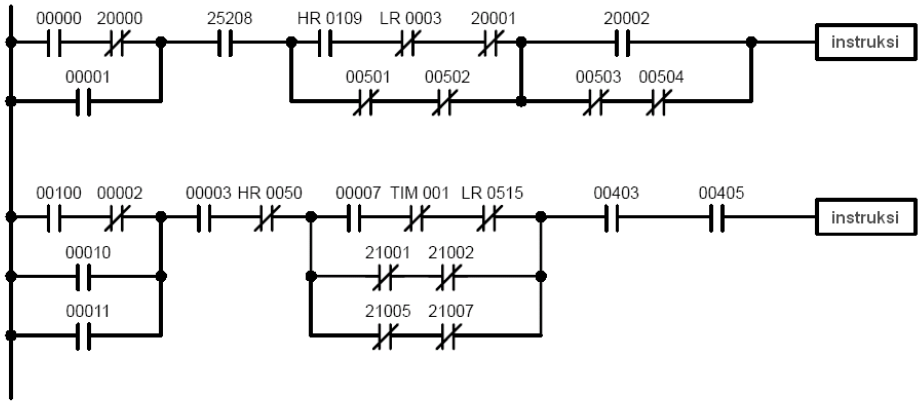
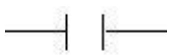
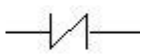


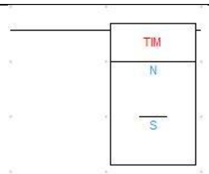
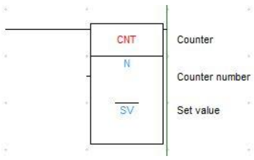
Figure 2. 12 Ladder Diagram singe rung
(source : agfi.staff.ugm.ac.id)

2.9.1. Basic Intstruction of Ladder Diagram

On making of ladder diagram, there are several basic instruction that often to use to make simple logic or complex logic. The instruction put in the each rung to work a logic for make the system. In the table 2.1 there several basic instruction that often to used.

Table 2. 2 Basic Instruction of Ladder Diagram

No	Name	Symbol	Explanation
1	Normally Open (NO) Contact		Instruction will has value of 1 when its active and will has value of 0 when not active
2	Normally Close (NC) Contact		Instruction will has value of 0 when its active and will has value of 1 when its not active

3	Normally Open (NO) Coil		Instruction for output that has value of 1 when its active, and 0 when its not active
4	Normally Close (NC) Coil		Instruction for output that has value of 0 when its active and 1 when its not active.
5	TIM (Timer)		Instuction will avtive when previous instruction is 1. Output from this instruction will active when set value (SV)=0
6	CNT (Counter)		Istruction will active when the previous instruction is 1. Output from this instruction will active when present value has value of 0

2.10 PID Thermometer Controller and Thermocouple

PID thermometer is a controller to process data from sensor input. This tool is a "brain" in charge of managing data input. In this controller there is set value and present value. The set value will be adjusted according to the existing value of the initial design that serves as a standart to give the next action. Present value is the input value obtained from the sensor according to the realtime condition. So this controller depends on the sensor itself, if sensor has some trouble so the actuator will be give an action not good enough.

Figure 2. 13 PID Thermometer and Thermocuple
(source : https://www.aliexpress.com/product/REXc-100)

Thermocouple is the type of sensor to detect or measure temperature. The Thermo-electric effect of this Thermocouple was discovered by an Estonian physicist named Thomas Johann Seebeck in 1821, in which a conductor metal gradient differed heat would produce an electric voltage. Working principle of this sensor is combine 2 metals. One type of metal conductor contained in the thermocouple will serve as a reference with a constant temperature (fixed) while the other one as a metal conductor that detects hot temperatures. (Suprianto, 2015)

2.11 Smoke Detector

One of parameters on this project is smoke. Smoke detector is sensor to detect some smoke because smoke is one of indication of fire but smoke is not always fire. This detector can turn the alarm and indicator lamp if there is some smoke that cacth by the sensor. Smoke detectors in large commercial, industrial, and residential buildings also in the ship are usually powered by a central fire alarm system, which is powered by the building power with a battery backup. Sensitive alarms can be used to detect, and thus deter, smoking in areas where it is banned.

Figure 2. 14 Smoke Detector
(source : http://www.dx.com/p/smoke-detector-alarm-optical-sensors-6674)

Smoke detector use 2 principle of working. The first one is use ionization adn the scond one use photoelectric principle. This sensor is also important because smoke not only caused by fire, it can from pantry or kitchen activity. Smoke also can be caused by cigarette. Although this tool has already installed on board, but accident about fire or smoke still happen.

2.12 Flame Detector

Flame detector is a sensor that can catch the spark or fire. This sensor is with the smoke detector and heat detector. This sensor captures the existing rays like ultraviolet and rays that have the same color composition as sparks. This tool is usually available in the form of a separate sensor because this sensor is flexible that can be combined with other controllers such as arduino and so forth. But there are also already available with the module. In industrial usually use the flame detector that become a package with a modile so it will be easy to install. The sensitivity of this sensor can be adjusted by rotating the existing pots in it, so it can fit the level of need.

(A) (B)

Figure 2. 15 Flame Detector
(A) Industrial (B) Prototype
(source : https://www.crowcon.com/uk/products/fixed-detectors/flame-detectors.html)

2.13 Relay

Relay is a device that is often found in the world of electronics because of its simple working principle and can be used as a safety. This tool is a switch that uses electricity to operate it. Relays are also commonly referred to as electromechanical components consisting of two main parts namely the coil or electromagnet and switch or mechanical contacts. Relay components use the electromagnetic principle as the driving contact of the switch, so by using a small electric current or low power, can deliver a current that has a higher voltage.

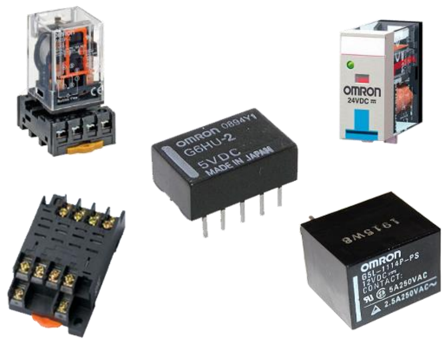


Figure 2. 16 Relay
(source : http://www.komponenonline.com/Omron-Electronic-Components.php)

The working principle of this tool is when the relay is given electricity according to the specification then the magnet in the relay will work so that the switch will respond according to the need whether it requires NO (normally open) or NC (normally close). The working principle of this tool is when the relay is given electricity according to the specification then the magnet in the relay will work so that the switch will respond according to the need whether it requires NO (normally open) or NC (normally close). In this final project relay is used for the safety of the signal does not go directly to the PLC but through this tool first so that if there is a konslet then the first to be damaged is a relay instead of PLC

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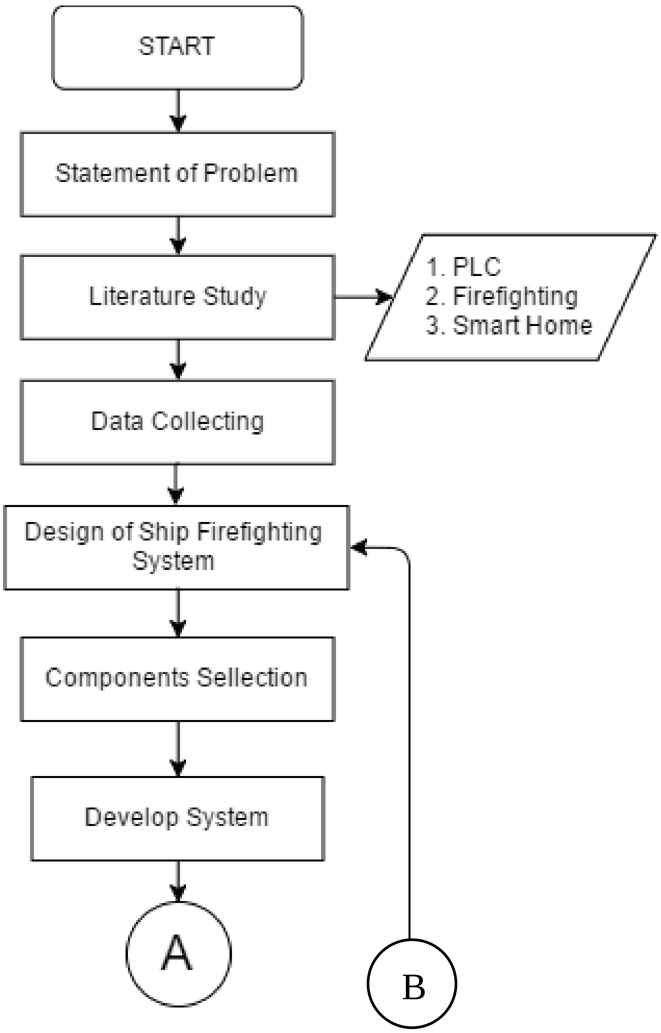
CHAPTER III
METHODOLOGY

The research methodology is the basic framework of the final task completion stage. The methodology includes all activities that will be carried out to solve the problem or perform the process of analysis of the problem of this thesis. The methodology of this final project can be seen completely through Figure 3.1.



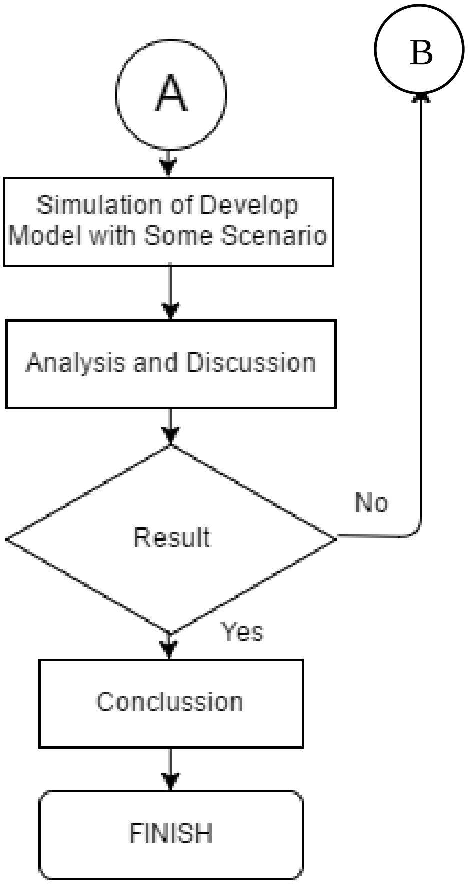


Figure 3. 1 Research Flowchart

3.1 Statement of Problem

Beginning of the step in the work of this thesis is to identify the existing problems which then formulated in the statement of problems that will be solved during the work of this thesis. In this final project there are several bacgrounds like trend of ship accidents in Indonesia is increasing every year so that this concern because the ship is a mass transportation that is still a favorite for many people, the occurrence of some accidents is also mostly caused by fire or explode so that the level of potential fire in the ship is still very high and requires handling which is faster than manual operation.In addition, there are also problem limits. This is intended to discuss the topic more detailed and not too widespread.

3.2 Literature Study

The next step is to conduct a literature study with the aim to summarize basic theories, references in general and specific, and to obtain various other supporting information like PLC, firefighting, smart home related to this final project work. This literature study can be obtained from journal books, papers or from the internet that support the discussion of this final project.

3.3 Data Collecting

Every installation of fire fighting equipment on board has rules. This step is how much sensor in every space on the ship regarding the rules. Appropriate treatment is given when there is a potential fire also determined here. This step also to know how the ship's firefighting system. This data can made as reference to develop the model.

3.4 Design of Ship Firefighting System

The design of model is designed to make the model shape according to the design and requirement. This stage is the stage to program the PLC according to the need for all sensors and actuators to work properly. At this stage it also creates a ladder diagram and matches the available addresses inside the hardware on the PLC with the current address at programming. For the PLC programming use the CX-Programmer.

3.5 Component Selection

Making a system definitely requires equipment that matches what is required so that when the assembly process can fit with other equipment. Before develop the model of firefighting system on the ship, first is sellect the several components that used for this project. The selected components include various sensors to be used, wiring cables, DC power supplies, acrylic boxes, and actuators such as pumps, pipes, hazard lamps and valves.

3.6 Develop System

This process is the assembly of all the components that have been selected in the previous stage. This assembly includes the installation of all sensors and actuators, wiring, and the installation of sensors and actuators to the PLC. This installation is made carefully so that the system has been designed before it can run and there is no error or short circuit to each equipment.

3.7 Simulation Develop System with Some Scenario

After the model is completed it is necessary to test whether the model can work according to the design that has been made and work well or not. This model will be try with 6 scenarios that has made. 3 scenarios are made on the accomodation room and 3 scenarios are made on the engine room. This stage is done to find out if all previously made scenarios can be applied to the model.

3.8 Analysis and Discussion

This step is analyze the data from the prototye that has been run. Those data like time needed for the sensor make response, time needed for the PLC can process the response from the sensor and give the action to the actuator.

3.9 Result

This step is the result of the analysis and discussion from trial the model. Whether this system of the prototype is working well or not. If the result is no do must be repeat to design of ship's model and automation system step.

3.10 Conclussion

After data analysis is done, so it can make the conclussion that this system is right to aplicate in firefighting system on the ship or not.

CHAPTER IV
DISCUSSION AND DATA ANALYSIS

4.1 Hardware Design

This final project is develop model of automatic firefighting system on board using PLC. Before author make the prototype of this final project, the design of this prototype must be done. The purpose of this step is to make easy when the author make and assembly the model.

As the explanation before, to handle the fire is to remove one of the fire triangle. To remove one of fire triangle the author use 2 material, are water and CO_2. Actually in fire fighting sytem not only use that 2 material but can use foam, powder. But foam and powder use in portable form not fixed (Indrajaya, 2018).

4.1.1 Accomodation Room

Fire handling must be done properly so that fire can be extinguished with a short time so as not to increase losses due to fire. Accomodation room is a room used for the purposes of the crew such as bedrooms, meeting rooms, pray room etc. In these rooms there are some materials such as wood, paper and plastic that can burn which is included in class A fires. Fire handling in the most appropriate and effective accommodation space is to use sprayed water using a pump. Figure 4.1 is design room that is considered as an accommodation room.

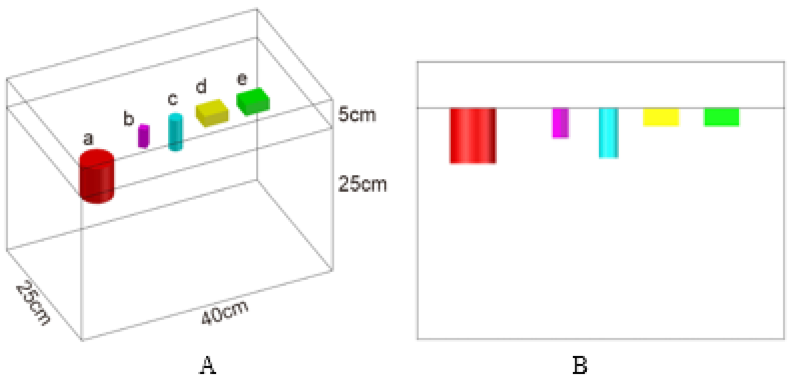


Figure 4. 1 Design of Accomodation Room Model

The design for the accomodation room is shown in figure 4.1 in the box with several instruments in the box. The flame detector (d) is located inside the box on the roof to catch a spark or fire inside the box. The smoke detector (e) is located just beside the flame detector in order to easily catch the smoke inside the box. The third sensor installed is a thermocouple (b) connected to a PID Thermometer to set the desired temperature range to detect a increasing temperature. In this design there is also a rotary lamp (a) that will light up in accordance with the ladder diagram that is made as the ouput of the installed sensor. Another output of the pump that will work automatically spray water (c) to be able to extinguish the fire in the box.

4.1.2 Engine Room

In all mass transportation, the engine room is the space that has the highest risk of accidents because there are some equipment that can injure a person. No exception on the ship, the engine room is also a room that has a high risk that can be caused by several things such as vibration, noise and condition of the room itself. The engine room is also synonymous with various fluids such as fuels, lubricants and other liquids required to operate the machine in order to work. Class B fires are a class of fire that is slightly more difficult to extinguish than class A. Liquid like fuel, effective lubricant is extinguished when using CO2 gas due to the different liquid properties of wood and plastic properties belonging to class A. Figure 4.2 is a design room that is considered as an engine room.

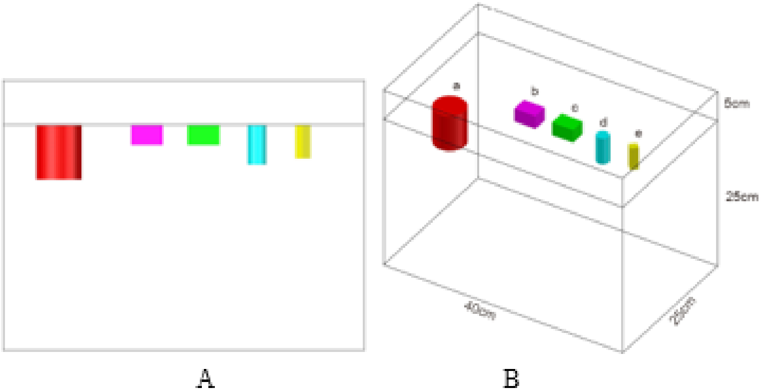


Figure 4. 2 Design of Engine Room Model

Basically the design of the model that is assumed as engine room is almost the same as the design model for the room akomodas only distinguish is how to handle the fire that is in the box. Flame detector (c) is installed in this design to detect spark or fire inside the box. In addition, there is another installed detector of smoke detector (b) and thermocouple (e) connected with PID thermometer to detect smoke and increasing temperature in the box. Same as the design on the accomodation room, in this room there is also a rotary lamp (a) as a hazard output if there is an indication of fire, heat or smoke in the box. In this room mounted solenoid valve that works open and close the flow of CO2 (d) coming from pressurized tubes to extinguish the fire that is in the room.

4.1.3 Wiring Diagram

Wiring diagrams are simple images that describe the electrical circuit (wiring) of a system. Wiring diagrams are like maps showing the function of an electronic device and its interlocking constituent components as an electronic circuit. It also shows the current flow in the electronic circuit. In this final project wiring diagram is made with simple and effective so that in the process of assembling the component becomes easy. Making wiring diagrams before assembly is very important to avoid short circuit on components. Wiring diagrams for firefighting system based on PLC are shown in Figure 4.3.

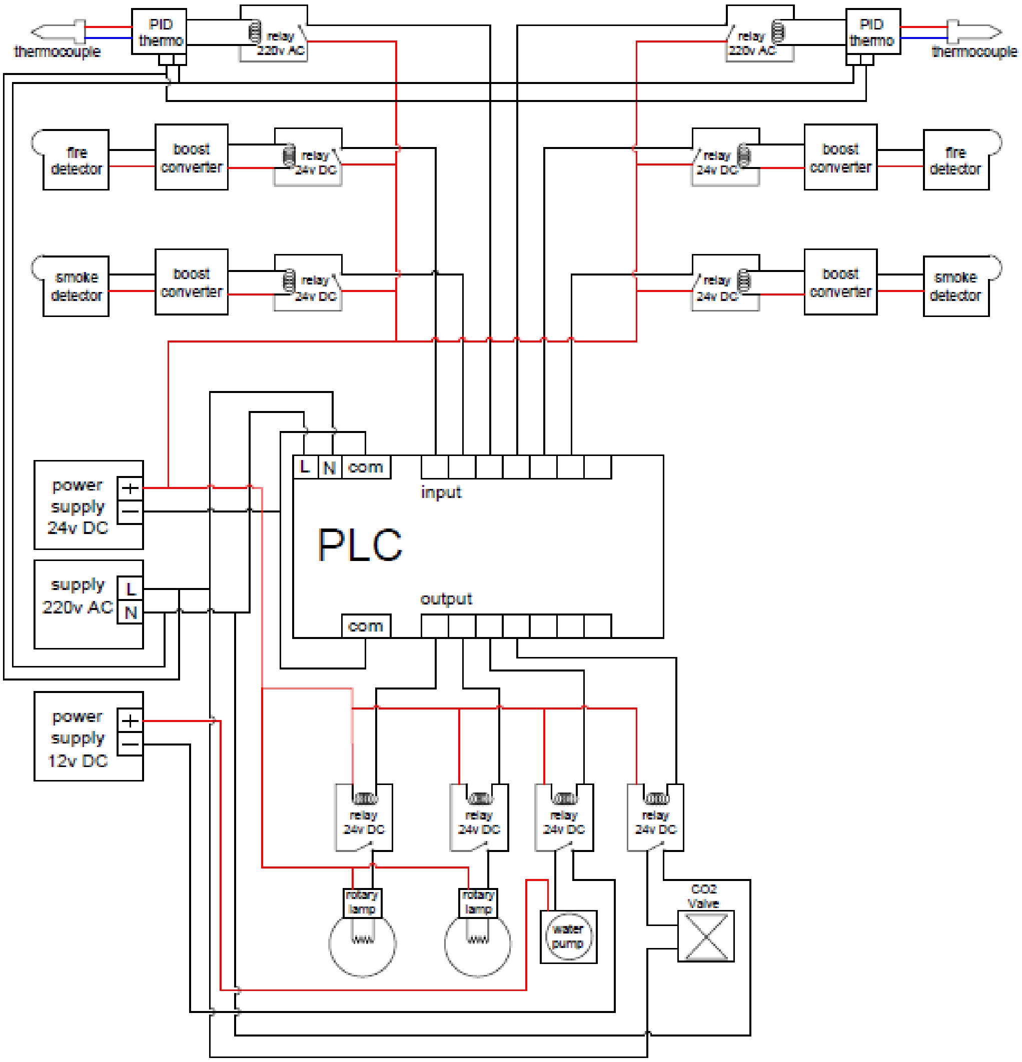


Figure 4. 3 Wiring Diagram of Model

Based on figure 4.3 PLC can work when given 220v AC supply to power the PLC and need 24v DC supply to turn on the signal contained in PLC. This system relies on several relays to adjust the input and output of the PLC due to safety reasons. In addition to 220v AC and 24v DC, on wiring there is also a 12v DC power supply to supply the voltage to the water pump.

4.2 Equipment

To support a system must be required equipment that is proper and in accordance with the needs for the system that has been in accordance with the desired design. Some components must also be adapted to other components in order to be able to connect well.

4.2.1 Flame Detector

Potential of spark and fire can be detected by flame detector. This sensor uses 5v dc power. The rays that can be captured by this detector are sparks and flames. This tool has the ability to detect the potential fire with a distance of about 50cm. This detector is equipped with a led indicator to provide information when it detects a potential fire. Sensitivity is also ajustable so it makes it easy whether it will be in the most sensitive setting or not as needed. The shape is not too large also allows this detector to be installed on the box that has been in the design. However, this detector has several weaknesses such as can not detect a blue fire and will light up when exposed to sunlight or lightning called false alarm. The author uses 2 flame detectors that are installed in 2 boxes.

Figure 4. 4 Flame Detector

4.2.2 Thermocouple and PID Thermometer

To detect an increase in temperature in the box that has been made, the authors use thermocouple and combined with PID thermometer. Thermocouple is a tool that uses the principle of temperature difference on 2 pieces of metal to detect increasing temperature. The author uses a K type thermocouple that has the ability to detect temperatures up to 400^{o}C.

In this final project the author uses PID brand thermometer RKc REX c-100. Thermocouple is connected with PID thermometer in order to set "set value". PID thermometer has display set value and present value. Set value (SV) is the value (temperature) specified as needed to provide analog signals. Present value (PV) is the realtime temperature detected by termocouple. If the present value has reached or exceeded the set value then this tool will provide a signal that will be connected to the relay. This tool requires 220v AC supply to run it. In addition to providing a signal, this tool also has an alarm function in it. The author uses 2 thermocouple K type dan 2 PID thermometer that are installed in each box.

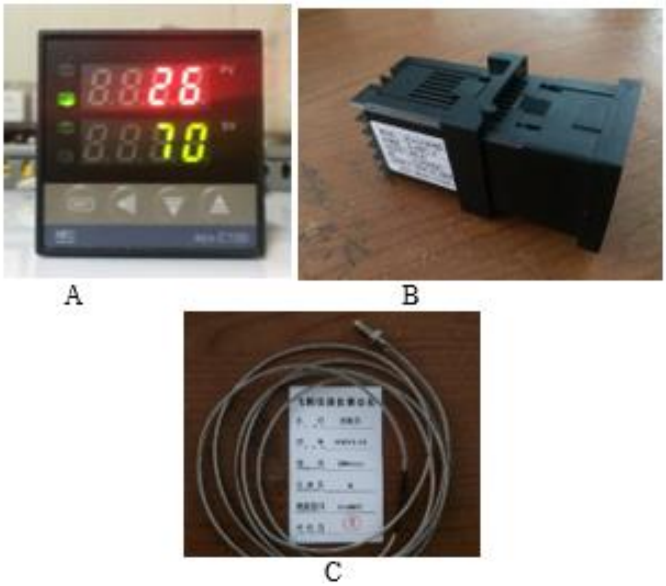


Figure 4. 5 (A)(B) PID Thermometer, (C) Thermocouple K Type

4.2.3 Smoke Detector

In addition to fire and temperature, in this final project there is also smoke as one of the points that must be detected and given the reaction automatically. The author uses smoke detector using photoelectric principle. The dimensions of this tool are the same as the flame detector. It also comes with a led indicator when it detects smoke or objects blocking the photoelectric process. This smoke detector requires 5v DC power supply. The output of this tool will be connected to the boost converter in order to give the trigger to the relay. the sensitivity of this tool is also ajustable so it can be tailored to the needs.

Figure 4. 6 Smoke Detector

4.2.4 Boost Converter

Boost converter is a tool used to convert the input voltage into a larger output voltage. This tool uses a principle like a transformer on an AC power source, but it is applied to a DC source. The use of this tool has a goal that is the output from the flame detector and smoke detector is 5v DC while on the market 5V DC relay hard to find so it must be boosted to 24v DC in order to provide a trigger to 24V DC relay. This Boost Converter can raise the voltage to a minimum of 3v to a maximum of 24v by adjusting the existing potenzio on the device.

Figure 4. 7 Boost Converter

4.2.5 Acrylic

Box that has been designed previously made using acrylic material because it is durable and not rotting and has a clean look. The author uses acrylic with a thickness of 4mm. To facilitate the assembly and maintenance process, the box is also made to be opened the front and top. Acrylic size used is 40cm x 25cm x 30cm. This box is made to have space above it to put wiring and look more neat.

Figure 4. 8 Acrylic Box

4.2.6 Relay

Relay is widely used in this series of automatic firefighting system. At each input and output mounted the relay in accordance with the appropriate voltage. The author uses 24V DC and 220v Ac relays with LY2N and MY2N types. What distinguishes both types of relays is just pin size on the relay where LY2N has in larger than MY2N. In this final project, author use 10 relay to working the system.

Figure 4. 9 Relay

4.2.7 PLC Omron CPM2A

OMRON CPM2A is used by author because it is available in the MEAS Laboratory. This type of PLC is a compact PLC where input, output and processor have become one in one hardware. Actually this type of PLC is an outdated PLC when compared to current PLC. This PLC has 30 I/O with 18 inputs and 12 outputs. The power source that must be channeled to this PLC is 220v AC to turn on the PLC and 24v DC to activate the signal on the PLC. This type of PLC can be inserted ladder by transferring ladder diagram from CX-Programmer using CIF cable.

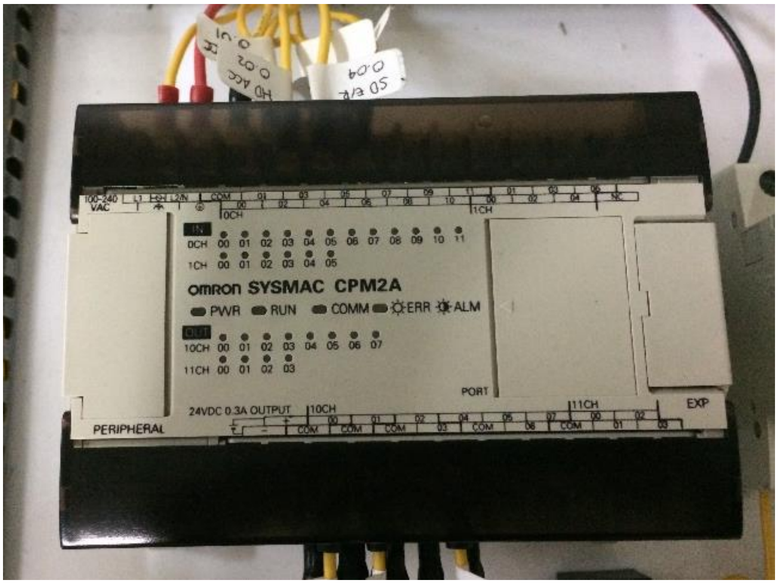


Figure 4. 10 PLC Omron CPM2A

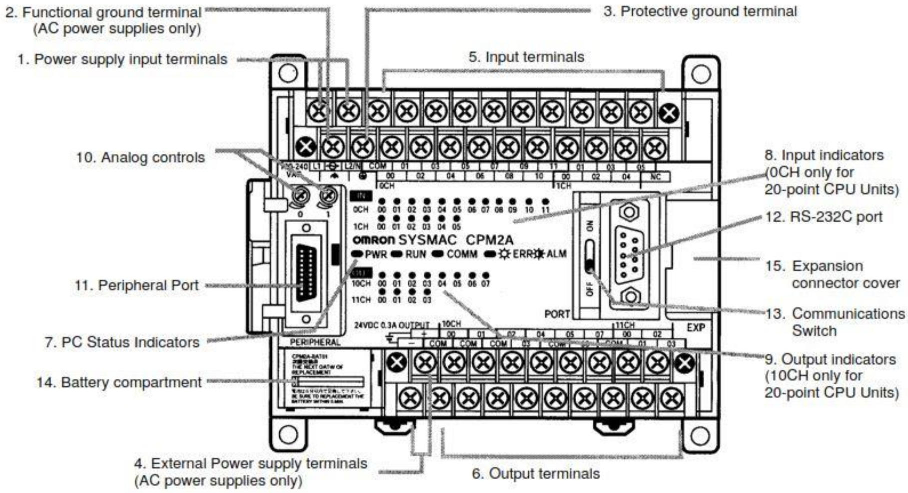


Figure 4. 11 PLC Omron CPM2A
(source: Sysmac omron cpm2a, 1999)

When the PLC is turned on, the power indicator lights up. Beside indicator there is com indicator and error indicator. In the PLC there is a signal indicator that will light up when the address is given a trigger. PLC also has a backup battery in case of undervoltage which must be changed every 5 years. If the battery is not replaced for more than 5 years then the error indicator on the PLC will turn on.

4.2.8 Water Pump

The water pump is used to spray water into a box that is assumed as an accommodation room. This pump is connected to the tank for water storage using pipes and channeled into the box. At the end of the pipe added mist head to spray the water can spread and reach the corner of the box. This equipment requires 12v DC power supply and is able to work with at a maximum pressure of 0.5Mpa and a maximal flow of 4.0L / Min.

A B

Figure 4. 12 (A) Water Pump (B) Head Mist

4.2.9 Solenoid Valve

To regulate the working operation of CO2 gas, the author uses a valve type solenoid valve. This valve uses a brass material with a maximum pressure of 1MPa and is able to work on fluid temperature -5-80oC. This tool requires 220v AC power supply. Fluids that can be applied to this valve are water, oil and air (gas). The working principle of this tool is normally close (NC) valve will open when given 220v AC power according to specifications, and will be closed again when not powered 220v AC.

Figure 4. 13 CO2 Solenoid Valve

4.2.10 . CO2 Tube

CO2 is used by writers to extinguish the fire inside the box that is assumed to be the engine room. CO2 tube used $1m^3$ size and has a maximum pressure of .... but can be set how the output is in want by turning the regulator. The authors use pressurized CO2 tubes with the aim that they are arranged only for valve openings to be simpler.

Figure 4. 14 CO2 Tube Gas

4.2.11 . Rotary Lamp

Hazard location information is one of goal in this final project. Author use rotary lamp to indicats if there is hazard on the box e.g smoke and sparks or flame. This equipment is combine lamp and buzzer. Rotary lamp supplied by 24v DC. This dimension is 9cm of diameter and 15cm of hight. The author uses 1 rotary lamp in each room. The size is not too big so right in install on the box.

Figure 4. 15 Rotary Lamp

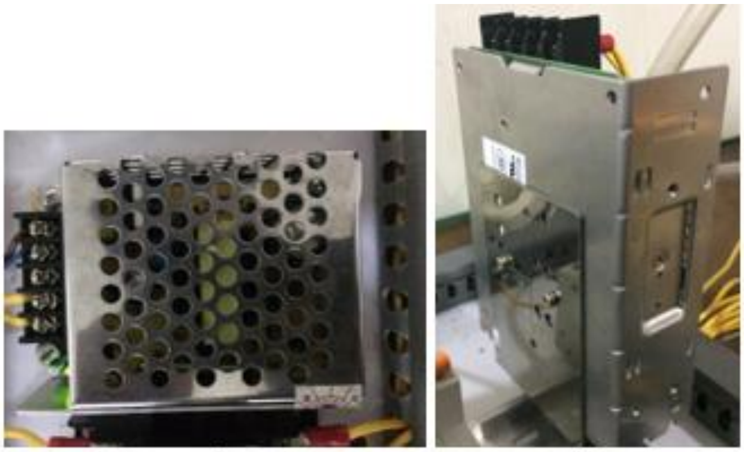
4.2.12 . Circuit Breaker

In making a series of electrical systems should pay attention to aspects of safety. To Prevent overcurrent on this system, author use circuit breaker. Circuit breaker is used 2A. Each circuit breaker installed in the box that assumed the engine room and the accomodation room. The circuit breaker will automatically break the current if the current passing exceeds the specification.

Figure 4. 16 Mini Circuit Breaker

4.2.13 Power Supply

To be able to turn on some equipment in this system needed DC power supply. In this thesis the author uses two types of power supply in accordance with the design and needs. The first power supply is Omron 24v DC with 2A current output. This tool is used to supply 24v DC power for various needs such as activating signal on Omron CPM2A PLC, turn on rotary lamp and as source to activate magnet on 24V DC relay. The author also uses a 12v DC power supply with a current output of 3A. This second power supply is used to supply electricity for water pumps. The working principle of these two power supplies is converting the 220v AC power into DC 24v and 12v.



A B

Figure 4. 17 (A) Power Supply 12VDC (B) Power Supply 24VDC

4.3 PLC Programming

PLC can work if given a program to run a desired system. PLC works based on the logic commonly called the ladder diagram. Each equipment that becomes input and output has its own address. Then ladder diagram transfered into the hardware of PLC.

4.3.1. List of Equipment and Address

Numbering on every equipment used in this system is important so that when making ladder no wrong address. Each equipment must also be grouped according to their respective functions whether included into the input or output of the system. Making a list of equipment also simplify when creating a ladder diagram because it is organized and structured.

In Omron CPM2A PLC, each input address always starts with 1 digit 0 or 1 while every output address on this PLC is always start with 2 digits 10 or 11. This is because to distinguish between the input and output addresses. List of equipment in this system can be seen in table 4.1.

Table 4. 1 List of Equipment and Address

No	Name	Address	Note	Code
1	Smoke Detector Accomodation Room	00.01	Input	SD ACC
2	Heat Detector Accomodation Room	00.02	Input	HD ACC
3	Fire Detector Accomodation Room	00.03	Input	FD ACC
4	Water Pump	10.00	Output	WP ACC
5	Rotary Lamp Accomodation Room	10.01	Output	BL ACC
6	Smoke Detector Engine Room	00.04	Input	SD E/R
7	Heat Detector Engine Room	00.05	Input	HD E/R
8	Fire Detector Engine Room	00.06	Input	FD E/R
9	CO2 Solenoid Valve	10.03	Output	SV E/R
10	Rotary Lamp Engine Room	10.04	Output	BL E/R
11	Memory from Smoke Detector Accomodation Room, Fire Detector Accomodation Room and Heat Detector Acomodation Room to generate Rotary Lamp Accomodation Room	200.01	Memory	-
12	Timer delay function from Smoke Detector Accomodation Room, Flame Detector Accomodation Room and Heat Detector Accomodation Room to generate 200.02 memory	TIM000	Timer Delay	-
13	Memory from Timer Delay 0 to generate Rotary Lamp Engine Room	200.02	Memory	-
14	Memory from Smoke Detector Engine Room, Flame Detector Engine Room and Heat Detector Engine Room to generate Rotary Lamp Engine Room	200.03	Memory	-
15	Timer delay function from smoke detector engine room, flame detector engine room and heat detector engine room to generate 200.04 memory	TIM001	Timer Delay	-
16	Memory from Timer Delay 1 to generate Rotary Lamp Accomodation Room	200.04	Memory	-

17	Timer Delay function from flame detector accomodation room to generate water pump	TIM002	Timer Delay	-
18	Timer delay from flame detector engine room to generate solenoid CO_2 valve	TIM003	Timer Delay	-

Table 4.1. List of Equiment and Address

4.3.2. Scenario and Ladder Diagram

Automation system always has diagram block to describe the system easier. Block diagram tell about input, controller, actuator etc in the automation system. Block diagrams are created to estimate process steps. The function of the block diagram is also to make it easier to estimate the equipment that will be involved in the assembly process. Figure 4.16 shows the block diagram for automatic firefighting system based on PLC in this final project.

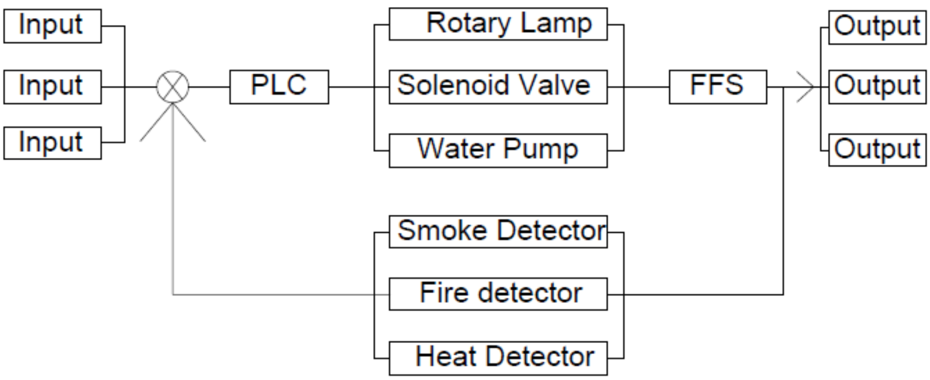


Figure 4. 18 Block Diagram of Automatic FFI System Based on PLC

4.3.2.1. Scenario

Automatic firefighting system based on PLC has 6 scenarios that must run to be able to detect and give action to the existence of fire potential on the acrylic box. The scenarios created are:

- 1st scenario is if heat detector in the accomodation room heated to reach the set value of 50°C then the accomodation room's rotary lamp will immediately light on and rotary lamp in the engine room will light on after 2 seconds.

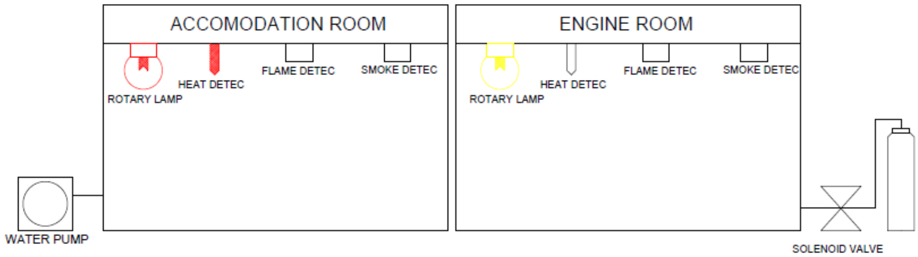


Figure 4. 19 1st Scenario

- 2nd scenario is if the flame detector in the accomodation room detects a spark or flame, the rotary lamp of the accomodation room will be immediately light on and 2 seconds later the water pump will on to spray water to the fire and the rotary lamp of engine room will also light on also.

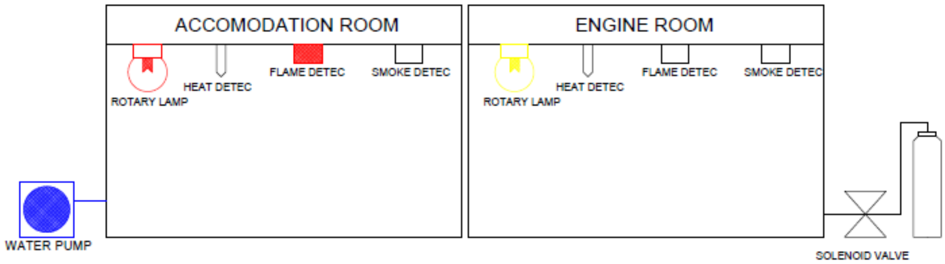


Figure 4. 20 2nd Scenario

- 3rd scenario is if the smoke detector in the accomodation room detect the presence of smoke then the rotary lamp in the accomodation room will immediately light on and 2 seconds later roraty lamp in the engine room will also light on

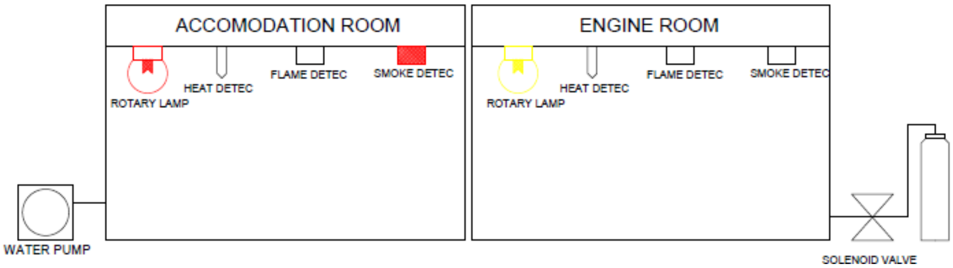


Figure 4. 21 3rd Scenario

- 4th scenario is almost same as the first scenario. The scenario is if the heat detector in the engine room is heated to reach the set value of 70^{o}C, then the rotary lamp in the engine room will immediately light on. Rotary lamps in the accomodation room will also light on but 2 seconds after the rotary lamp in engine room on.

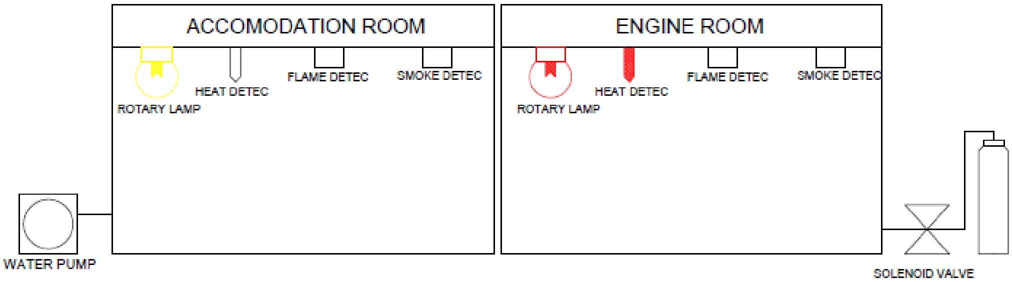


Figure 4. 22 4th Scenario

- 5th scenario is if the flame detector in the engine room detects sparks or flames, the rotary lamps in the engine room will immediately light on. 2 seconds later the solenoid valve will open to supply CO2 gas to extinguish the fire in the engine room and the rotary lamp in the accomodation room will also light on after 2 seconds the rotary lamp on the engine room is on.

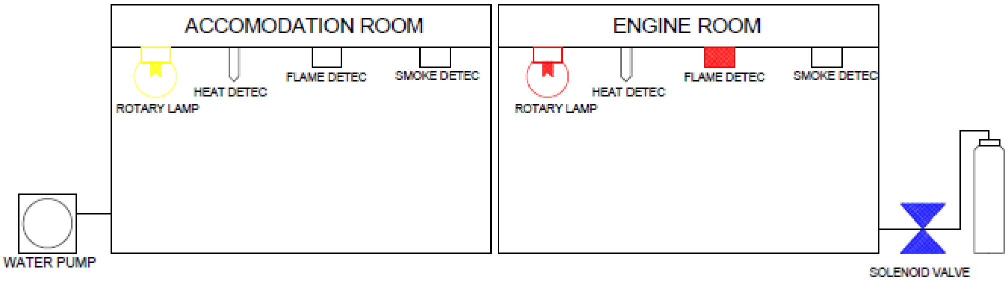


Figure 4. 23 5th Scenario

- 6th scenario is if the smoke detector that is in the engine room to detect the smoke so rotary lamp on the engine room immediately lights on and 2 seconds later the rotary lamp in the accomodation room is also on.

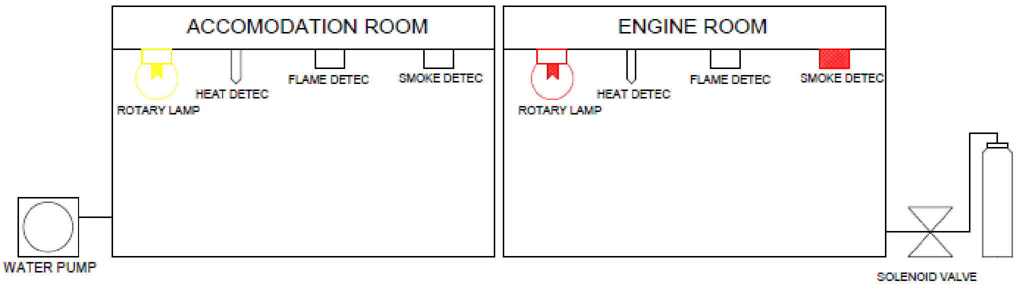


Figure 4. 24 6th Scenario

4.3.2.2. Ladder Diagram

PLC is controller that can process the input and give an action to the output. In this controller also have the program to solve the scenarion as the requirement. For the first scenarion will be different with second and the other scenario so the program must be different too. On PLC that program called Ladder Diagram. The ladder diagram in this final project use CX Programmer as the software because PLC that used is OMRON. Every PLC development has own software.

The programming software for all Omron's PLC series, is fully integrated into the CX-One software suite. CX-Programmer includes a wide variety of features to speed up the development of PLC program. New parameter-setting dialogues reduce setup time, and with standard function blocks in IEC 61131-3 structured text or conventional ladder language, CX-Programmer makes development of PLC programs a simple drag and drop configuration.

Figure 4. 25 CX Programmer for OMRON

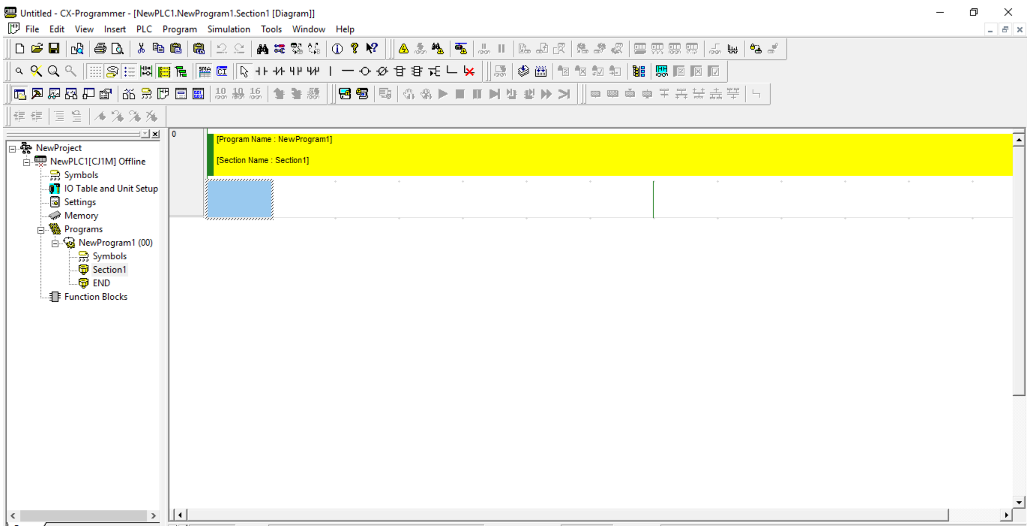


Figure 4. 26 User Interface CX Programmer

Ladder diagrams are based on predetermined scenarios so that PLC can work to receive input signals and provide appropriate output signals on each device. CX Programmer has a function that can be used to actualize scenarios that have been created such as timer counter and timer delay. Basically in designing ladder diagram can come from various input and output. Some address inputs can provide a trigger to a single output address but the address output can only be one. Ladder diagram for input address in the accomodation room shown in figure 4.19.

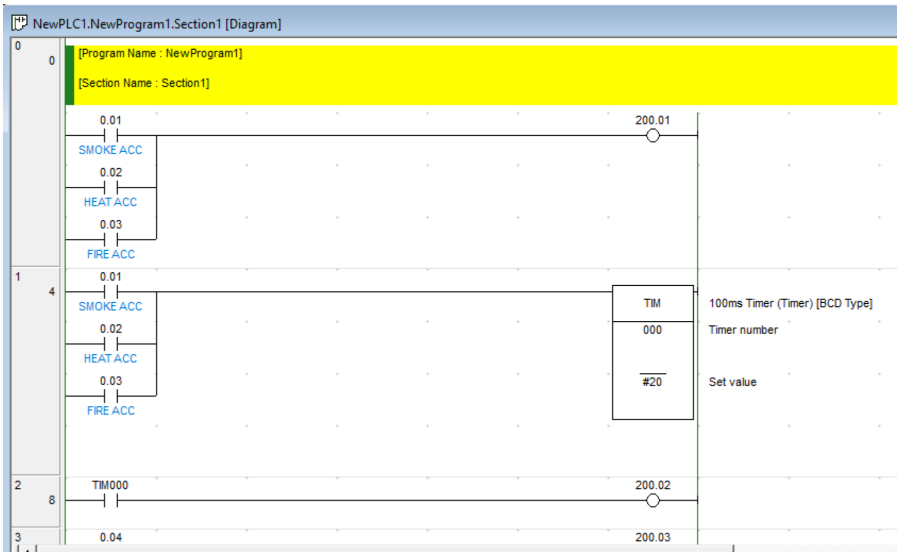


Figure 4. 27 Ladder Diagram of Input Address in the Accomodation Room

According to figure 4.19, smoke detectors accomodation room 0.01, fire detectors accomodation room 0.02, and heat detectors accomodation room 0.03 have their respective addresses. The input used by the author for each detector is the NC contact and uses a close coil for the output. Each input and output is connected by vertical and horizontal line. In the rung (line) 0 there are 0.01, 0.02 and 0.03 conected to the coil 200.01 as e memory. Memory is coil output use for not real actuator only for call another address. In rung 6 200.01 will generate the real coil actuator rotary lamp accomoadtion room 10.01. In the rung 1 there is a delay timer function for 2 seconds. Timer delay is one of function in ladder diagram CX Programmer to call or to generate output but with delay for several time. Ladder diagrams allow output to be input in the next rung. TIM000 is a delay timer function 0 that is used as input to generate next memory 200.02. Ladder diagram for input address in the engine room shown in figure 4.20.

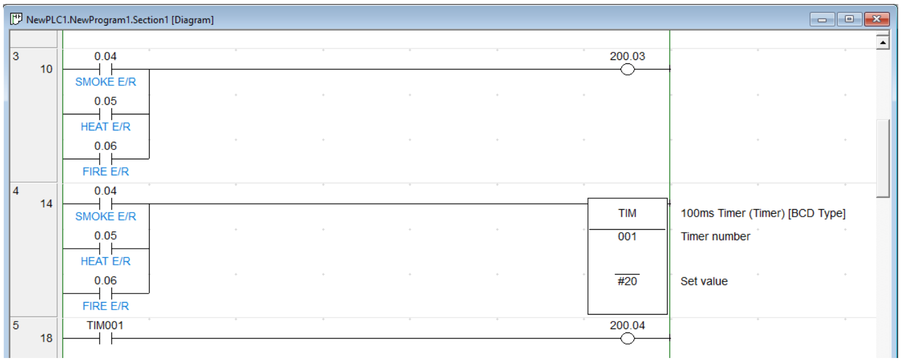


Figure 4. 28 Ladder Diagram of Input Address in the Engine Room

Ladder diagram for the engine room is almost the same as the previous ladder, it's just the address of each different equipment. Ladder in figure 4.20 the author also uses NC contact as input and close coil as output. In rung 3 there are detectors in the engine room that is smoke detector 0.04, fire detector 0.05 and heat detector 0.06. All three sensor activate memory 200.03 which will provide a trigger to the real output. All three input addresses also enable the timer delay function 2 seconds to activate other outputs. As well as the second delay timer function (TIM001) will also enable the memory to give the trigger to the real output. TIM001 will generate the next memory 200.04 and in rung 6 200.04 will generater the real output actuator rotary lamp accomodation room 10.01. Ladder diagram for output address in the engine room and accomodation room shown in figure 4.21.

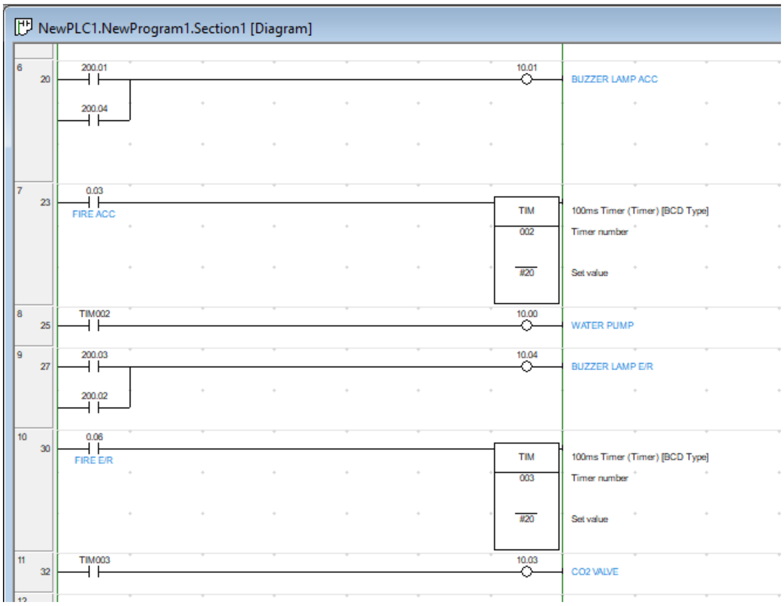


Figure 4. 29 Ladder Diagram of Output Address

Figure 4.21 shows that the memory in the previous rung is become input to activate the output actoators. In rung 6 200.01 and 200.04 as memory from previous rung will generate the rotary lamp accomodation room 10.01. In rung 7 there is input address 0.03 which is flame detector accomodation room will activate timer delay TIM002 for 2 seconds. TIM002 will generate the water pump 10.00 in rung 8. In rung 9 the previous memory 200.03 and 200.2 will generate the real output actuator rotary lamp engine room 10.04. The next rung is flame detector engine room 0.06 will generate the T003 for 2 seconds and at the last rung, that function timer delay will generate the real output actuator solenoid valve 10.03.

After the process of making the ladder diagram is complete it can be to the next step is running process. But before doing the running process, ladder diagrams that have been made in the compile first to find out whether the ladder is made to have errors and warnings or not. If there is an error or warning then there is an error when creating a ladder diagram. Figure 4.22 show the compiling process.

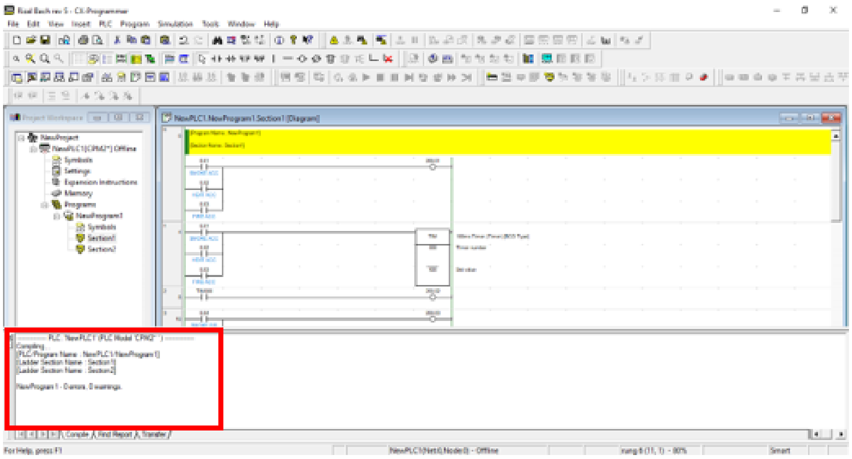


Figure 4. 30 Compiling Process

If the compiling process runs smoothly and there is no error or warning, then the ladder diagram is ready to be simulated. To simulate the CX Programmer by pressing "work online simulator" on the toolbar. But not all types of PLC can be done online simulator work, so if you want to do the simulation before transferred then the type of PLC must be replaced with PLC available for work online simulator.

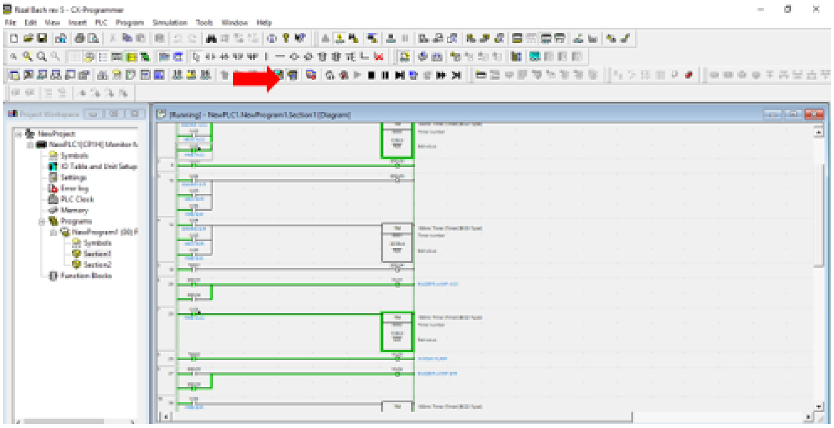


Figure 4. 31 Work Online Simulation

In Omron PLC there are 4 modes in the settings in CX Programmer that is program mode, debug mode, monitor mode and run mode. Each mode has its own function. Program mode is used when in the process of making a ladder diagram. to transfer the ladder diagram to the PLC must be in program mode. When in this mode PLC can not operate. After successful ladder diagram transfer process the PLC must be converted into run mode in order to operate.

4.3.3. HMI (Human Machine Interface)

HMI (Human Machine Interface) is an interface between human with machine. HMI is also a user interface and control system for manufacturing. Omron PLC has software to make the program not only for the ladder diagram but software to make HMI (Human Machine Interface). CX designer must be connected with the CX programmer for running the system. In this software so many icon for each equipment like pipe, pump, valve, tank etc. On CX Programmer usually use Bitlamp and Push Button. From the scenario that made on CX programmer can visuallization. The use of CX Designer requires a ladder diagram from CX Programmer, so if the ladder diagram created in CX Programmer is correct then just use the same address as CX Programmer.

Figure 4. 32 CX Designer

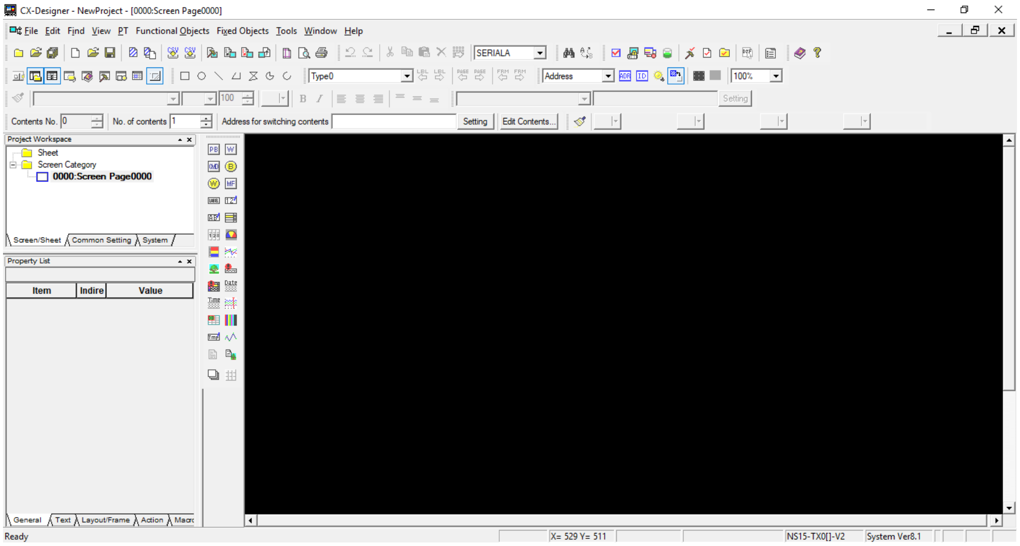


Figure 4. 33 User Interface of CX Designer

4.3.3.1. Designing of HMI

On CX Programmer so many function that can made for human machine interface for a system. Bit lamp, push button and command button are function that often used. This design made for easier people to understand the system that made.

Figure 4. 34 Push button, Command button, and bitlamp on toolbar.

Push button is input on PLC. In real equipment, push button can replaced by witch, push button level sensor and so on. In CX Programmer, there are 2 type of push button push button and switch button. Push button has ability for momentary and switch button has ability for alternate. For opsional setting by double click on the icon that has made.

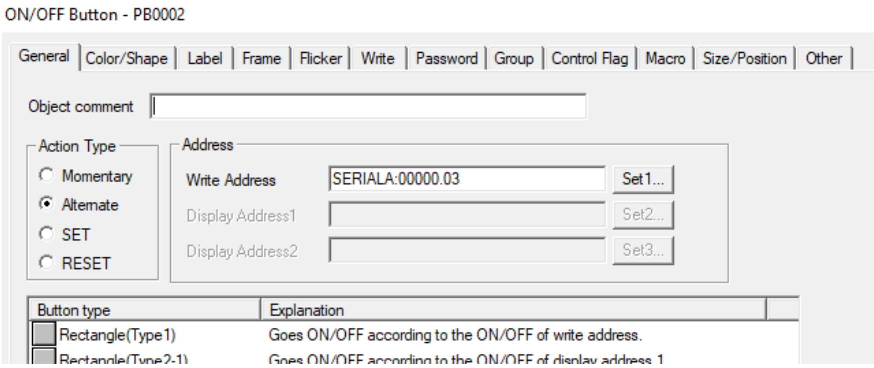


Figure 4. 35 Optional setting for push button and switch button

Bit lamp is output on PLC. In real equipment, bit lamp can replaced by actuators like pump, heater, buzzer and so on. Condition on/off bit lamp depends on ladder diagram on CX Programmer. Choosing of bitlamp based on ouput on tab color/shape. On **figure 4.36** show to setting the bitlamp shape.

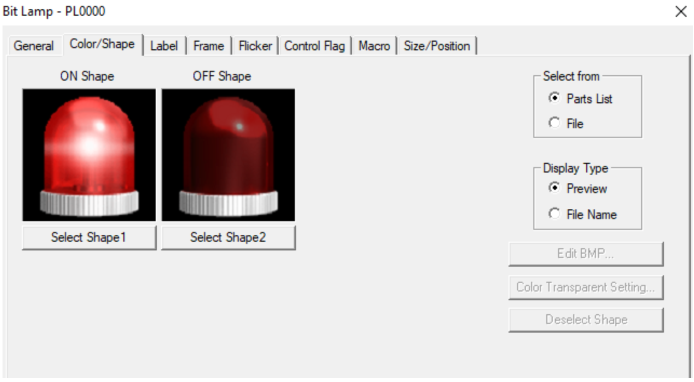


Figure 4. 36 Optional setting address and shape

Every address on bitlamp and push button in CX Designer must be the same with address with ladder diagram on CX Programmer. After designing the HMI and addressing done CX Designer and CX Programmer must be synchronized. **Figure 4.37** and **figure 4.38** show the simulation in CX Designer based on ladder diagram in CX Programmer.

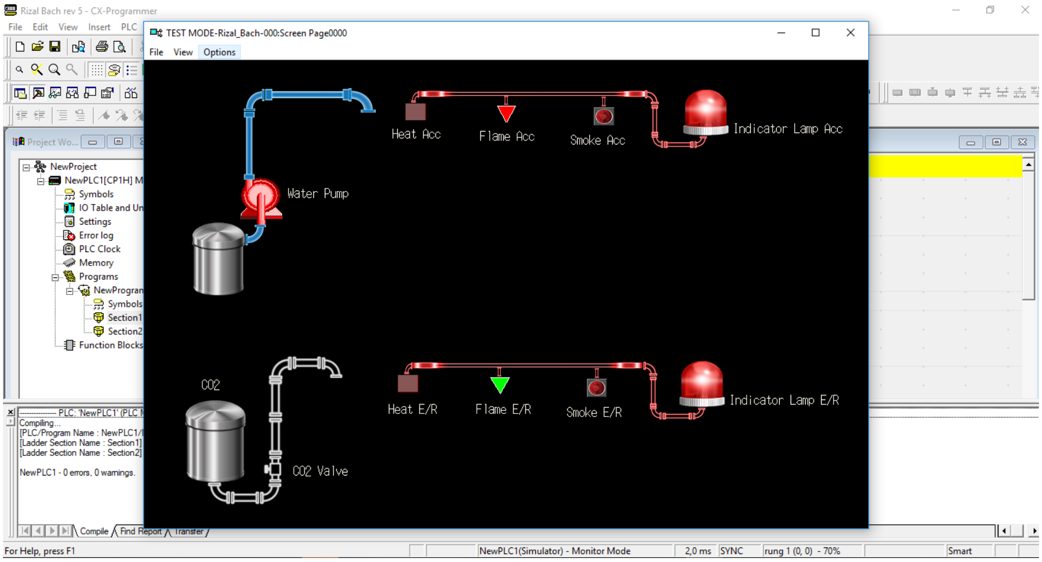


Figure 4. 37 Simulation on 2nd scenario

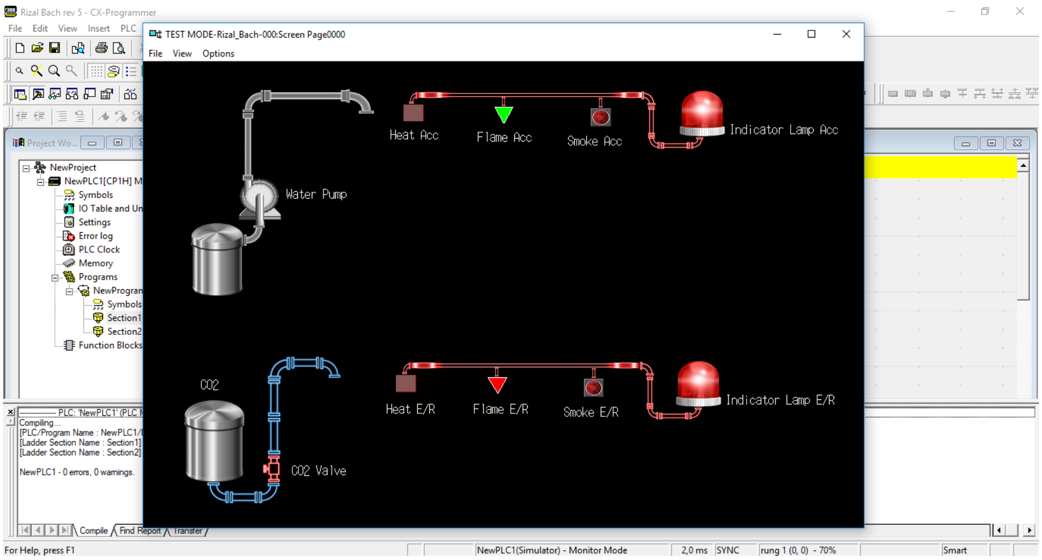


Figure 4. 38 Simulation on 5th scenario

4.4 Result and Discussion

From the 6 scenarios that have been planned, the model is capable of running all the scenarios. The model is able to provide a dangerous warning, turn on the pump and open the valve to extinguish the fire. However, the response speed of each scenario is different due to several factors such as fluid flow, volume of fire and so on.

First scenario can done in accordance with the design of ladder diagrams on CX Programmer. The author conduct 5 times of trial by heating the thermocouple from the initial temperature of 27ºC (room temperature) up to 50ºC and the hazard warning indicated by the rotary lamp that was loght on in the accomodation room and the engine room. Table 4.2 show the respons time for 1st scenario.

Table 4. 2 Time Respons of 1st Scenario

Trial	Time (seconds)
1st	27,7
2nd	34,7
3rd	26,6
4th	28
5th	25,2

From table 4.2 the avergae time respons of 1st scneario start from thermocouple heated until temperature reach $50^{O}C$ and rotary lamp on is 28,44 seconds. In each trial obtained different data because the author uses a solder to heat the thermocouple so that the heat detected by the sensor is uneven and next trial begin with the thermocouple at a state not completely in the room temperature

Second scenario can done in accordance with the design of ladder diagrams on CX Programmer. The author conduct 5 times of trial by make the fire with candle and put into accomodation room until hazard warning indicated by rotary lamp, water pump is on and fire can be extinguished. Table 4.3 show the time respons for 2nd scenario.

Table 4. 3 Time Respons of 2nd Scenario

Trial	Time (seconds)
1st	2,25
2nd	2,44
3rd	1,85
4th	2,16
5th	2,28

From table 4.3 the average time respons of 2nd scenario start from the fire is on until rotary lamp is on and fire can be extinguished is 2,19 seconds. In each trial obtained different data because condition of fire is fluctuate so the spray of water can not extinguish in one spray.

Third scenario can done in accordance with the design of ladder diagrams on CX Programmer. The author conduct 5 times of trial by make smoke on the accomodation room until hazard warning indicated by the rotary lamp that was light on in the accomodation room and the engine room. Table 4.4 show the time respons of 3rd scenario.

Table 4. 4 Time Respons of 3rd Scenario

Trial	Time (seconds)
1st	11,1
2nd	10,45
3rd	13,98
4th	14,02
5th	11

From table 4.4 the average time respons of 3rd scenario start from author make smoke in the accomodation room until rotary lamps is on the accomodation room and engine room is 12,11 seconds. In each trial obtained different data because condition of smoke is fluctuate so the smoke detector cant detect the smoke immediately.

Fourth scenario can done in the accordance with the design of ladder diagrams on CX Programmer. Same with the first scenario, author conduct 5 timesof trial by heating the thermocouple from the initial temperature of 27^{o}C (room temperature) up to 70^{o}C and the hazard warning indicated by the rotary lamp that was light on in the accomodation room and the engine room. Table 4.5 show the respons time for 4th scenario.

Table 4. 5 Time Respons of 3rd Scenario

Trial	Time (seconds)
1st	31,9
2nd	26,99
3rd	29,07
4th	26
5th	28,45

From table 4.5 the avergae time respons of 1st scneario start from thermocouple heated until temperature reach 70^{O}C and rotary lamp on is 28,48 seconds. In each trial obtained different data because the author uses a solder to heat the thermocouple so that the heat detected by the sensor is uneven and next trial begin with the thermocouple at a state not completely in the room temperature.

Fifth scenario can done in accordance with the design of ladder diagrams on CX Programmer. Almost same with second scenario, the author conduct 5 times of trial by make the fire with candle and put into engine room until hazard warning indicated by rotary lamp, solenoid valve is open and fire can be extinguished by CO2. Table 4.6 show the time respons for 5th scenario.

Table 4. 6 Time Respons of 5th Scenario

Trial	Time (seconds)
1st	1,96
2nd	1,9
3rd	1,85
4th	1,85
5th	2,28

From table 4.3 the average time respons of 2nd scenario start from the fire is on until rotary lamp is on and fire can be extinguished by CO2 gas is 1,9 seconds. In this trial fire can extinguished very fast because flow of CO2 is very high so the fire can handled easier than use water.

Last scenario can done in accordance with the design of ladder diagrams on CX Programmer. Almost same with 3rd scenario, the author conduct 5 times of trial by make smoke on the engine room until hazard warning indicated by the rotary lamp that was light on in the engine room and the accomodation room. Table 4.7 show the time respons of 3rd scenario.

Table 4. 7 Time Respons of 6th Scenario

Trial	Time (seconds)
1st	14,6
2nd	17,1
3rd	12,38
4th	11,40
5th	11,70

From table 4.7 the average time respons of 6th scenario start from author make smoke in the engine room until rotary lamps is on the engine room and accomodation room is 13,44 seconds. In each trial obtained different data because condition of smoke is fluctuate so the smoke detector cant detect the smoke immediately.

CHAPTER V
CONCLUSION

5.1 Conclusion

Based on the results of developing model and running that has been done, it can be concluded that :

1. Already made the design of automatic ship firefighting system. The system can work properly as program in ladder diagram by using CX Programmer as software to design the ladder diagram, PLC Omron CPM2A as controller, smoke detector, flame detector and heat detector as input also rotary lamp, pump and solenoid valve as output. All scenario which is planned can work properly and the system need 2,1 seconds for handle the fire by spraying water and 1,9 seconds by CO2 gas.

5.2 Sugestion

1. Further researches should be use more complex scenario for automatic firefighting system.
2. Developing further model with larger scale to know the reliability of each equipments.
3. Combine with the automatic escape rute on the ship.

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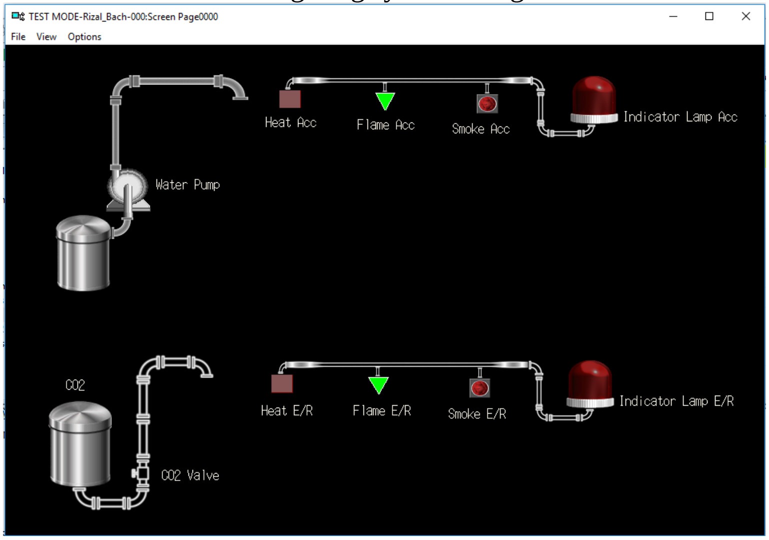
ATTACHMENT

- Attachment 1
  Model of automatic firefighting system using PLC

- Attachment 2
  HMI for automatic firefighting system using PLC



- Attachment 3
  Spesification of CPU unit Omron CPM2A

2-1 Specifications

2-1-1 General Specifications of CPU Units

Item		CPU Units with 20 I/O points	CPU Units with 30 I/O points	CPU Units with 40 I/O points	CPU Units with 60 I/O points
Supply voltage	AC power	100 to 240 VAC, 50/60 Hz			
	DC power	24 VDC			
Operating voltage range	AC power	85 to 264 VAC			
	DC power	20.4 to 26.4 VDC			
Power consumption	AC power	60 VA max.			
	DC power	20 W max.			
Inrush current	AC power	60 A max.			
	DC power	20 A max.			
External power supply (AC power supplies only)	Supply voltage	24 VDC			
	Output capacity	300 mA: Use for input devices only. Cannot be used to drive outputs. (When the external power supply provides an overcurrent or is short circuited, the external power supply voltage will drop and PC operation will stop.)			
Insulation resistance		20 MΩ min. (at 500 VDC) between the external AC terminals and protective earth terminals			
Dielectric strength		2,300 VAC 50/60 Hz for 1 min between the external AC and protective earth terminals, leakage current: 10 mA max.			
Noise immunity		Conforms to IEC6100-4-4; 2 kV (power lines)			
Vibration resistance		10 to 57 Hz, 0.075-mm amplitude, 57 to 150 Hz, acceleration: 9.8 m/s^2 in X, Y, and Z directions for 80 minutes each (Time coefficient; 8 minutes × coefficient factor 10 = total time 80 minutes)			
Shock resistance		147 m/s^2 three times each in X, Y, and Z directions			
Ambient temperature		Operating: 0° to 55°C Storage: −20° to 75°C			
Humidity		10% to 90% (with no condensation)			
Atmosphere		Must be free from corrosive gas			
Terminal screw size		M3			
Power interrupt time		AC power supply: 10 ms min. DC power supply: 2 ms min. (A power interruption occurs if power falls below 85% of the rated voltage for longer than the power interrupt time.)			
CPU Unit weight	AC power	650 g max.	700 g max.	800 g max.	1,000 g max.
	DC power	550 g max.	600 g max.	700 g max.	900 g max.
Expansion I/O Unit weight		Units with 20 I/O points: 300 g max. Units with 8 output points: 250 g max. Units with 8 input points: 200 g max.			
Expansion Unit weight		Analog I/O Units: 150 g max. Temperature Sensor Units: 250 g max. CompoBus/S I/O Link Units: 200 g max.			

- Attachment 4

Spesification of CPU unit Omron CPM2A

2-1-2 Characteristics

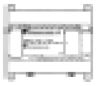
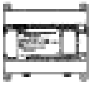
Item		Specification			
Control method		Stored program method			
I/O control method		Cyclic scan with direct output (Immediate refreshing can be performed with IORF(97).)			
Programming language		Ladder diagram			
Instruction length		1 step per instruction, 1 to 5 words per instruction			
Instructions		Basic instructions: 14 Special instructions: 105 instructions, 185 variations			
Execution time		Basic instructions: 0.64 µs (LD instruction) Special instructions: 7.8 µs (MOV instruction)			
Program capacity		4,096 words			
Max. I/O capacity	CPU Unit only	20 points	30 points	40 points	60 points
	With Expansion I/O Units	80 points max.	90 points max.	100 points max.	120 points max.
Input bits		IR 00000 to IR 00915 (Words not used for input bits can be used for work bits.)			
Output bits		IR 01000 to IR 01915 (Words not used for output bits can be used for work bits.)			
Work bits		928 bits: IR 02000 to IR 04915 and IR 20000 to IR 22715			
Special bits (SR area)		448 bits: SR 22800 to SR 25515			
Temporary bits (TR area)		8 bits (TR0 to TR7)			
Holding bits (HR area)		320 bits: HR 0000 to HR 1915 (Words HR 00 to HR 19)			
Auxiliary bits (AR area)		384 bits: AR 0000 to AR 2315 (Words AR 00 to AR 23)			
Link bits (LR area)		256 bits: LR 0000 to LR 1515 (Words LR 00 to LR 15)			
Timers/Counters		256 timers/counters (TIM/CNT 000 to TIM/CNT 255) 1-ms timers: TMHH(—) 10-ms timers: TIMH(15) 100-ms timers: TIM 1-s/10-s timers: TIML(—) Decrementing counters: CNT Reversible counters: CNTR(12)			
Data memory		Read/Write: 2,048 words (DM 0000 to DM 2047)* Read-only: 456 words (DM 6144 to DM 6599) PC Setup: 56 words (DM 6600 to DM 6655) *The Error Log is contained in DM 2000 to DM 2021.			
Interrupt processing		External interrupts: 4 (Shared by the external interrupt inputs (counter mode) and the quick-response inputs.)			
Interval timer interrupts		1 (Scheduled Interrupt Mode or Single Interrupt Mode)			
High-speed counter		One high-speed counter: 20 kHz single-phase or 5 kHz two-phase (linear count method) Counter interrupt: 1 (set value comparison or set-value range comparison)			
Interrupt inputs (Counter mode)		Four inputs (Shared by the external interrupt inputs (counter mode) and the quick-response inputs.) Counter interrupts: 4 (Shared by the external interrupt inputs and quick-response inputs.)			
Pulse output		Two points with no acceleration/deceleration, 10 Hz to 10 kHz each, and no direction control. One point with trapezoid acceleration/deceleration, 10 Hz to 10 kHz, and direction control. Two points with variable duty-ratio outputs. (Pulse outputs can be used with transistor outputs only, they cannot be used with relay outputs.)			
Synchronized pulse control		One point: A pulse output can be created by combining the high-speed counter with pulse outputs and multiplying the frequency of the input pulses from the high-speed counter by a fixed factor. (This output is possible with transistor outputs only, it cannot be used with relay outputs.)			
Quick-response inputs		Four points (Min. input pulse width: 50 µs max.)			
Analog controls		2 controls, setting range: 0 to 200			

- Attachment 5

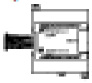
Appendix of CPM2A

Appendix A
Standard Models

CPU Units

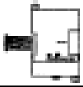
Description	Input points	Output points	Power supply	Model number		
				Relay outputs	Transistor outputs	
					Sinking	Sourcing
CPU Units with 20 I/O points 	12 points	8 points	AC	CPM2A-20CDR-A	—	—
			DC	CPM2A-20CDR-D	CPM2A-20CDT-D	CPM2A-20CDT1-D
CPU Units with 30 I/O points 	18 points	12 points	AC	CPM2A-30CDR-A	—	—
			DC	CPM2A-30CDR-D	CPM2A-30CDT-D	CPM2A-30CDT1-D
CPU Units with 40 I/O points 	24 points	16 points	AC	CPM2A-40CDR-A	—	—
			DC	CPM2A-40CDR-D	CPM2A-40CDT-D	CPM2A-40CDT1-D
CPU Units with 60 I/O points 	36 points	24 points	AC	CPM2A-60CDR-A	—	—
			DC	CPM2A-60CDR-D	CPM2A-60CDT-D	CPM2A-60CDT1-D

Expansion I/O Units

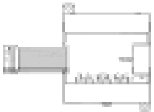
Description	Input points	Output points	Model number		
			Relay output	Transistor output	
				Sinking	Sourcing
Expansion I/O Unit with 20 I/O points 	12 points	8 points	CPM1A-20EDR1	CPM1A-20EDT	CPM1A-20EDT1
Expansion I/O Unit with 8 input points 	8 points	—	CPM1A-8ED (no outputs)		
Expansion I/O Unit with 8 output points 	—	8 points	CPM1A-8ER	CPM1A-8ET	CPM1A-8ET1

Expansion Units

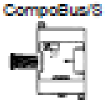
Analog I/O Unit

Description	Specifications	Model number
Analog I/O Unit 	2 analog inputs and 1 analog output	CPM1A-MAD01

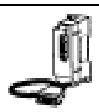
Temperature Sensor Units

Description	Specifications	Model number
Temperature Sensor Unit 	2 thermocouple inputs: K, J	CPM1A-TS001
	4 thermocouple inputs: K, J	CPM1A-TS002
	2 platinum resistance thermometer inputs: Pt100 (100 Ω), JPt100 (100 Ω)	CPM1A-TS101
	4 platinum resistance thermometer inputs: Pt100 (100 Ω), JPt100 (100 Ω)	CPM1A-TS102

CompoBus/S I/O Link Unit

Description	Specifications	Model number
CompoBus/S I/O Link Unit 	Operates as a CompoBus/S Slave and provides 8 inputs and 8 outputs to the CPM1A or CPM2A PC.	CPM1A-SRT21

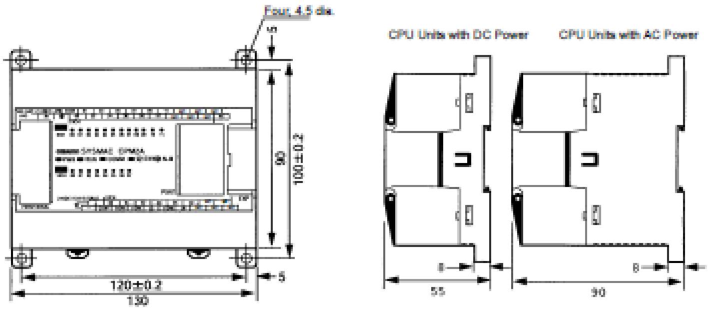
Adapters and Connecting Cables (1:1 Connection)

CPM2A port	Name	Appearance	Model number	Comments	Cable length
Peripheral	RS-232C Adapter		CQM1-CIF01	For a 25-pin computer serial port	3.3 m
			CQM1-CIF02	For a 9-pin computer serial port	3.3 m
			CPM1-CIF01 (+ XW2Z-□00S)	For a 25-pin computer serial port	3.3 m (+□ m)
RS-232C	RS-232C Cable		XW2Z-200S	For a 25-pin computer serial port	2 m
			XW2Z-500S		5 m
			XW2Z-200S-V	For a 9-pin computer serial port	2 m
			XW2Z-500S-V		5 m

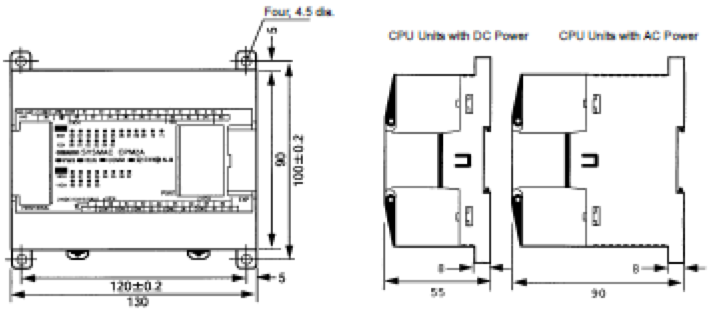
Appendix B
Dimensions

All dimensions are in millimeters.

CPM2A-20CD□-□ CPU Units



CPM2A-30CD□-□ CPU Units



AUTHOR BIOGRAPHY

Author's name is Ahmad Rizal Saputra, was born on 29th April 1996 in Sidomulyo. His father's name is Fatkur and his mother's name is Tanti Prihartini. The author has completed the formal education in TK Kartika, SD Negeri 1 Tanggul Angin, SMP Negeri 6 Metro, and SMA Negeri 1 Metro. The author continued his study for bachelor degree in Double Degree Programme of Marine Engineering (DDME) of Institut Teknologi Sepuluh Nopember (ITS) and Hochschule Wismar, with student registration number is 04211441000007. During his study program, besides the formal academic activities the author follow several non academic activites, namely committee of 32nd Marine Engineering as equipment, Marine Icon 2015 as Pop-Pop Boat Race, Marine Icon 2016 as Eco Solar Boat, and Marine Icon 2017 as Eco Solar Boat. Besides being a committee, author active in Himasiskal FTK-ITS as staff Marine Technology and Innovation Club (METIC) 2015 and Head of METIC Himasiskal FTK-ITS 2016. The author also as participant of Deconbotion Undip 2015 and 2017. During his study program, the author took an area of expertise in Marine Electrical and Automation System (MEAS) Laboratory. The author has done the first on the job training in PT. Yasa Wahana Tirta Samudera, Semarang and the second on the job training in Marine Region IV, Pertamina RU IV, Cilacap.

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