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PLC Controlled Automatic Cooling System of Water-Cooled Compressor

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ABSTRACT: *Water-cooled compressors are well known for providing reliable starting air for marine diesel on small, medium-sized and large ships and engine based power station. This type of compressors is the best choice if the engine room temperature is very high. The water for the cooling system of these compressors are supplied by centrifugal pumps and has radiator system for cooling the hot water that comes out from the compressor. Air production could be hampered either by operators wrong manual operation of centrifugal pumps or heat exchanger system which eventually affect engine operation also. The aim of this paper is to describe the methods of the PLC controlled system to maximize the process efficiency, avoiding the operator alienation and keeps it safe through automated system with PLC logic.*

Keywords– *PLC, Temperature Controller, Level controller, Pressure switch, Buzzer.*

I. INTRODUCTION

Today, programmable logic controllers (PLCs) are a fundamental component of automated systems. With significant advantages like easy handling and robustness, the PLCs continue to provide success in the industrial operations[1]. In this system, I have applied a PLC-based controlling technique to operate the pumps and heat exchanger. There are two centrifugal pumps driven by the A.C. Induction Motors. Out of two pumps, one pump supplies water to the compressor (Figure-1.1) while the other pump is kept as standby. In the case of failure of running pump, the standby one should be started. Sometimes it is not started manually if an operator is not present over there and as a result, the compressor trips for low cooling water pressure. Moreover, if the fan of the air-cooled heat exchanger is not run accordingly with water temperature, again the compressor also be tripped due to high coolant temperature. So an automation project is essential to design for smooth operation of pumps and heat exchanger. The paper is divided into several sections where the first phase of the paper explains the description of the product. The second phase then gives the functional description of the Ladder Logic.

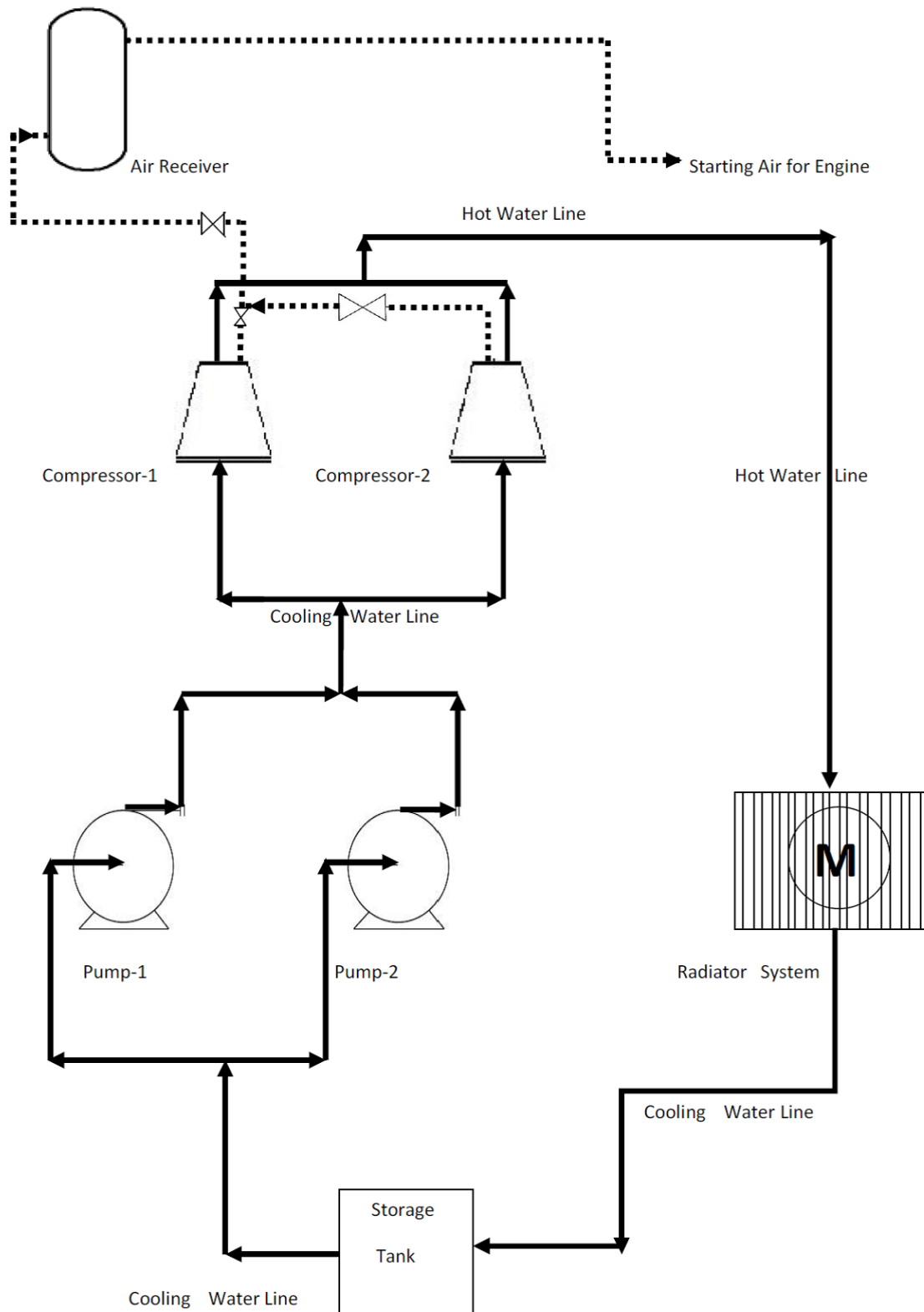


Figure 1.1: Single line diagram of cooling system for Water-cooled piston compressor

II. DESCRIPTION OF DEVICES

It is a PLC based on automation, which consists of various components those are connected to PLC's inputs and outputs.

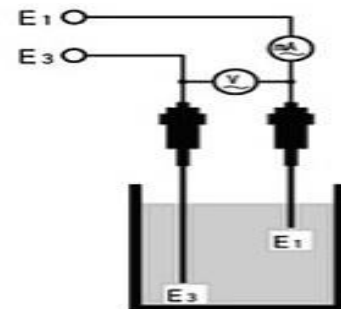
Temperature controller

Temperature controller often called a PID controller is an instrument used to control temperature. The temperature controller takes an input from a temperature sensor and has an output that is connected to PLC input. To accurately control process temperature without extensive operator involvement, a temperature control system relies upon a controller, which accepts a temperature sensor such as a thermocouple or RTD as input. It compares the actual temperature to the desired control temperature, or set point, and provides an output to PLC.



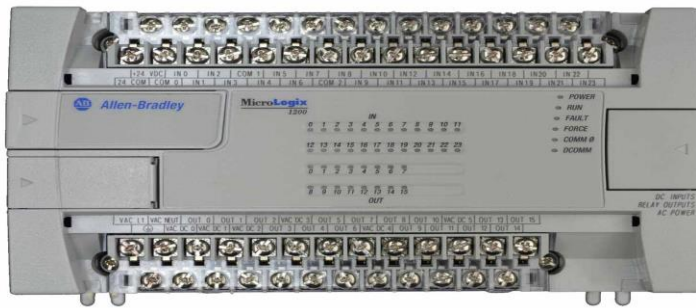
Float less Level Controller

Float less Level Controller uses electrodes to electrically detect the liquid level. The following figures illustrate this simple operating principle. When electrode E1 is not in contact with the conductive liquid, the electrical circuit is open, and no current flows between electrodes E1 and E3. Consequently, relay does not operate. However, when liquid is supplied to the tank, so that the liquid contacts or immerses E1, the circuit closes. Relay operates, and the PLC input port which is connected to the relay contacts gets signal.[4]



A programmable logic controller (PLC)

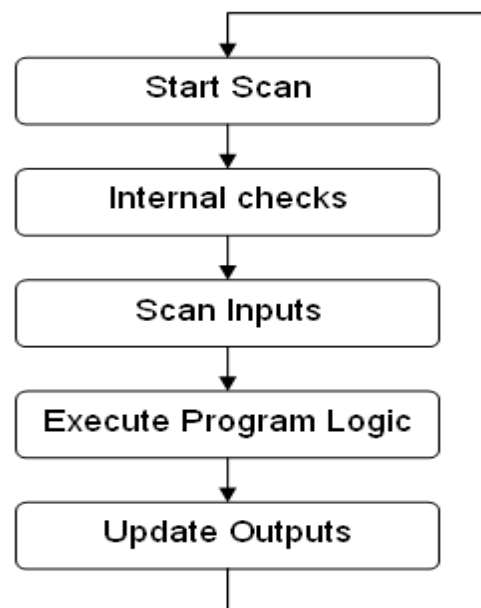
PLC is an industrial solid-state computer that monitors inputs and outputs, and makes logic-based decisions for automated processes or machines. The PLC receives information from connected sensors or input devices, processes the data, and triggers outputs based on pre-programmed parameters. Depending on the inputs and outputs, a PLC can monitor and record



run-time data such as machine productivity or operating temperature, automatically start and stop processes, generate alarms if a machine malfunctions, and more. Programmable Logic Controllers are a flexible and robust control solution, adaptable to almost any application.

The brain of the whole PLC is the CPU module. This module typically lives in the slot beside the power supply. Manufacturers offer different types of CPUs based on the complexity needed for the system. The CPU consists of a microprocessor, memory chip and other integrated circuits to control logic, monitoring and communications. The CPU has different operating modes. In programming mode it accepts the downloaded logic from a PC. The CPU is then placed in run mode so that it can execute the program and operate the process. Since a PLC is a dedicated controller it will only process this one program over and over again. One cycle through the program is called a scan time and involves reading the inputs from the other modules, executing the logic based on these inputs and then updated the outputs accordingly. The scan time happens very quickly (in the range of 1/1000th of a second). The memory in the CPU stores the program while also holding the status of the I/O and providing a means to store values.

CPU Operating Cycle



Pressure Switch

A pressure switch turns an electric circuit on or off at a preset pressure. This pressure is referred to as the set point of the switch. A bourdon tube, a diaphragm, or a bellows can actuate the switch. The contacts in a pressure switch may be normally open or normally closed if the pressure is below the set point. The contacts in a normally open (N.O) switch remain open until the pressure increases above the set point. Then the sensing element makes the contact snap to the closed position. The contacts open again when the pressure decreases below the set point. The contacts in a normally closed (N.C) switch remain closed until the pressure increases above the set point. Then the contact snap open and remain open until the pressure decreases below the set point position. Most pressure switches contains two sets of contacts. One normally open and the other normally closed. Thus the switch will work regardless of which kind of contact is needed in a particular installation. PLC takes signal from this contacts.



Buzzer

The buzzer consists of an outside case with two pins to attach it to power and ground. Inside is a piezo element, which consists of a central ceramic disc surrounded by a metal (often bronze) vibration disc. When current is applied to the buzzer it causes the ceramic disk to contract or expand. Changing the This then causes the surrounding disc to vibrate. That's the sound that you hear. By changing the frequency of the buzzer, the speed of the vibrations changes, which changes the pitch of the resulting sound.



III. SELECTION OF PLC

Selection of a PLC is usually based upon the required inputs, outputs and functions of the controller. The first decision is the type of controller; rack, mini, micro, or software based. This decision will depend upon the basic criteria listed below.

- Number of logical inputs and outputs.
- Memory - Often 1K and up. Need is dictated by size of ladder logic program. A ladder element will take only a few bytes, and will be specified in manufacturers documentation.
- Number of special I/O modules - When doing some exotic applications, a large number of special add-on cards may be required.

- Scan Time - Big programs or faster processes will require shorter scan times. And, the shorter the scan time, the higher the cost. Typical values for this are microsecond per simple ladder instruction
- Communications - Serial and networked connections allow the PLC to be programmed and talk to other PLCs. The needs are determined by the application.
- Software - Availability of programming software and other tools determines the programming and debugging ease.

By considering above factors Rockwell Micrologix PLC has been selected for the project.

IV. LADDER LOGIC

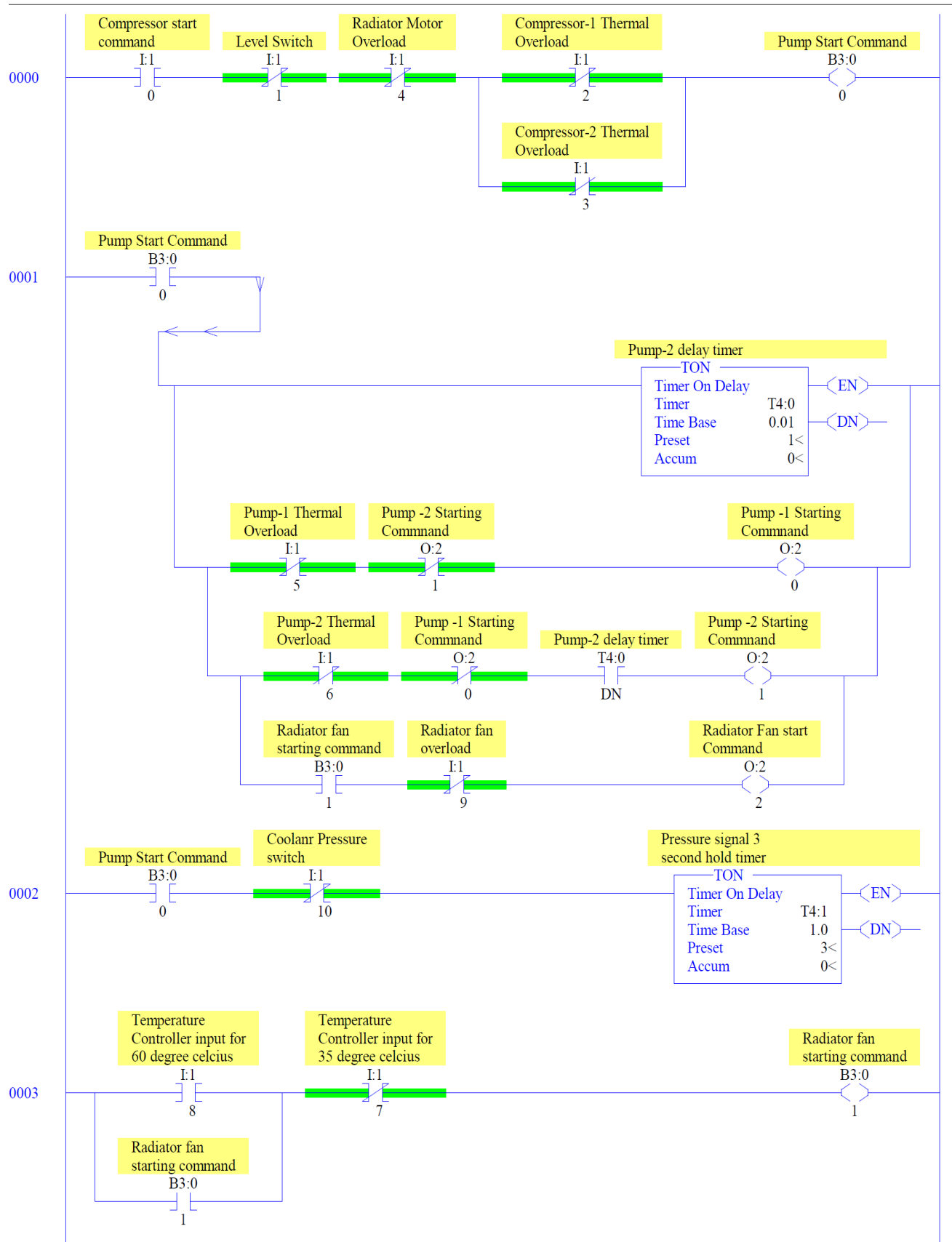
Ladder logic is a programming language that creates and represents a program through ladder diagrams that are based on circuit diagrams. It is mainly used in developing programs or software for programmable logic controllers (PLCs), which are used in industrial applications. The language evolved from originally being a method for documenting the design and construction of relay racks used in manufacturing and process control, with each relay rack represented by a symbol on the ladder diagram that has connections to devices below them that look like vertical rails. The relay symbols themselves look like rungs in a ladder.[3]

Ladder logic is described as a rule-based language rather than a procedural or imperative one. Each "rung" in the ladder represents a rule, so when implemented to relays and various electromechanical devices, these rules execute simultaneously and immediately. But if the program is applied to PLCs, the rules are executed sequentially through software and in a continuous loop. By executing the loop quickly enough, the effect still seems like a simultaneous and immediate execution within the required time tolerance. The capabilities of the PLC being used have to be considered during programming as the electromechanical nature of the devices connected to it might not be able to keep up with the instructions, and it may seem that some rules are being skipped when the devices really just cannot keep up. Ladder logic is widely used in industrial settings for programming PLCs where sequential control of manufacturing processes and operations is required. The programming language is quite useful for programming simple yet critical systems or for reworking old hard-wired systems into newer programmable ones. The idea behind ladder logic is that even personnel without programming backgrounds can quickly program since it makes use of conventional and familiar engineering symbols for programming. But this advantage is quickly negated since manufacturers of PLCs often also provide ladder logic programming systems with their products, which sometimes do not use the same symbols and conventions as those made for other models of PLCs from other manufacturers; in fact, the programming system is usually meant only for specific models, so the programs cannot be ported easily to other PLC models or must be outright rewritten.

In this automatic controlling system PLC requires the cooling water pressure signal, temperature controller signals, driven motor (both compressors and pumps) thermal overload status, compressor running status, buzzer isolation command. Moreover, a signal from the reserve tank water level is necessary to ensure that pump never runs without sufficient water level. That's why twelve digital inputs are required for the PLC. For controlling the pumps and heat exchanger system five outputs (Fig-1.2) are needed from the PLC among those two for the pump driving, one for the buzzer signal, another for driving the fan of the heat exchanger and one for compressor trip. The detail ladder logic diagram of the PLC is as follows:

PLC CONTROLLED AUTOMATIC COOLING SYSTEM OF WATER-COOLED COMPRESSOR

LAD 2 - --- Total Rungs in File = 7



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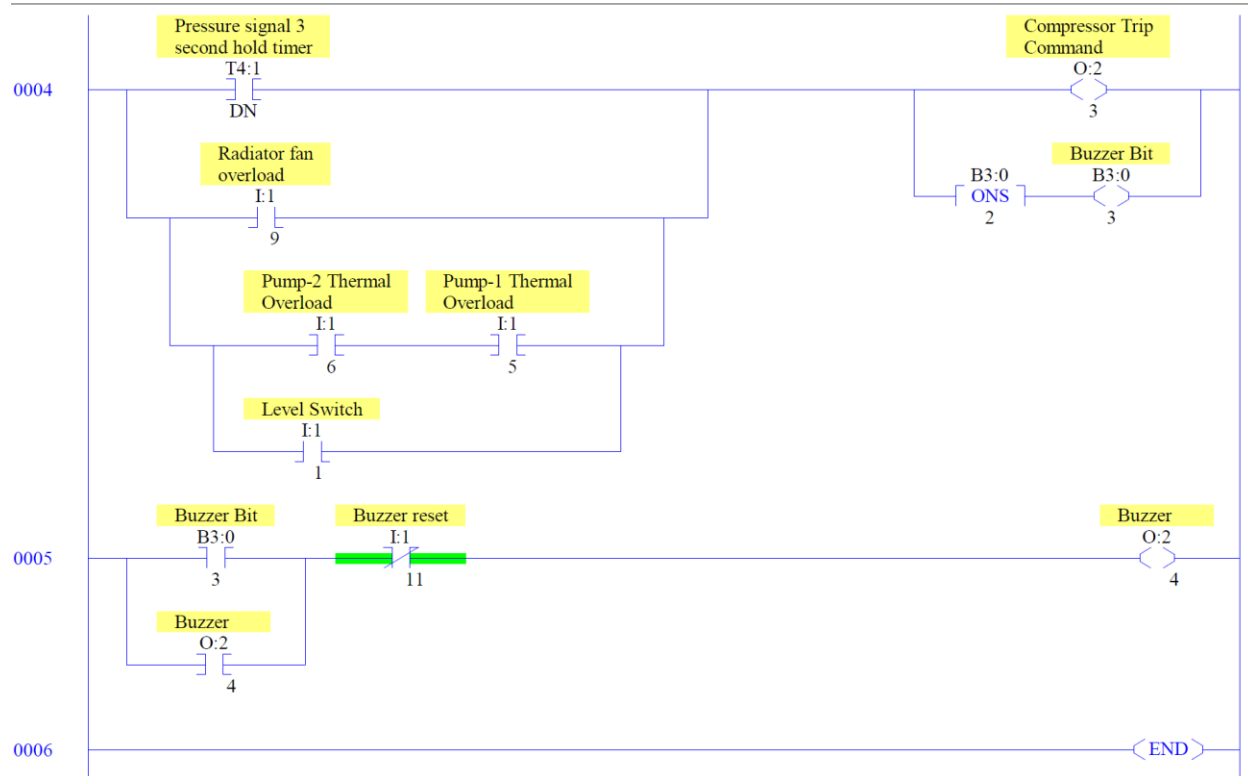


Figure 1.2: PLC Ladder Logic Diagram.

In my design from twelve digital inputs, I have assigned Input I-1/0 for compressor starting command and Input I-1/11 for manual acknowledging of the buzzer signal. Input I-1/11 is employed to receive the signal of level switch from the storage tank, in the same way I have used Input I-1/5 & Input I-1/6 to receive the status of thermal overload of pump motor-1 & pump motor-2. Input I-1/10 is utilized to receive the signal from the cooling water pressure switch. Besides, Input I-1/8 & Input I-1/7 are employed for getting the signals of two temperature controller to control the fan automatically. Finally, Input I-1/2, Input I-1/3, Input I-1/9 are used to monitor the thermal overload status of Compressor-1, Compressor-2 and fan of the air cooled heat exchanger. In the initial state when the motor is just started it needs a few seconds to develop its full rpm, in this period pumps pressure became low from its standard level. As, in my program the circuit continuously checked the pressure of the coolant, in that period if it gets any low pressure signal then logic trips automatically the entire system. To avoid this circumstance in the starting period I have attached a time delay in the program. Moreover before starting the pump motor in my program it checks the level switch, compressor motor, radiator fan thermal overload, individual motor overload, standby status simultaneously. When it found all those status normal as well as the compressor starting command (as the system depended on compressor start/stop condition) then only it starts the system automatically. I have developed the program such a way that when one cooling pump is started the other is kept on standby mode so that If one trips then the other could go to the service. Those two pump motors are driven by two digital outputs O:2/0, O:2/1. I have assigned the digital output O:2/2 to start the radiator fan

automatically, when the water temperature reaches at 60° Celsius & stops at 35° Celsius. To drive the buzzer I have employed an output contact O:2/4 to provide alarm for low water pressure, low water level and for failure of any thermal overload. Likewise used one other digital output contacts O:2/4 for both compressors so that if the level, pressure went low or any thermal overload trips then the compressor could stop automatically to avoid unsafe operation.

V. RESULT

As the engine starting system completely depends on air supply system, that's why for improper operation when the compressor is tripped then for inadequate air pressure at times engine could not be started. It increases downtime as well as electricity production also hampers. After finishing my project those problems related to manual operation system is removed, and no extra operator does not require for manual operation, which also saves money. Besides, earlier the fan of the heat exchanger runs all over the day. After my project it runs at 60° Celsius & stops at 35° Celsius (Now running almost 14 hour in a day) which definitely saves energy as well as reduces electric bill.

Calculation Energy consumption of the heat exchanger fan

The energy E in kilowatt-hours (kWh) per day is equal to the power P in watts (W) & times number of usage hours per day t is divided by 1000 watts per kilowatt:

$$E \text{ (kWh/day)} = P \text{ (W)} \times t \text{ (h/day)} / 1000 \text{ (W/kW)}.$$

Here, P = Fan rating 8KW

$$T = (24-14) \text{ h/day} \\ = 10 \text{ h/day}$$

$$\text{So, } E \text{ (kWh/day)} = 8 \text{ KW} \times 10 \text{ h/day} / 1000 \text{ (W/kW)}. \\ = 80 \text{ KWh}$$

$$\text{Units saved in kWh per annum} = (80 \times 365) \text{ kWh} \\ = 29200 \text{ KWh}$$

$$\text{Savings in cost per annum} = (29200 \times 9.20) \text{ BDT [Per KWh price is 9.20 BDT]} \\ = 268,640 \text{ BDT/3358 USD}.$$

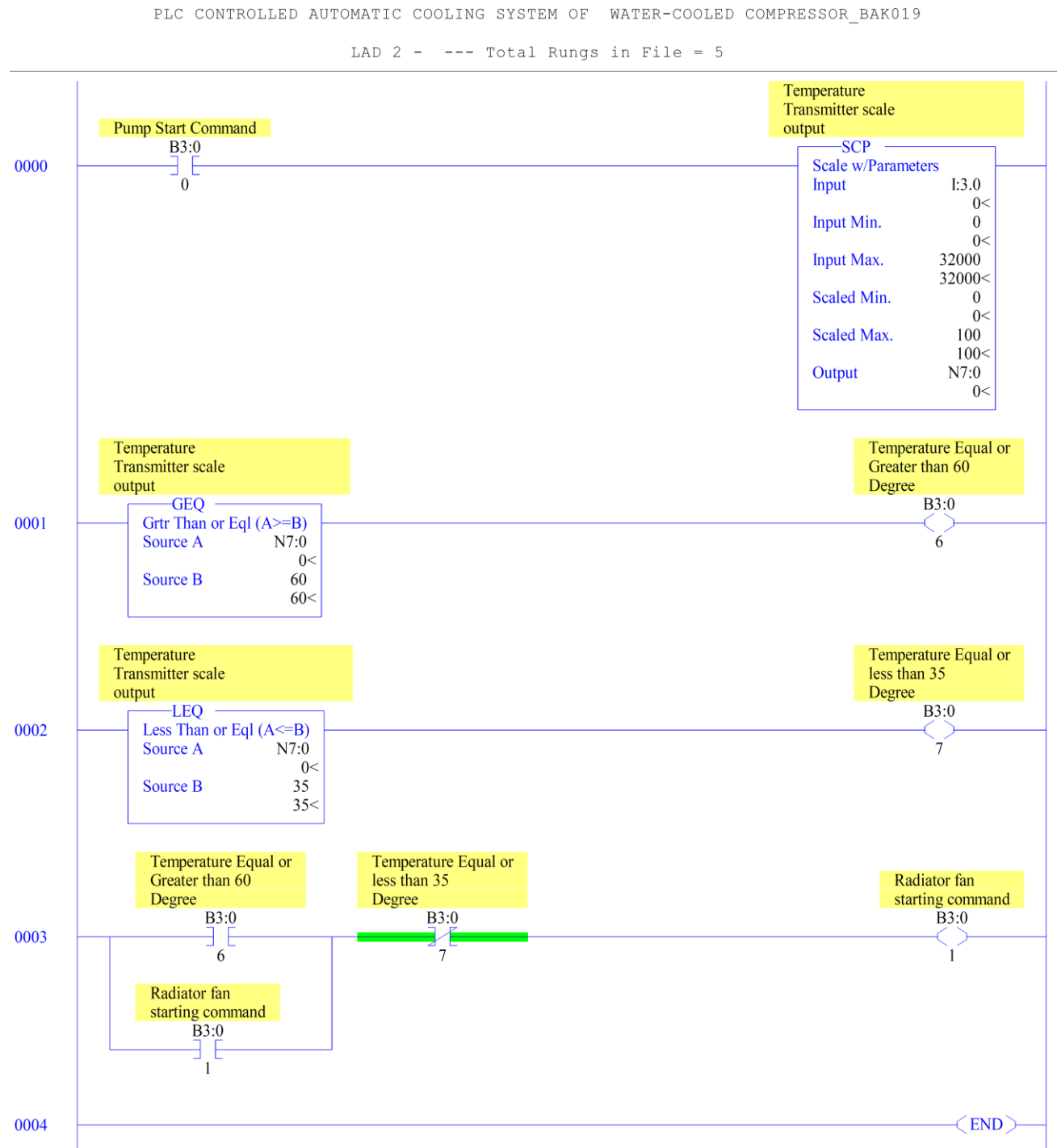
VI. LIMITATION

Motor vibration is the root of a number of serious issues that can cause irreparable damage. The oscillation of components inside electric motors – bearings, belts, gears and so forth causes of vibration are varied and typically act in tandem to exacerbate and amplify their individual effects. When first detected, these causes can usually be corrected, however, if the core issues are ignored they will grow more and more pronounced and, over time, lead to additional damage and more costly solutions. To detect the first problem, vibration monitoring sensors are required. It could be a vibration switch or a vibration transmitter to constantly monitoring the vibration level through PLC logic. If the vibration level increases and exceeds predetermined set point then the respective motor is tripped.



VII. FUTURE WORK

In this project, I have used two temperature controller and two digital input of PLC to control the radiator fan operation. Instead of those if I used a single temperature transmitter with output 4-20 mA then only one analog input is required instead of two digital input. The ladder logic diagram for temperature transmitter and radiator fan control is as follows:



VIII. CONCLUSION

Today, PLC applications has a imperative influence in process engineering. The PLC has penetrated this field because of its software and hardware for fail-safe, intrinsically safe and solutions that speak the language of the process. It controls the whole system. The cost of installation is not cheap but it can efficiently run for a long period of time [2]. It reduces the operation cost as well as energy consumption. If official studies from some years ago were to be taken in consideration, PLCs were supposed to be replaced by PC which meant that PLCs would have very little or no role at all in automating industrial systems. However, the fact is that PLC has remained popular with its market increasing worldwide because without PLCs growth in automation is not possible.

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