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PLC Used Automation in Oil Industry for Multiple Induction Motors

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Abstract

Most of the industries require continuous monitoring and inspection at frequent intervals. There are possibilities of errors at various stages due to human intervention and lack of few features of microcontrollers. Hence automation in industries using Programmable Logic Controllers came into picture. PLC is used for the internal storage of instruction for implementing functions such as logic, sequencing, timing, counting, and arithmetic control through digital or analog input and output modules and various other types of machine processes. Industrial automation is largely based on PLC-based control systems. They are used to monitor and control a plant or equipment in industries such as water and waste control, energy, oil and gas refining and transportation. Automation also increases product quality, productivity and decreases breakdown. Conventional equipments or systems are prone to errors due to involvement of humans for data collection and processing using complicated mathematical expressions. Computer integrated manufacturing, computer numerical control; robots, flexible manufacturing system, automated inspection and process control are directing the technology toward one goal, the fully automated factory of the future. Coming to Induction motors, in the conventional case due to long use of a particular induction motor in oil rig related plants more mechanical faults arise due to overheating and may lead to failure which affects production. In case of using two or more induction motors and automating the duty cycle shifting using PLC, the effectiveness of the system increases. Also in case of tripping of a particular motor, other idle motors backs up the operation thereby preventing the plant to go to standstill, hence increasing the overall plant efficiency.

Keywords: *automation, PLC, ladder logic, duty cycle shifting, tripping*

1. Introduction

In early days industrial operations were carried out manually and manpower was behind each and every movement which took place in any company. When the number of operations of a process got increased, it became difficult to handle the complexity of hard wiring resulting in increase in fault occurrence and decrease in productivity. Hence a new method to control industrial operations using relays was introduced.

Relays are of on and off type, in which the relay passes on the control in one direction for one command and in another direction for the opposite command. But using relays to automate the entire system was not feasible due to its complexity, high power consumption and difficulty in fault identification. Hence automation with a better technology became the need of the hour. Automation was made better slowly and steadily with the introduction of Programmable Logic Controllers. PLC is an electronic device with variable number of input and output ports and this characteristic enables the PLC to control and automate many operations. The efficiency of automation has also increased with the use of PLC.

PLC's are designed to withstand high temperatures, humidity, vibrations, electrical noise and power interruptions generally encountered in industrial environments. PLC's programming language is easy to understand and to learn. Now in PLC it is possible to modify a control system without changing the input and output devices but by modifying the set of instructions. Thus the PLC based system is a flexible system which can be used to control various applications which vary quite widely in their nature and complexity.

Automation is the use of control systems (such as numerical control, programmable logic control, and other industrial control systems), in concern with other applications of information technology (such as computer-aided technologies [CAD, CAM]), to control industrial

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machinery and processes, reducing the need for human intervention. In the scope of industrialization, automation is a step beyond mechanization. Whereas mechanization provided human operators with machinery to assist them with the muscular requirements of work, automation greatly reduces the need for human sensory and mental requirements as well. One of the earliest promises of automation was to allow more free time, without any threat of income reduction. Another major shift in automation is the increased demand for flexibility and convertibility in manufacturing processes. Processes and systems can also be automated to increase productivity.

Automation plays an increasingly important role in the world economy and in daily experience. Engineers strive to combine automated devices with mathematical and organizational tools to create complex systems for a rapidly expanding range of applications and human activities. Specialized hardened computers, referred to as programmable logic controllers (PLCs), are frequently used to synchronize the flow of inputs from sensors and events with the flow of outputs to actuators and events. This leads to precisely controlled actions that permit a tight control of almost any industrial process. Automation has been responsible for the shift in the world economy from industrial jobs to service jobs in the 20th and 21st centuries. Automation has various other advantages like higher productivity, superior quality of end product, efficient usage of raw materials and improved safety in working conditions. The Figure 1 represents the history of automation; this manual control forms the base of the pyramid followed by the relay and electronic logic control which had their respective disadvantages which decrease the productivity. PLC marks the evolution of automation which is peaked by the Distributed Control System.

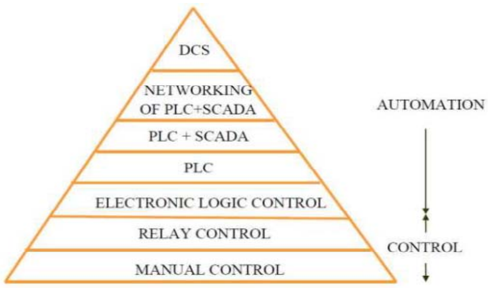

Figure 1. Hierarchy of System Control

Figure 2 represents the structure of automation. In this method, the control and automation are done by manual operations. Human errors subsequently affect quality of end product. Companies undertake project in automation for variety of good reasons. Some of the important reasons for automating are increased productivity, high cost of labour, labour shortage, safety, high cost of raw materials, improved product quality, reduced manufacture lead time, reduction in process inventory and high cost of non-automation. All of these factors act together to make production automation a feasible and attractive alternative to manual methods of manufacture. The type of automation tool opted for test automation in this project is PLC since a PLC is used to control, time and regulate a sequence. PLC is efficient and economical considering the requirements of the project.

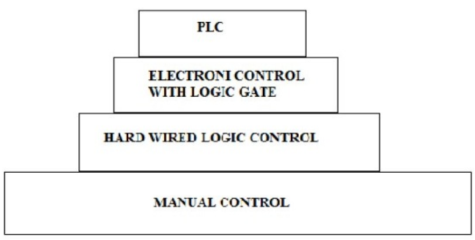

Figure 2. Structure of Automation

2. Automation of Induction Machines

Automation is the use of control systems and information technologies to reduce the need for human work in the production of goods and services. In the scope of industrialization, automation is a step beyond mechanization. Whereas mechanization provided human operators with machinery to assist them with the muscular requirements of work, automation greatly decreases the need for human sensory and mental requirements as well. Automation plays an increasingly important role in the world economy and in daily experience. Automation has had a notable impact in a wide range of industries beyond manufacturing where it began. Once telephone operators have been replaced largely by automated telephone switchboards and answering machines. Medical processes such as primary screening in electrocardiography or radiography and laboratory analysis of human genes, sera, cells, and tissues are carried out at much greater speed and accuracy by automated systems. Automated teller machines have reduced the need for bank visits to obtain cash and carry out transactions. In general, automation has been responsible for the shift in the world economy from industrial jobs to service jobs in the 20th and 21st centuries.

In oil industries crude oil is the primary resource available. From this crude oil we are processing various petroleum products like diesel, petrol, kerosene etc. through a process called Fractional Distillation. In these oil industries it is very much important to have 24*7 (non-stop operation) running motors so that crude oil can be pumped from its source and is stored in a storing tank, from where it is taken for fractional distillation. So our project is to automate this process using PLC. Here the duty cycles of motors are automatically shifted and when any motor gets tripped, then the backup motor will occupy its position.

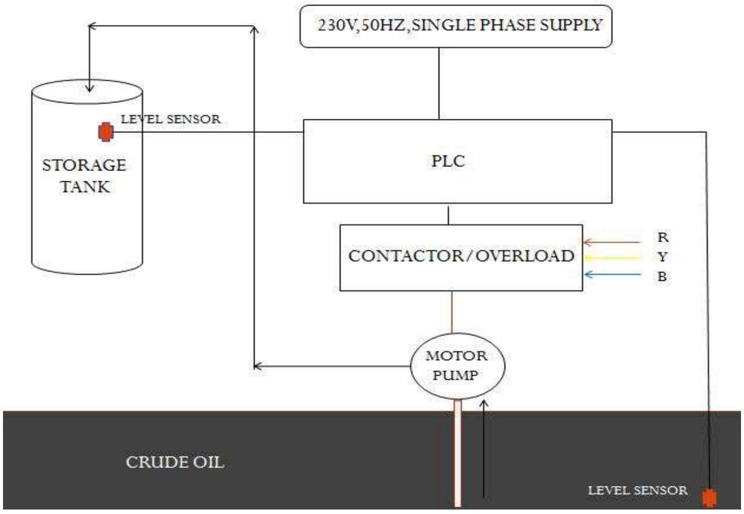

Figure 3. Block Diagram of Application in Oil Industry

As shown in Figure 3, a 230V, 50Hz, single phase AC supply is given to the PLC as a supply voltage. Also, a three phase supply is given to the motors through the contactor/overload set. Two level switches, one at the oil reserve to sense the minimum level of crude oil and one at the storage tank to sense the maximum level to avoid spillage respectively, are given as an input to the PLC. As shown in Figure 4, the PLC used here has got only 8 inputs and 4 outputs in the main body. Since, we need a total of six outputs we are inserting another input/output card to the main body to meet the requirement. In the project we are demonstrating with one motor and three incandescent bulbs due to cost constraints. A 230V, 50Hz, single phase AC supply is given to the PLC as the supply voltage and a 415V, 50 Hz, three phase supply is given to the motor through the contactor/overload set. Output.5 (Q5) and output.6 (Q6) are warning and critical indication lamps respectively.

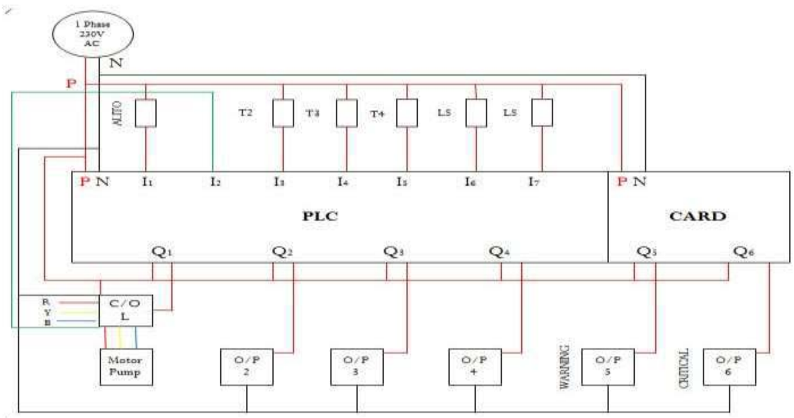

Figure 4. Circuit Diagram

The main power ON/OFF is given to the PLC as input at I1. The trip signal from the contactor/overload is given at I2. At I3, I4 and I5 manual trip signals are given. The signals from low and high level switches are given at I6 and I7 respectively. In the output side, the signal to the contactor/overload from the PLC is taken from Q1. Similarly, signals to outputs 2, output 3, output 4, output 5 and output 6 are taken from the PLC output terminals Q2, Q3, Q4, Q5 and Q6 respectively is shown in Table 1.

Table 1. Parameter details of Automation

Sl. No	Notation	Description
1.	Auto	Main power ON/OFF
2.	T_2	Trip for motor 2
3.	T_3	Trip for motor 3
4.	T_4	Trip for motor 4
5.	LS	Level switch
6.	Q_1	PLC output signal to C/OL
7.	Q_2	PLC output signal to O/P 2
8.	Q_3	PLC output signal to O/P 3
9.	Q_4	PLC output signal to O/P 4
10.	Q_5	PLC output signal to O/P 5
11.	Q_6	PLC output signal to O/P 6
12.	O/P 2	Incandescent lamp 2
13.	O/P 3	Incandescent lamp 3
14.	O/P 4	Incandescent lamp 4
15.	O/P 5	Warning lamp
16.	O/P 6	Critical state indicator lamp
17.	P	Phase
18.	N	Neutral

3. PLC Programming

The CPU contains an “Executive” program that tells the PLC how to execute the control instructions, how to communicate with other devices, other PLCs, Programming devices, I/O devices, etc. The program also tells the PLC how to perform housekeeping activities, diagnostics, etc. This program is stored in “non-volatile” memory i.e., the program will not be lost if power is removed. This program receives its input from various sources like switches and pushbuttons, sensing devices, limit switches, photoelectric sensors, proximity sensors, condition sensors, pressure switches, level switches, temperature switches, vacuum switches, float switches and encoders. The program is executed and the output is controlled in return. The various outputs are valves, motor starters, solenoids, actuators, control relays, horns & alarms, stack lights, fans, counter/totalizer, pumps and printers. PLC programs are typically written in a special application on a personal computer, and then downloaded by a direct-connection cable or over a network to the PLC. The program is stored in the PLC either in battery-backed-up

RAM or some other non-volatile flash memory. Often, a single PLC can be programmed to replace thousands of relays. The International Electro technical Commission (IEC) has formatted five different languages by which a PLC can be programmed. The five programming techniques are: Function Block Diagram (FBD), Structured Text (ST), Instruction List (IL), Ladder Diagram (LD), Sequential Function Chart (SFC).

Early PLCs did not have accompanying programming terminals that were capable of graphical representation of the logic, and so the logic was instead represented as a series of logic expressions in some version of Boolean format, similar to Boolean algebra. As programming terminals evolved, it became more common for ladder logic to be used, for the aforementioned reasons. Newer formats such as State Logic and Function Block (which is similar to the way logic is depicted when using digital integrated logic circuits) exist, but they are still not as popular as ladder logic. A primary reason for this is that PLCs solve the logic in a predictable and repeating sequence, and ladder logic allows the programmer (the person writing the logic) to see any issues with the timing of the logic sequence more easily than would be possible in other formats. An argument that aided the initial adoption of ladder logic was that a wide variety of engineers and technicians would be able to understand and use it without much additional training, because of the resemblance to familiar hardware systems. This argument has become less relevant given that most ladder logic programmers have a software background in more conventional programming languages, and in practice implementations of ladder logic have characteristics such as sequential execution and support for control flow features that make the analogy to hardware somewhat inaccurate. Ladder logic is widely used to program PLCs, where sequential control of a process or manufacturing operation is required. Ladder logic is useful for simple but critical control systems, or for reworking old hardwired relay circuits. As programmable logic controllers became more sophisticated it has also been used in very complex automation systems. Often the ladder logic program is used in conjunction with a HMI program operating on a computer workstation. Ladder logic can be thought of as a rule-based language, rather than a procedural language. A "rung" in the ladder represents a rule. When implemented with relays and other electromechanical devices, the various rules "execute" simultaneously and immediately. When implemented in a programmable logic controller, the rules are typically executed sequentially by software, in a continuous loop (scan). By executing the loop fast enough, typically many times per second, the effect of simultaneous and immediate execution is relatively achieved to within the tolerance of the time required to execute every rung in the "loop" (the "scan time"). It is somewhat similar to other rulebased languages, like spread sheets or SQL. However, proper use of programmable controllers requires understanding the limitations of the execution order of rungs.

The language itself can be seen as a set of connections between logical checkers (contacts) and actuators (coils). If a path can be traced between the left side of the rung and the output, through asserted (true or "closed") contacts, the rung is true and the output coil storage bit is asserted (1) or true. If no path can be traced, then the output is false (0) and the "coil" by analogy to electromechanical relays is considered "de-energized". The analogy between logical propositions and relay contact status is due to Claude Shannon. Ladder logic has contacts that make or break circuits to control coils. Each coil or contact corresponds to the status of a single bit in the programmable controller's memory. Unlike electromechanical relays, a ladder program can refer any number of times to the status of a single bit, equivalent to a relay with an indefinitely large number of contacts. So called "contacts" may refer to physical ("hard") inputs to the programmable controller from physical devices such as pushbuttons and limit switches via an integrated or external input module, or may represent the status of internal storage bits which may be generatedelsewhere in the program. Each rung of ladder language typically has one coil at the far right. Some manufacturers may allow more than one output coil on a rung. --( )-- a regular coil, energized whenever its rung is closed --(\)-- a "not" coil, energized whenever its rung is open --[ ]-- A regular contact, closed whenever its corresponding coil or an input which controls it is energized.--[\]-- A "not" contact, open whenever its corresponding coil or an input which controls it is energized. The "coil" (output of a rung) may represent a physical output which operates some device connected to the programmable controller, or may represent an internal storage bit for use elsewhere in the program.

4. Testing and Results

Initially the auto switch (I1) is switched on. The motors won't start its operation until the minimum level switch (I6) turns on after sensing whether the minimum level is present. Once I6 turns on, the duty cycle of motors starts with motor1 (Q1) and motor2 (Q2) starting initially. As per the time set in the timer, the duty cycle is shifted from motor1 (Q1)-motor2 (Q2) then to motor2 (Q2)-motor3 (Q3), motor3 (Q3)-motor4 (Q4), motor4 (Q4)- motor-1 (Q1), motor1 (Q1)-motor-2 (Q2) and so on. At any point of the working if the maximum level switch (I7) senses a maximum level (I7.ON), the motors are turned off. Once I7 is off, again the duty cycle continues, but the duty changes by one step, this is done to increase the efficiency. The simulation output view is as shown in Figure 5.

Figure 5. Simulation Output View

At the initial start of the working, the motors 2 and 3 start in place of 1 and 2. This is due to the adding of code for duty change after the maximum level switch ON condition. But this won't affect the plant operation as this will take place during the commissioning stage. During the rest of the operation, the motors shift in the exact order. In between the operation, different trip conditions arise due to over voltage, over current, frequency variations, etc.

Table 2. Case.1: Motor 1, Motor 2 (Duty)/Motor 3, Motor 4 (Standby)

Motor 1, Motor 2 Running	Motor 1 - Trip Motor 2, Motor 3 - Run	Motor 2 - Trip Motor 3, Motor 4 - Run
		Motor 3 – Trip Motor 2, Motor 4 - Run
	Motor 2 – Trip Motor 1, Motor 3 - Run	Motor 1- Trip Motor 3, Motor 4 - Run
		Motor 3 – Trip Motor 1, Motor 4 - Run

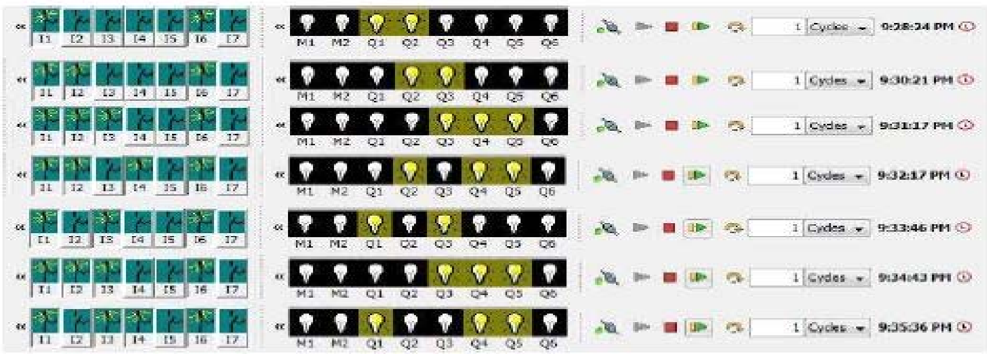

Figure 6. Trip Condition: Case.1

As shown in Figure 6, initially when motor1 and motor2 starts running, there is a chance for motor1 to get tripped, when motor3 takes over and the operation continues. This has another possibility where either motor2 or motor 3 may get tripped in which case the operation is carried on by motor3-motor4 and motor2-motor4 respectively. Also in the initial case motor2 may get tripped instead of motor1 where motor 3 takes over and having possibilities of motor1 and motor3 getting tripped where operation is carried on by motor3-motor4 and motor1-motor4 respectively. These cases are tabulated as shown in Table 2.

Figure 7. Trip Condition: Case.2

As shown in Figure 7, initially when motor2 and motor3 starts running, there is a chance for motor2 to get tripped, when motor4 takes over and the operation continues. This has another possibility where either motor3 or motor4 may get tripped in which case the operation is carried on by motor4-motor1 and motor3-motor1 respectively. Also in the initial case motor3 may get tripped instead of motor2 where motor4 takes over and having possibilities of motor2 and motor4 getting tripped where operation is carried on by motor4-motor1 and motor2-motor1 respectively. These cases are tabulated as shown in Table 3.

Table 3. Case.2: Motor 2, Motor 3 (Duty)/Motor 4, Motor 1 (Standby)

<table>
<tr><td rowspan="4">Motor 2, Motor 3 Running</td><td rowspan="2">Motor 2 - Trip
Motor 3, Motor 4 - Run</td><td>Motor 3 - Trip
Motor 4, Motor 1 - Run</td></tr>
<tr><td>Motor 4 – Trip
Motor 3, Motor 1 - Run</td></tr>
<tr><td rowspan="2">Motor 3 – Trip
Motor 2, Motor 4 - Run</td><td>Motor 2- Trip
Motor 4, Motor 1 - Run</td></tr>
<tr><td>Motor 4 – Trip
Motor 2, Motor 1 - Run</td></tr>
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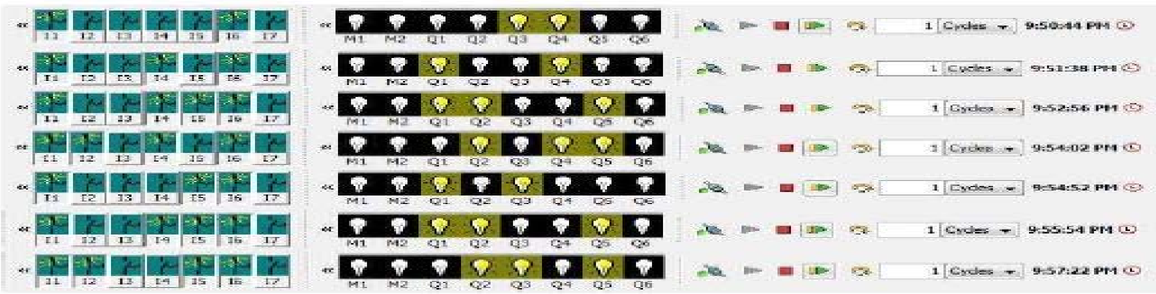

Figure 8. Trip Condition: Case.3

As shown in Figure 8, initially when motor3 and motor4 starts running, there is a chance for motor3 to get tripped, when motor1 takes over and the operation continues. This has another possibility where either motor4 or motor1 may get tripped in which case the operation is carried on by motor1-motor2 and motor4-motor2 respectively.

Table 4. Case.3: Motor 3, Motor 4 (Duty)/Motor 1, Motor 2 (Standby)

Motor 3, Motor 4 Running	Motor 3 - Trip Motor 4, Motor 1 - Run	Motor 4 - Trip Motor 1, Motor 2 - Run
		Motor 1 – Trip Motor 4, Motor 2 - Run
	Motor 4 – Trip Motor 3, Motor 1 - Run	Motor 3- Trip Motor 1, Motor 2 - Run
		Motor 1 – Trip Motor 3, Motor 2 - Run

Also in the initial case motor4 may get tripped instead of motor3 where motor1 takes over and having possibilities of motor3 and motor1 getting tripped where operation is carried on by motor1- motor2 and motor3-motor2 respectively. These cases are tabulated as shown in Table 4.

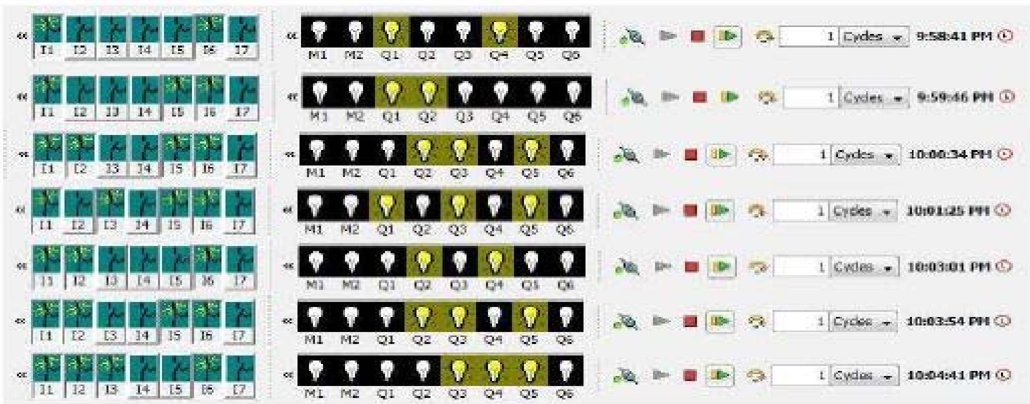

Figure 9. Trip condition: Case.4

As shown in Figure 9, initially when motor4 and motor1 starts running, there is a chance for motor4 to get tripped, when motor2 takes over and the operation continues. This has another possibility where either motor1 or motor2 may get tripped in which case the operation is carried on by motor2-motor3 and motor1-motor3 respectively. Also in the initial case motor1 may get tripped instead of motor4 where motor2 takes over and having possibilities of motor4 and motor2 getting tripped where operation is carried on by motor2- motor3 and motor4-motor3 respectively. These cases are tabulated as shown in Table 5.

Table 5. Case.4: Motor 4, Motor 1 (Duty)/Motor 2, Motor 3 (Standby)

Motor 4, Motor 1 Running	Motor 4 - Trip Motor 1, Motor 2 - Run	Motor 1 - Trip Motor 2, Motor 3 - Run
		Motor 2 – Trip Motor 1, Motor 3 - Run
	Motor 1 – Trip Motor 4, Motor 2 - Run	Motor 4- Trip Motor 2, Motor 3 - Run
		Motor 2 – Trip Motor 4, Motor 3 - Run

List of various inputs and outputs to and from the PLC are shown in Table 6 and Table 7 respectively.

Table 6. Various PLC Inputs

Sl. No	Notation	Description
1	I_1	Main power ON
2	I_2	Trip signal from Motor.1
3	I_3	Trip signal from Motor.2
4	I_4	Trip signal from Motor.3
5	I_5	Trip signal from Motor.4
6	I_6	Signal from low level switch
7	I_7	Signal from high level switch

Table 7. Various PLC Outputs

Sl. No	Notation	Description
1	Q_1	Output signal to motor.1
2	Q_2	Output signal to motor.2
3	Q_3	Output signal to motor.3
4	Q_4	Output signal to motor.4
5	Q_5	Output signal to warning lamp
6	Q_6	Output signal to critical lamp

In the hardware as shown in Figure 10 we have used a plywood panel to set the components. Due to cost constraints, we are using one three phase load instead of four and replacing the others with incandescent bulbs. The PLC and load is interfaced through a contactor/overload. Also to demonstrate the various trip conditions we have used ON/OFF switches. We have used one level switch instead of two and replaced the other with ON/OFF switch. We have used two lamps to indicate warning, i.e. when two motors out of four are tripped and critical, i.e. when three out of four motors are tripped.

Figure 10. Hardware Model of Automation of Induction Motors

4. Conclusion

Thus we have designed an automated model using Programmable Logic Controller replacing manual control of motors. This automated model has lower fault occurrence and requires very less human assistance. Even during a fault in a particular motor the plant operation is not disturbed as another backup motor takes over thereby increasing the efficiency of the plant as a whole. In this project initially a study was done on the current scenario of industries where the motors were not automated. In such industries since a particular motor was used for a large amount of time the motor suffers mechanical faults by overheating due to continuous operation. To adopt automation, a testing kit was designed using PLC and the programming was done based on the requirements. The programming was done using ladder logic in Siemens LOGO! Soft (Version 7.0). Due to cost constraints we designed the kit using one motor and three incandescent bulbs replacing the other three motors. Programmable Logic Controllers are widely used in industrial control and automation because they are east to install and flexible in applications. Custom designin of particular control panels cost more and it is difficult to adopt changes based on future requirements whereas when using PLC, we can easily make changes based on requirements in the program. Thus in many ways automated testing kit is much higher in performance than the manual control and hence automation is a feasible and attractive alternative to manual methods of control. This technology has a lot of advantages and can be worked upon in the future. Speed sensing and control can also be integrated into this technology. This technology can also be implemented with Lab VIEW.

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