Hydraulic Pressure Test on Insulator Using PLC

Anuja A. Khot and Ravindra G. Patil

Abstract: This paper describes the use of advanced Programmable Logic Controller (PLC) over relay controller for disc insulator testing under certain pressure using Hydraulic pressure testing machine. The PLC used in this paper is micro PLC of the MITSUBSHI Company's FX3U. The inputs and outputs of PLC differ from one to another.

PLC logic control system is the advanced technology. The speed of work done in case of PLC logic is more when compared to relay logic. Circuit connection can be changed simply by changing the program as per the requirement of the user with respect to number of inputs and outputs of PLC. The space occupied by the relay logic system is more when compared to PLC logic system because of circuit connections. Hence, the space used for the system installation can be reduced in case of PLC. The study of basic principles of relay and PLC logic is done, hence got inferred that PLC will decrease the complexity compared to relay logic and PLC appears to be an excellent solution for many different problems which will improve the status of production.

Keywords: **Hydraulic Pressure Test Machine, Ladder Logic Diagram (LLD), Programmable Logic Controller (PLC), Relay.**

I. INTRODUCTION

Industry has begun to recognize the need for quality improvement and increase in productivity in the sixties and seventies. Flexibility also became a major concern (ability to change a process quickly became very important in order to satisfy consumer needs). Try to imagine automated industrial production line in the sixties and seventies. There was always a huge electrical board for system controls, and not infrequently it covered an entire wall. Within this board there were a great number of interconnected electromechanical relays to make the whole system work. By word "connected" it was understood that electrician had to connect all relays manually using wires. An engineer would design logic for a system, and it would receive a schematic outline of logic that had to implement with relays.

These relay schemas often contained hundreds of relays. The plan that was given was called "ladder schematic". Ladder displayed all switches, sensors, motors, valves, relays, etc. found in the system. One of the problems with this type of control was that it was based on mechanical relays. Mechanical instruments were usually the weakest connection in the system due to their moveable parts that could wear out. If one relay stopped working, it would have to examine an entire system and it would be out until a cause of the problem was found and corrected. The other problem with this type of control was in the system's break period when a system had to be turned off, so connections could be made on the electrical board. If a firm decided to change the order of operations or to make even a small change, it would turn out to be a major expense and a loss of production time until a system was functional again.

The PLC acts as a total replacement for hard wired relay logic with an effective reduction in wiring and panel size with increase in flexibility and reliability. Since their development in early 1970's, Programmable Logic Controllers (PLC) have evolved to challenge not only relays but other control devices such as, stepping switches, drum sequencers etc. The simplicity of reprogramming a PLC, when modifications were required in the existing control, as compared to the cumbersome process of rewiring a hardwired control panel has been widely accepted. The comparatively small size of the PLC accompanied with less hardwired interlocks reduces the panel size considerably. The use of solid state devices make PLC very reliable as compared to the electromechanical devices used in hardwired control panels.

It is experienced that, in a system using PLC's, about 90% of the faults that occur, are due to causes external to PLC. Malfunctioning of limit switches, opening of wires due to loose connections, wire breakage etc. contributes to major causes of breakdowns. In a system using PLC's, apart from carrying out the logical decisions, the troubleshooting is considerably simplified.

The process status, timer values, counter values, process parameters like temperature, pressure etc. can be displayed on an alphanumeric display of a seven segment display. The fault code for a corresponding fault can be displayed to pinpoint the fault, resulting in fast diagnosis. Thus the duration of machine stoppage and down time are considerably reduced due to efficient man-machine communication.

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II. HYDRAULIC PRESSURE TEST MACHINE PROFILE

A. Machine Profile

The hydraulic press is one of the oldest of the basic machine tools. They present a price and weight benefit over the equivalent electro-mechanical systems needed to generate the same force or torque. Hydraulically actuated systems are used in a wide range of industrial applications, and continue to be a popular and relatively inexpensive power source and modern hydraulic presses offer good performance and reliability. The machine used in this paper is Hydraulic Pressure testing machine. It is used to test the disc insulators of different sizes and the machine is capable to generate up to 300bars of pressure. The press has two hydraulic servomechanisms: a hydraulic cylinder, driven by a servo-solenoid flow control valve, to support the punch tool; a hydraulic cylinder, where the chamber pressure is controlled by a servo-solenoid pressure control valve, to support the operations of loading and unloading of the press blank holder [1]. Disc insulators of various rating of 70KN to 420KN can be tested here at specific pressure to check mechanical strength. Machine is working with Hydraulic Pressure system i.e all the operations are hydraulically operated as shown in fig.1 and the hydraulic circuit for Hydraulic Pressure Test Machine as show in fig.2.

B. Existing control system

1. Machine is controlled by electrical panel
2. Relay logic has been used for electrical system
3. 415V, 3 phase from main panel and stepped down to 230V, 1 phase to control panel
4. Here disc insulators are tested under 200 Kg/cm^2 of pressure.

C. Working Principle

The hydraulic press depends on Pascal's principle: the pressure throughout a closed system is constant. At one end of the system is a piston with a small cross-sectional area driven by a lever to increase the force. Small-diameter tubing leads to the other end of the system. A fluid, such as oil, is displaced when either piston is pushed inward. The small piston, for a given distance of movement, displaces a smaller amount of volume than the large piston, which is proportional to the ratio of areas of the heads of the pistons. Therefore, the small piston must be moved a large distance to get the large piston to move significantly. The distance the large piston will move is the distance that the small piston is moved divided by the ratio of the areas of the heads of the pistons.

Fig. 1: Hydraulic Pressure testing machine

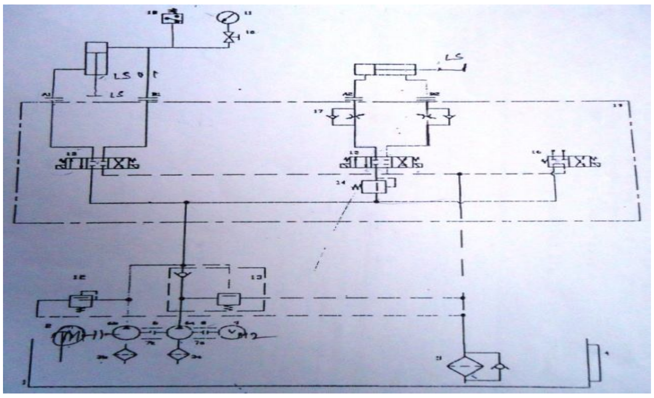

Fig. 2: Hydraulic circuit for Hydraulic Pressure Test Machine

III. SWITCHGEAR ELEMENTS

A. Relays

The relays are devices that monitor various parameters in various ways. The types of relays can be broadly classified as electromechanical relays and static relays (analog and digital). The electromechanical relays have been dominating the electrical protection field until the use of silicon semiconductor devices became more common. Because a relay is able to control an output circuit of higher power than the input circuit, it can be considered, in a broad sense, to be a form of an electrical amplifier.

Operating Principle: When a current flows through the coil, the resulting magnetic field attracts an armature that is mechanically linked to a moving contact. The movement either makes or breaks a connection with a fixed contact. When the current to the coil is switched off, the armature is returned by a force approximately half as strong as the magnetic force to its relaxed position. Usually this is a spring, but gravity is also used commonly in industrial motor starters. Most relays are manufactured to operate quickly. In a low voltage application, this is to reduce noise. In a high voltage or high current application, this is to reduce arcing.

B. Contactor

A contactor is an electrical device used for switching a power circuit. A contactor is activated by a control input which is a lower voltage / current than that which the contactor is switching. Contactors come in many forms with varying capacities and features. Unlike a circuit breaker a contactor is not intended to interrupt a short circuit current.

Operating Principle: When current passes through the electromagnet, a magnetic field is produced which attracts ferrous objects, in this case the moving core of the contactor is attracted to the stationary core. Since there is an air gap initially, the electromagnet coil draws more current initially until the cores meet and reduce the gap, increasing the inductive impedance of the circuit.

For contactors energized with alternating current, a small part of the core is surrounded with a shading coil, which slightly delays the magnetic flux in the core. The effect is to average out the alternating pull of the magnetic field and so prevent the core from buzzing at twice line frequency.

C. Circuit Breaker

A circuit breaker is an automatically-operated electrical switch designed to protect an electrical circuit from damage caused by overload or short circuit. Unlike a fuse, which operates once and then has to be replaced, a circuit breaker can be reset (either manually or automatically) to resume normal operation. Circuit breakers are made in varying sizes, from small devices that protect an individual household appliance up to large switchgear designed to protect high voltage circuits feeding an entire city.

Operating Principle: Magnetic circuit breakers are implemented using a solenoid (electromagnet) that's pulling force increases with the current. The circuit breaker's contacts are held closed by a latch and, as the current in the solenoid increases beyond the rating of the circuit breaker, the solenoid's pull releases the latch which then allows the contacts to open by spring action. During an overload, the solenoid pulls the core through the fluid to close the magnetic circuit, which then provides sufficient force to release the latch. The delay permits brief current surges beyond normal running current for motor starting, energizing equipment, etc. Short circuit currents provide sufficient solenoid force to release the latch regardless of core position thus bypassing the delay feature. Ambient temperature affects the time delay but does not affect the current rating of a magnetic breaker.

IV. PROGRAMMABLE LOGIC CONTROLLER (PLC)

A. Introduction

A Programmable Logic Controller (PLC) preferred in this paper is of the MITSUBISHI Company's FX3U and it is microprocessor-based control system that can be programmed to sense, activate and control industrial equipment and therefore incorporates a number of input/output terminals for interfacing to an industrial process as shown in the fig. 3. A control program stored in the PLC memory determines the relationship between the inputs and outputs of the PLC [2].

Fig.3. Mitsubishi FX3U PLC with the expansion block

B. History

In 1960's PLC were first developed to replace relays and relay control system. Relays, while very useful in some applications, also have some problems. The main problems are the fact that they are mechanically. This means that they wear down and have to be replaced every so often. Also relays take up a quite a bit of space. These along with other considerations led to the development of PLC's. More improvement of PLC's occurred in the 70's.

In 1973 the ability to communicate between PLC's was added. This also made it possible to have the controlling circuit quite a ways away from the machines it was controlling. However at this time the lack of standardization in PLC's created other problems. This was improved in 1980's. The size of PLC's was also reduced then, thus using space even more efficiently. The 90's increased the collection of ways in which a PLC could be programmed (block diagram, instruction list, C etc) [4].

C. Block Diagram

The block diagram of the PLC is as shown in the fig. 4. The processor is a solid state device designed to replace relays, timers, counters etc. The necessary voltage and current requirements for the internal working of the PLC is generated by the power supply.

The field elements dare interfaced to the input or the output sections. Typical input elements are push buttons, limit switches, proximity switches, relay contacts, selector switches, thumbwheels etc. Typical output elements are solenoid valves, relay coils, indicator lights, LED display etc. These field elements are selected by the end user. The necessary power supply for the input and output elements is built external to the PLC.

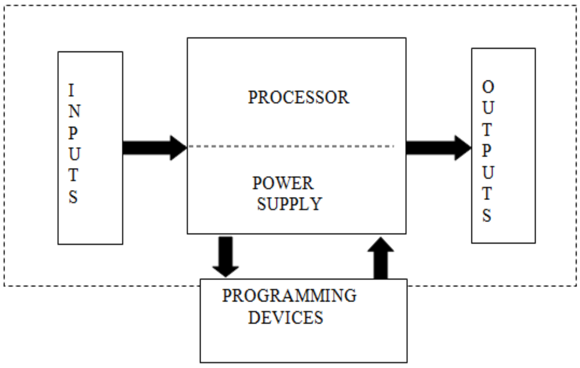

Fig.4. Block diagram of Programmable Logic Controller

The PLC power supply is designed and rated only to operate the internal structure and dot the field elements. The processor is programmed in a similar way as the hardwired control panels, known as ladder diagrams.

The programming device is the device where, by the programmer or operator can enter or edit program instructions or data. The programmer can be handheld unit that is a personal computer, or an industrial computer-programming terminal.

V. LADDER LOGIC DIAGRAM (LLD)

A. Ladder Logic

The main modeling language of the PLC is based on the so-called Ladder Logic Diagram (LLD). This graphical symbolic language is widely used in the design of PLC for industrial automation. LLD models the actual combination of relay contacts. The term "ladder" derives from the appearance of the diagram [3]. The ladder diagram is to be read left to right, then top to bottom. A relay contact or a step in LLD is either (a) normally closed (NC), represented symbol by **-| / |-** or (b) normally open (NO), represented by the symbol **-| |-.** They are controlled by logical inputs and state variables which are represented by the labels (e.g. alarm, stop). When an input triggers the step, the corresponding relay state changes to the opposite state, that is, the NC step is turned ON while the NO step is turned OFF. A PLC ladder program consists of N/O contacts are and N/C. The relays coils are represented by the symbol **- ( )-** [5]. These symbols are associated with the determined OP (operation) codes which instruct the CPU to take specific action while executing the ladder. The ladder is the combination of the above symbols interconnected with each other in a sequence and in a predetermined syntax. One branch of such a ladder is known as a "RUNG".

B. Ladder Structure

The ladder program is arranged in a set of ladder rungs. The structure of each ladder rung allows to program.

- Maximum 9 contacts and one output coil in series (columns)
- Maximum 6 contacts / coils in parallel (rows)

The rungs are numbered serially by the programming devices and are executed sequentially. Each rung is identified by a unique number from 000 to 999. Insertion / deletion of rungs results in renumbering of all the succeeding rungs i.e. if rung number 0,1,2,3 are existing in the ladder and if rung number 1 is deleted then rung number 2 will become rung number 1, rung number 3 will become rung number 2 whereas rung number 0 will remain as it is. Similarly if a new rung is inserted in between two rungs the addresses of the succeeding rungs to the new rung is shifted by 1.

C. Ladder Execution

The PLC performs its task in a definite cycle. This is called as the PLC Scan the definite cycle of PLC scan is as shown in fig. 5. PLC Scan means that contribute the input processing, program processing and output processing together.

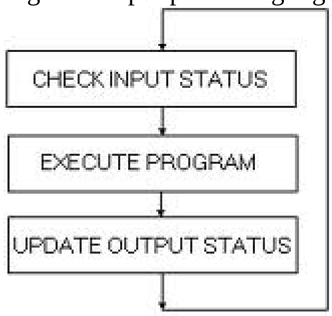

Fig.5. PLC scan process

When the PLC is performing these scan it is said to be in the RUN mode, otherwise it is said to be in STOP mode. The PLC reads the status of all the inputs and updates their images in the memory. This is called as input scan. Depending upon the status of inputs read in input scan the PLC solves the logic written by the user in User Memory Cassette (UMC). This is called as logic scan. The status of the outputs generated in the logic scan is transferred on to the output module in the output scan.

One input scan followed by one logic scan followed by one output scan together contributes to one PLC scan. As soon as PLC processor completes a scan it immediately starts another scan forming continuous loops.

In the logic scan the rungs programmed in UMC are executed in the sequence in which they are entered. It is important to note that the execution of complex ladder rung having multiple coils will follow the thumb rules as below.

- ➢ The PLC will evaluate the status of all the coils in a rung sequentially from top to bottom. This will be done considering all the different paths controlling that coil. Each path will be traversed from left to the right only. No contact or link will conduct from right to left.
- ➢ The status of those node points required to evaluate the status of the first coil considering all its paths are decided. The node points are those points where one or more parallel paths being or end. Using this status of node points the status of the first coil is evaluated.
- ➢ In evaluating the status of subsequent coils and nodes within that rung, the status of previously evaluated coils and nodes are used again, without reevaluating them.

VI. EXPERIMENTAL SETUP

A. Electrical Wring Diagram of Hydraulic Pressure Test Machine

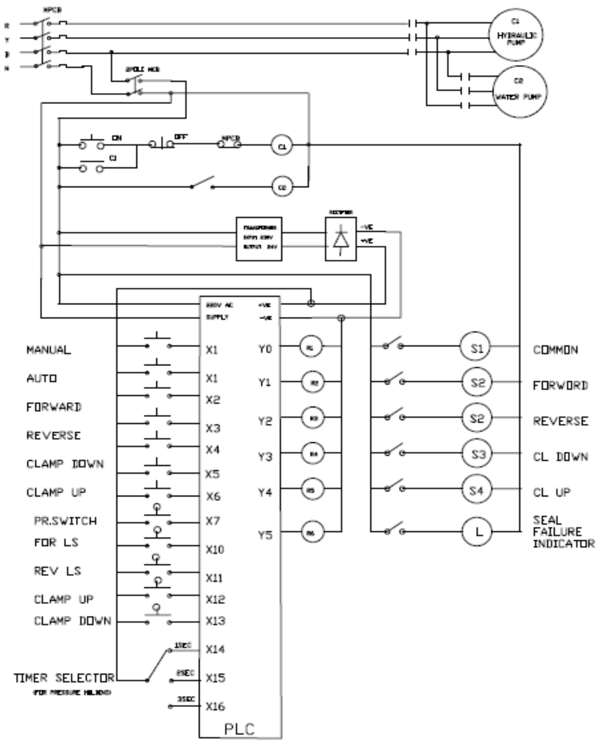

Fig.6. Electrical wiring diagram of Hydraulic Pressure Test Machine

B. Working Sequence of Hydraulic Test Machine

- Initial Condition:
  - Main paper should be switched ON.
  - Hydraulic motor should be switched ON.
  - Clam should be in UP position.
- Auto mode and Manual mode:
  - Auto ready should be on.
  - Any of the carriage moment (forward or backward) should move to the center.
  - Once carriage comes to the center cylinder should be declamp and should start coming down.
  - Once seal get fixed to the insulator a pressure of 200 Kg/cm^2 is created.
  - When the pressure attains 200 Kg/cm^2 and after a permitted time cylinder moves upward and stops.
  - The cylinder touches the clamp top limit cylinder will stop and auto cycle will be completed.

The flow chart of the working sequence of the Hydraulic Pressure Test Machine is as shown in the fig. 7.

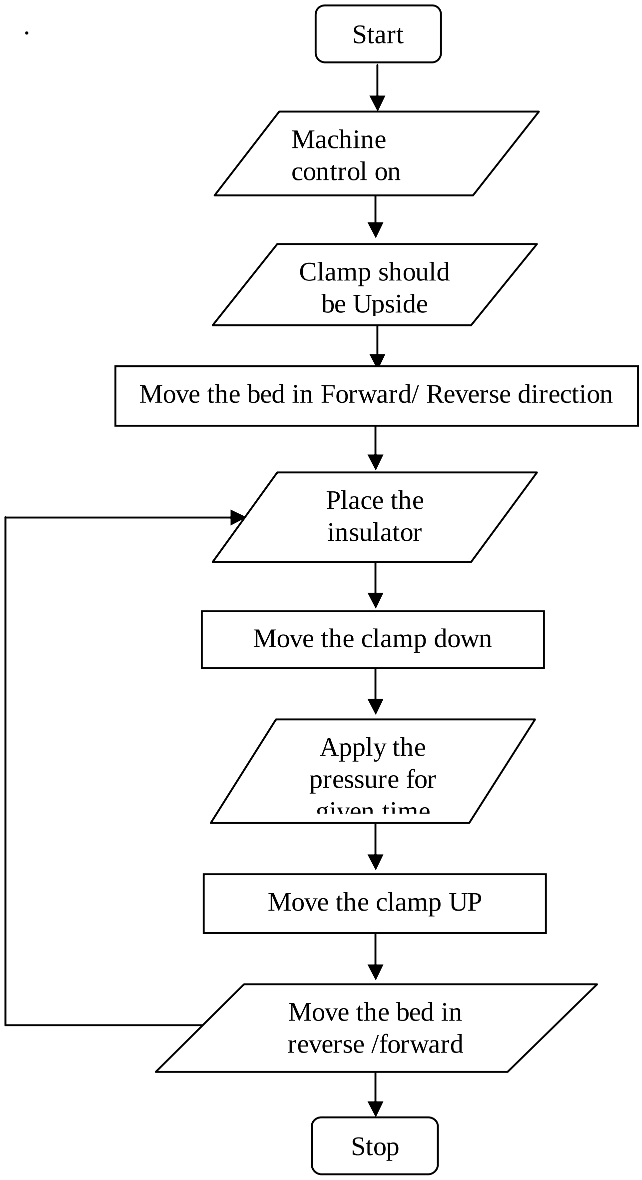

Fig.7. Flow chart of the working sequence of Hydraulic Pressure Test Machine

C. Advantages of PLC over Relay

- Electrical system including motors, switch gear elements, cables, transformers etc. were more than 20 years old. So the system will be giving frequent problems. Old system has balanced with PLC, switch gear elements etc. which increase the life of machine
- Circuit alteration in the new PLC system becomes easier by changing the PLC program, the circuit can be altered. Contrary, to this relay logic it is very difficult to change the circuit because it requires lots of hardware alterations which is the time consuming and prone to errors.
- Ideal planner size was very big because lot of relays and contactors were required for interlocking circuits. Now, the panel size is reduced to 50% because very few relays are required for field input,

output. Interlocking circuit can be written through the PLC program.

- The new PLC system will reduce the breakdown time and increase the availability of time which will increase the production statistics.

VII. CONCLUSION

Replacing the relay control system with PLC makes more efficient and effective control system. The very nature of PLC design as well as its application, offers numerous benefits to industrial users to control and troubleshoot the faults.

Testing of the disc insulators under certain pressure using PLC logic is possible, which decreases the complexity in operation compared to relay logic. So, PLC appears to be an excellent solution for many different problems which improves the status of production.

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