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Application of PLC's for Automation of Processes in Industries

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ABSTRACT
Several industries utilize sequential industrial process which is respective in nature. For such processes industries have to depend upon use of relays, stepping drum, timers and controls, considerable difficulties experienced in reprogramming necessitated due to change in the nature of production. Often the whole system has to be scrapped and a redesigning is required. To overcome these problems PLC control system was introduced. The PLC can be described as a control ladder comprising a sequence program. PLC sequence program consists of normally open and normally closed contacts connected in parallel or in series. It also has relay coils, which turns ON and OFF as the state of these contacts change. In this paper, about all aspects of these powerful and versatile tools and its applications to process automation has been discussed.
***Keywords*:** Automation, Programmable Logic Controller (PLC), Programming Languages, Process Automation.

I. INTRODUCTION

With the upcoming technologies and availability of motion control of electric drives, the application of Programmable Logic Controllers with power electronics in electrical machines has been introduced in the development of automation systems. The use of PLC in automation processes increases reliability, flexibility and reduction in production cost. Use of PLC interfaced with power converters, personal computers and other electric equipment makes industrial electric drive systems more accurate and efficient [1]. PLCs have been gaining popularity on the factory floor and will probably remain preponderant in coming years. Most of this is because of the advantages they offer, like

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

The PLC was contrive in response to the needs of the American automotive manufacturing industry. Automotive industries were the first to adopt programmable logic controllers, where software alteration replaced the rewiring of hard-wired control panels when production models changed. In manufacturing automobiles, earlier, the control, sequencing and the safety interlock logic was accomplished using hundreds or thousands of relays, drum sequencers, cam timers, and closed-loop controllers. The process for updating such facilities for the yearly model change-over was very expensive and time consuming as electricians have to individually rewire each and every relay. Digital computers, being general-purpose programmable devices, were applied for the control of industrial processes. Early computers required specialist programmers and essential operating environmental control for temperature, cleanliness, and power quality. The general-purpose computer used for process control required protecting the computer from the plant floor conditions. An industrial control computer possess several attributes: it would tolerate the shop-floor environment, it would not require years of training to use, and it would permit its operation to be monitored, it would support discrete (bit-form) input and output in an easily extensible manner. The response time of any computer system must be fast enough to be useful for control; the required speed varying according to the nature of the process [2].

In 1968, the design criteria for the first programmable controller were specified by the Hydromantic Division of the General Motors Corporation. Eliminating the high costs associated with inflexible, relay-controlled systems was their primary goal. The specifications required a solid-state system with computer flexibility able to (a) Survive in an industrial environment, (b) Be easily programmed and maintained by plant engineers and technicians, (c) Be reusable

Such control system would reduce machine downtime and provide expandability for the future. The automotive industry is still one of the largest users of PLCs [13].

II. LITERATURE REVIEW

PLC and the SCADA systems are widely used in most industrial processes e.g. chemical industries, steel manufacturing, power generations, etc. Automated level control systems using PLC, SCADA and HMI are used ubiquitously in industrial applications. To prevent industrial accidents by overfilling of any open container, to prevent overfilling of any closed container thereby creating overpressure condition. Therefore, process control industrial applications requires effective supervise level control in multiple tanks.

A paper on the design of bottle filling plant using PLC wherein a bottle filling and capping operation takes place in a synchronized manner. The user can input the desired volume of liquid to fill in the bottles. The entire system is more flexible and time saving [3]. Another application in which microcontroller based automated system was developed. The developed system improved the performance by reducing the time delay using fast switching transistors. The system was tested for electro pneumatic and electro hydraulic systems resulting in faster time response and stable duty cycle [4].

The system designed for the temperature control of solar cell lamination machine using double microcontroller as its core. In this the control system based on double microcontroller improves the temperature control precision and to achieve a closed loop control on the lamination temperature a PID control algorithms are designed. Thus not only dynamic response, temperature control accuracy and uniformity improved but also detects and controls the vacuum of the working room [5].

A PLC based monitoring and control scheme for a three-phase induction motor suggested that PLC can be used in automation industries involving control of induction motor. A control program was developed, through which PLC continuously monitored the inputs and activated the outputs accordingly. A current sensor was employed for load current feedback, a speed sensor for speed feedback, and an additional current sensor was attached to stator circuits. The speed control of motor achieved through PLC gave the system high accuracy in speed regulation at constant speed for variable load operation. The efficiency of the induction motor system fed by an inverter was increased appreciably by using PLC. At high speeds and loads, the efficiency of PLC-controlled system is increased up to 10–12% [6]. A water control system using variable frequency principle and constant pressure principle using PLC is designed. Using variable frequency control to adjust the speed of the AC motor, not only its speed can be varied continuously but also the relationship between frequency and voltage is adjusted based on various load characteristics so that the motor is always running efficiently [7].

III. PROGRAMMING

The programming technique for the first PLCs were based on relay logic wiring schematics. This eliminated the need to teach the technicians, electricians and engineers how to program a computer but this method has stuck and it is the most common technique for programming PLCs today.

According to IEC 61131-3 five programming languages is defined for programmable control systems: LD (Ladder diagram), ST (Structured text), SFC (Sequential function chart), FBD (Function block diagram), and IL (Instruction list, similar to assembly language) [13, 14].

IV. INDUSTRIAL AUTOMATION SYSTEMS

Industrial automation is the use of computer and machinery aided systems to operate the various industrial operations in well controlled manner. Based on the operations involved, the industrial automation systems are majorly divided into two types; (a) Manufacturing automation and (b) Process plant automation systems.

4.1 Manufacturing Automation System

The manufacturing industries make the product out of raw materials using robotics/machines. Some of these manufacturing industries include paper making, glass and ceramic, textile and clothing, food and beverages, etc. New trends in manufacturing systems have been using automation systems at every stage such as material handling, machining, assembling, inspection and packaging. With the computer aided control and industrial robotic systems, the manufacturing automation becomes very flexible and efficient.

4.2 Process Plant Automation

In process industries, the product results from many chemical processes based on some raw materials, some of the industries are cement industry, pharmaceutical, paper industry, petrochemical, etc. Thus the overall process plant is automated to produce the high quality, more productive, high reliable control of the physical process variables.

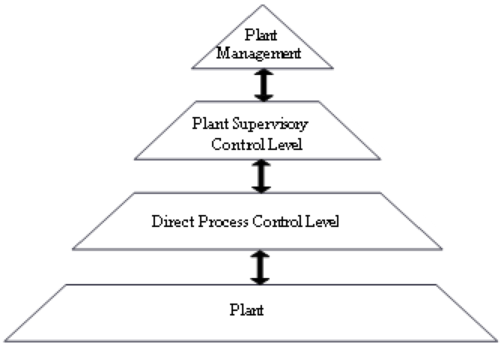

Fig. 1 Process automation system

The fig. 1 shows the process automation system. The various layers represents widespread of components in a process plant.

4.2.1 Plant:

This level consists of machines which are closest to processes. In this sensors and actuators are used to translate the signals from the machines and physical variables for the purpose of analysis and to produce the control signals.

4.2.2 Direct process control:

In this level, automatic controllers and monitoring systems acquire the process information from sensors and correspondingly drives the actuator systems.

4.2.3 Plant supervisory control:

This level commands the automatic controllers by setting the targets or set points. It looks after the control equipment for an optimal process control.

4.3 Automated Dyeing Machine

In textile industry, dyeing machine is automated using PLC technology to automatically control the temperature and established the automatic temperature adjustment in the working process of dyeing machine. The control objective of dyeing machine and the structure of its temperature control system is shown fig. 2 [9]. The temperature of the system ranges from 20°C to 150°C, as water cannot attain the temperature of 150°C glycerin is used. Under normal pressure, glycerin can achieve 150°C.

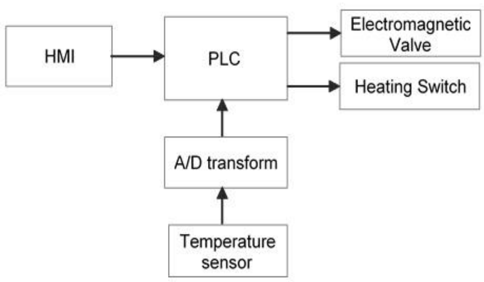

Fig. 2 Structure of temperature control system

According to the technical requirement, the temperature of glycerin in the dyeing trough must change. If the temperature of glycerin is lower than the predefined value the temperature control system should close the heat switch till the set value of temperature is reached. If the temperature is higher than set value then system should connect the cooling valve to drop the temperature. Thus dyeing technology of the textile needs strict requirement of the temperature control due to the difficulty in manual control [8].

4.4 Automated Boiler System for Thermal Power Plant

Boiler is one of the most important parts in any power plant. Which require continuous monitoring and inspection at frequent interval. In Power plants it has number of boiling section. This boiling section produces the high temperature water of the steam. Boiler steam temperature in thermal power plant is very complex and hard to control, due to poorly understanding of the working principles; Boilers have many serious injuries and destruction of property. It is critical for the safe operation of the boiler and the steam turbine. Too low a level may overheat boiler tubes and damage them. Too high a level may interfere with separating moisture from steam and transfers moisture into the turbine, which reduces the boiler efficiency.

Various controlling mechanism are used to control the boiler system so that it works properly, many control strategies have been applied to it. Block diagram of the automated boiler system for the thermal power plant is shown in fig. 3 [9]. In order to automate a power plant and minimize human intervention, there is a need to develop a Boiler Automation system. It is achieved by using Programmable Logic Controller & Supervisory Control and Data Acquisition system that helps to reduce the errors caused by humans and avoids the catastrophic failure.

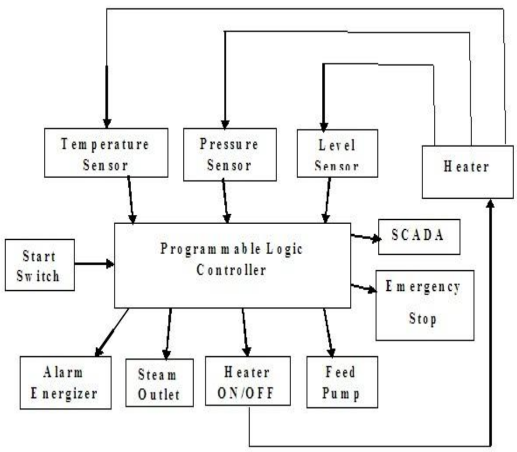

Fig. 3 Block diagram of boiler automation system

In boiler automation process using PLC and SCADA different sensors are used to measure the water level, temperature and pressure. PLC is used to control the process whereas SCADA monitors the various process parameters. If the pressure and temperature exceed the set value then the entire system shuts down and the valves automatically are opened to release the steam and pressure. Thus PLC can be programmed to function as an energy management system for boiler control for maximum efficiency and safety. In the burner management system it can be used to control the process of purging, pilot light off, flame safety checks, main burner light off and valve switching for changeover of fuels [9].

4.5 Induction Steel Heating Furnaces using PLC

Induction heating is a thermal heating process, when a material is heated within an induction steel heating furnace (ISHF) its magnetic permeability and resistivity fluctuate, which proves detrimental to the control of power within the furnace. So to improve an power control within an ISHF programmable logic controller (PLC) is used. PLC not only helps in pressure, position and temperature control within ISHF but also provides over current and over voltage protection. PLC also allows heating to take place at constant power while maintaining a steady resonance frequency [10].

V. SALIENT FEATURES OF PLC

The various functionalities of programmable logic controller has evolved over the years to include sequential relay control, distributed control systems, process control, motion control and networking. PLC control system is that it regards PLC as control key component, utilize special I/O module to form hardware of control system with a small amount of measurement and peripheral circuit, to realize control to the whole system through programming.

5.1 High Reliability

In order to make PLC work stably and efficiently in strong interferential conditions, very high reliability and strong anti-interference quality are the most important features of PLC. Software control instead of relay control can decrease faults which are brought about by original electric contact spot outdoor working badly. Industrial grade components made by advance processing technology can sustain interferences, and self-diagnosis measures of watchdog circuit for protecting memory can improve performance of PLC greatly [2].

5.2 Good Flexibility

There are various programming languages for PLC including ladder diagram, SFC, STL, ST and so on. If operator can master any one of the programming languages, he can operate PLC well. The person who want to use PLC has a good choice. Based on engineering practice, function and capacity can be expanded by expanding number of module, so PLC has a good flexibility.

5.3 Quality of Strong Easy-Operating

It is very easy to change or modify and edit program for PLC by computer offline or online. It is very easy to find out where the fault occurred by showing the information of fault location and function of self-diagnosing and all these makes repair and maintenance for PLC easier. Configuring PLC is very easy due to modularization, standardization and serialization of PLC.

5.4 Scan Time

A PLC program is generally executed continuously as long as the controlled system is running. The status of physical input signals is copied to an area of memory accessible to the processor, sometimes called the "I/O Image Table". The program is then executed from its first instruction down to the last one as shown in figure 4. It takes some time for the processor of the PLC to evaluate all the instructions and update the I/O image table with the status of outputs. This time of scan may be a few milliseconds for a small program or on a fast processor, but older PLCs executing very large programs could take much longer i.e. up to 100 ms to execute the program [2]. If the scan time were too long, the response of the PLC to process conditions would be sluggish to be useful.

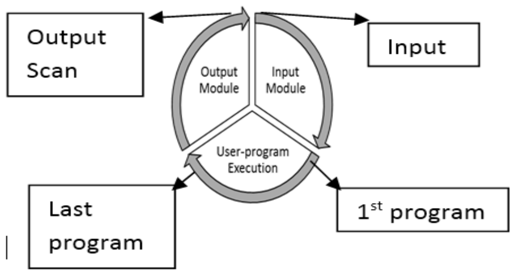

Fig 4 PLC Scan Cycle

5.4.1 Input scan

During the input scan, the current status of every signal from input module is stored in the input image (memory) table, making it up-to-date. Thus all the status of the input devices (which in turn is connected to the input module) are updated in the input memory table of PLC.

5.4.2 Program scan

Following the input scan, the CPU enters into its user program execution, or program scan. The execution involves starting from the first program instruction, then moving on to the second instruction and carrying out its execution sequence. This continues up to the last instruction of the program. Throughout the user-program execution, the CPU continually keeps its output image (memory) table up-to-date.

5.4.3 Output scan

During program scan, the output modules are not updated continually. Instead, the entire output image table is transferred to the output modules during the output scan which comes after the program execution. Thus the output devices are activated accordingly during the output scan.

VI. PLC COMPARED WITH OTHER CONTROL SYSTEM

6.1 Relay Control System

Any desired logic functions can be generated by connecting the input and output contacts in series and/or in parallel. Combinations of several logic elements may be used to create fairly complex control plans. For a simple task, the number of control relays required could be so numerous leading in a large control panel. A typical relay system may consist of several hundred or thousand switching contacts, which presents the design engineer with a considerable task. Once the system is wired, it is extremely difficult to change the control function of a panel and is likely to involve a complete re-wiring of the system [2, 12]. Together with the other disadvantages of cost, speed and reliability, the above demerits for relay control system have led to the replacement of relay control systems by modern alternatives based on microprocessors and electronics systems. Relay continues to be used extensively as output devices (actuators) on other types of control system, being ideal for the conversion of small control signals to higher-current/higher-voltage driving signals.

6.2 Digital Logic Control Systems

Digital ICs, which deal exclusively with binary signals, process this information through various logic 'gates'. Logic gates operate at much higher speeds and consume considerably less power than an equivalent relay circuit. Although digital ICs have the advantage of small size, it cannot switch higher power signal. Relay is used to convert small control signals to higher power driving signals [2].

6.3 Electronic continuous control systems

The operational amplifier (op-amp) available for analog computing operations, which involve the performance of mathematical operations such as integration, differentiation, etc. were quickly adopted into the field of continuous control (Closed-loop feedback systems) and provided a much simplified solution to complex control functions compare with existing discrete electronic systems. Analog control is now heavily based on linear integrated circuits, and remains the fastest form of control available. However, the 'fine tuning' of feedback systems during design and commissioning remains a difficult task. This, coupled with the fixed nature of electronic circuit construction, results in a control medium that cannot easily have its function changed - the complete electronic system may have to be replaced if this proves necessary.

6.4 Computer Control System

Today, powerful low-cost micro- and mini-computers are available, and are often used in both sequence and continuous control systems. Microprocessor-based control panels are small enough to locate at (or near) the point of final control, simplifying connection requirements. In large processes it is now common for several microcontrollers to be used instead of a single large mainframe control computer, with resulting benefits in performance, cost and reliability. Each micro can provide optimal local control, as well as being able to send or receive control data via other microcontrollers or a host supervisory computer (mini or micro) [2, 12]. This is termed distributed control and allows for greater sophistication of control than was with a centralized strategy using a single large computer, since the control function is divided between several dedicated processors.

VII. AREAS OF APPLICATION OF PLC

Every system or machine has a controller. Depending on the type of technology used, controllers can be divided into pneumatic, hydraulic, electrical and electronic controllers. Frequently, a combination of different technologies is used. Furthermore, differentiation is made between hard-wired programmable (e.g. wiring of electro-mechanical or electronic components) and programmable logic controllers. The first is used primarily in cases, where any reprogramming by the user is out of the question and the job size warrants the development of a special controller. Typical applications for such controllers can be found in automatic washing machines, video cameras, and cars. However, if the job size does not warrant the development of a special controller or if the user is to have the facility of making simple or independent program changes, or of setting timers and counters, then the use of a universal controller, where the program is written to an electronic memory, is the preferred option. The PLC represents such a universal controller. It can be used for different applications and, via the program installed in its memory, provides the user with a simple means of changing, extending and optimizing control processes. The original task of a PLC involved the interconnection of input signals according to a specified program and, if "true", to switch the corresponding output. Boolean algebra forms the mathematical basis for this operation, which recognizes precisely two defined statuses of one variable: "0" and "1" [2].

Proper application of a PLC begins with an economical justification analysis. The batch process in chemical, cement, food and paper industries are sequential in nature, requiring time or event based decisions. PLCs are being used more and more as total solutions to a batch problem in these industries rather than just a tool. In batch process savings are developed principally from reduced cycle time and scheduling. Cycle automation provides rigid control enforcement to eliminate human errors and to minimize manual interventions. Increased efficiency in scheduling is to be expected with maximum utilization of equipment and reduction of fluctuating demands on critical equipment [13, 14].

In large process plants PLCs are being increasingly used for automatic start up and shutdown of critical equipment. A PLC ensures that an equipment cannot be started unless all the permissive conditions for safe start have been established. It also monitors the conditions necessary for safe running of the equipment and trip the equipment whenever any abnormality in the system is detected.

A. 7.1 Advantages of programmable controller

- Less operating time.
- High flexibility
- Absence of moving parts increases reliability
- Low power consumption
- Easy maintenance due to modular fabrication.
- Easy fault finding and diagnostic.
- Capable of handling of complicated logic operations.
- Good documentation and data collecting facilities
- Easy to interface with the process computers.
- Analog signal handling and close loop control programming.
- Timer, counter and comparator can be programmed.

VIII. CONCLUSION

The automation of the design of industrial control processes has a history of strong innovations. In this paper the concept of Programmable logic controllers and its applications are discussed. PLC applications are typically highly customized systems so the cost of a packaged PLC is less compared to the cost of a specific custom-built controller design. Development of small modular structure in comparison with earlier structures have increased the flexibility of PLC configurations, PLC computing, scan time, data processing, network communication, graphics display, and other functions. The PLC programming tools are constantly developing, so it can be used more widely in the applications of numerical control technology, control of machining center which will be more flexible and reliable.

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