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Optimized Programmable Logic Controller Based System for Machinery

[1]F. Onaifo, [2]A.A. Adelakun, [3]B.J. Adenle, [4]K.G. Adekusibe & [5]O.O. Akinrogunde
[1]Department of Electrical and Electronic engineering, Olabisi Onabanjo University, Ibogun, Ogun state
[2]Department of Electrical and Electronic Engineering, Ogun State Institute of Technology, Igbesa, Nigeria
[3]Department of Computer Hardware Engineering,Dots institute of Technology, Abeokuta, Nigeria
[4]Department of Computer Engineering, Ogun State Institute of Technology, Igbesa
[5]Department of Electrical and Electronic engineering, Ogun State Institute of Technology, Igbesa
[1]excitefranko@yahoo.com, [2]adeolaadelakun30@yahoo.com, [3]bamidelejohnson2@gmail.com, [4]kusibus@yahoo.com,
[5]akinrogunde2015@gmail.com

ABSTRACT

Abstract: The simplification of engineering, technology and precise control of manufacturing process can result in significant cost savings. The most cost-effective way, which can pay big dividends in the long run, is flexible automation, a productivity approach towards integrated control systems. PLCs, automation need not to be high too sophisticated but scalable. That is where Industrial electronics system, has been a breakthrough in the field of automation and control techniques.[5]

Keywords: Controller, Modern, Programmable, Logic, Technology

1. INTRODUCTION

The integration of programmable logic controller improves system functionality and its reliability in modern era. In the 1960's when control systems were still handle using relay control. During this time the control rooms consisted of several walls containing many relays, terminal blocks and mass of wires. The problems related to such kind of system were many such as; the lack of flexibility to expand the process, as well as the inordinate amount of time needed to adjust the process when changes were needed.The early days of the PLCs however, were not as straightforward nor as simple.

There were many things that made the cceptance of the PLCs very difficult. As Morley explains, "We had some real problems in the early days of convincing people that a box of software, albeit cased in cast iron, could do the same thing as 50 feet of cabinets, associated relays, and wiring." Morley recounted that in 1969,"all computers required a clean, air-conditioned environment, yet were still prone to frequent malfunctions. Thus, even though PLCs were and are beside these difficulties, another one was rising due to the dedicated hardware terminals employed to program the early PLC versions. These terminals posed high challenges for the PLC programmers. In this way, according to Scott Zifferer co-founder of ICOM software, and Neil Taylor owner of Taylor Industrial Software found the source of inspiration to begin the evolution of the PLC programming and documentation and to make enormous impacts on the shape of industrial automation.[1]

The way many industrial processes look today, is the result of many years of research, to improve their functionality and productivity of the organization.A Programmable controller is a solid state user programmable control system with functions to control logic, sequencing, timing, arithmetic data manipulation and counting capabilities. It can be viewed as an industrial computer that has a central processor unit, memory, input output interface and a programming device. The central processing unit provides the intelligence of the controller. It accepts data, status information from various sensing devices like limit switches, proximity switches, executes the user control program store in the memory and gives appropriate output commands to devices like solenoid valves, switches etc.

Input output interface is the communication link between field devices and the controllers; field devices are wired to the I/O interfaces. Through these interfaces the processor can sense and measure physical quantities regarding a machine or process, such as, proximity, position, motion, level, temperature, pressure, etc. Based on status sensed, the CPU issues command to output devices such as valves, motors, alarms, etc. Programmer unit provides the man machine interface. It is used to enter the application program, which often uses a simple user-friendly logic.[5]

An automated system is characterized by the presence of memory or reverse links (feedback, response). In this way it evolves in time without needing human intervention. For automatic contact and relays storing the previous state is achieved by means of contact auto maintenance k which is also a reverse link from the output relay entry the output y (level measured in meters) of the adjusted automatically in the installation, the device 1 (transducer), device 2 (automatic), device 3 (the execution), electromagnetic S1, the valve V1 and the entry u (flow measured in m3 / h) process.. For example, there is a loop adjustment level and the symbol of the three devices begins with the letter L. The way how it is implemented the automatic influences many powerful economic and technical characteristics of the system automatically. This technology has been and still is widespread automated systems to small and cheap. There is a great experience in this technology, gained over decades of use. The automated systems achieved by using this are robust, cheap, can operate in hostile environments, are least sensitive to disturbance, may be achieved in a large number of variants to adapt to very different processes and can be easily maintained by a staff a not too high qualification.

1.1 The PLC As A Computer

A PLC is a computer, but a different type form the one we are probably used to seeing and working with. Most of people are familiar with data-processing computers, especially microcomputers such as those from Apple, and IBM. These machines sit on your desk, or even on your lap, and have powerful systems and applications software that let you play games, do word processing, create computer-aided design (CAD) drawings, and layout spread sheets. Such computers process reams of data, which is why they are called data-processing machines. Their input peripherals are the keyboard and mouse; their output peripherals, the video display terminal (VDT), Printer, and plotter.

There is another type of computer, however, known as a process-control computer. Although it, of course, processes data, its main function is to control manufacturing and industrial processes (machinery, robots, assembly lines. etc).

Such computers are said to be event driven. Although they may have a keyboard input peripheral, their control inputs are switches and sensors, and although output peripherals such as VDTs and printers may be attached, the process-control computer primarily controls such devices as motors, solenoids, lights, and heaters. Such process-control computers, which number in the millions, are the control element in virtually all modern factory operations.

PLCs are a type of process-control computer: small relatively inexpensive environmentally hardened, and easy to program, operate, maintain, and repair. They are often installed close to the machinery or process they control and are thus seen as an extension of industrial equipment.

Although PLCs are similar to 'conventional' computers in terms of hardware technology, they have specific features suited to industrial control:

- Rugged, noise immune equipment
- Modular plug-in construction, allowing easy replacement/ addition of units (e.g. input/output);
- Standard input/output connections and signal levels;
- Easily understood programming language (e.g. ladder diagram or function chart)
- Ease of programming and reprogramming in-plant

These features make programmable controllers highly desirable in a wide variety of industrial-plant and process-control situations.

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1.1.1 OVERALL PLC-SYSTEM

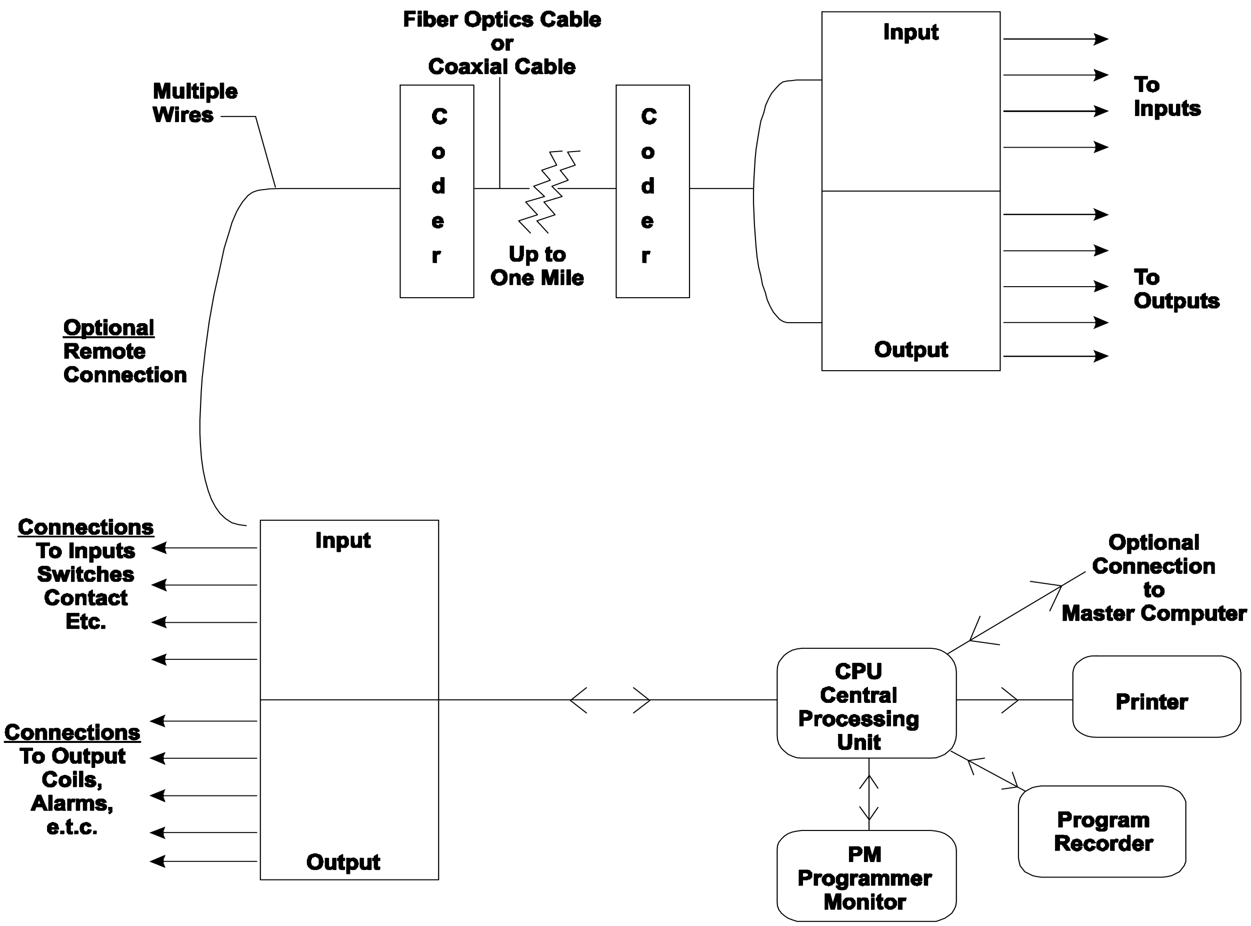

Fig. 1.1: PLC System Layout and Connection

Fig. 1.1 shows in block form, the four major units of a PLC system and how they are interconnected. The four major parts are:

1. Central Processing Unit, which is the 'heart' or the 'brain' of the system. It has 3 sub-parts:
   - (a) Processor
   - (b) Memory
   - (c) Power Supply

2. Programmer/Monitor
3. I/O Modular
4. Racks and Chassis

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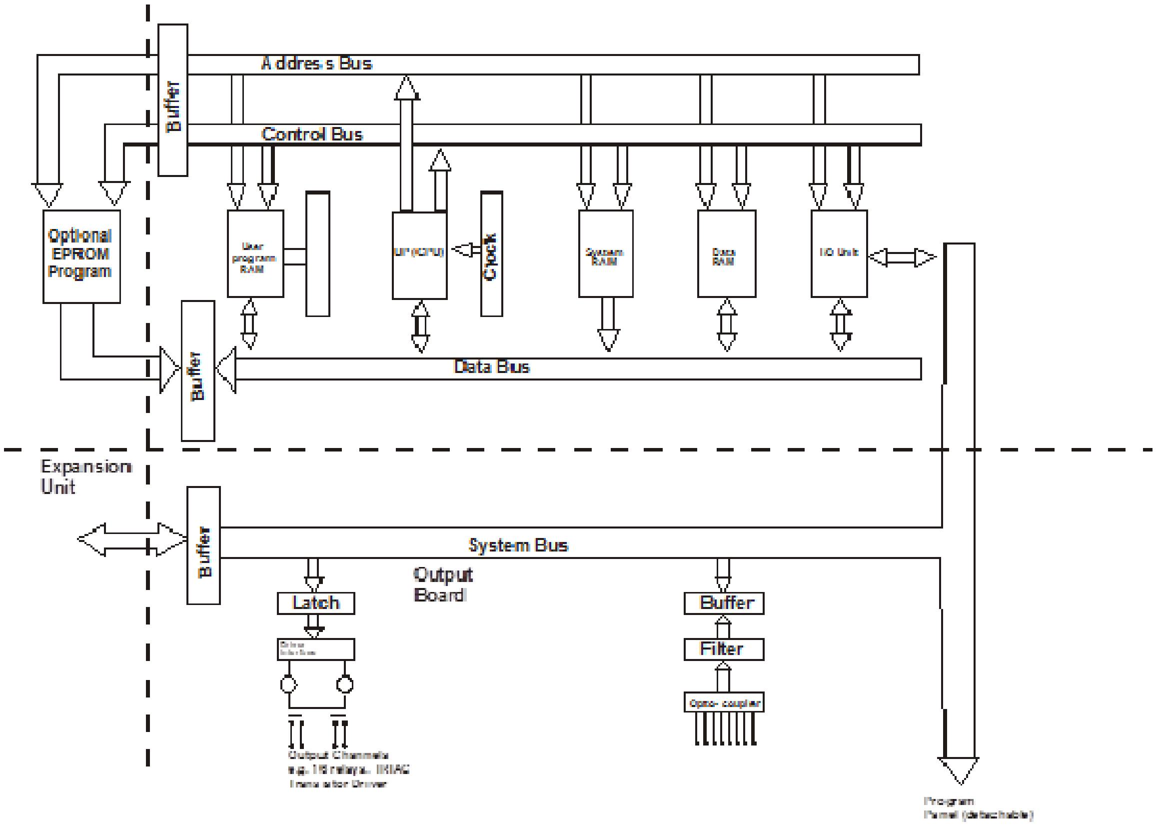

Figure 1.2 Detailed PLC- Architecture.

1.2 PLC Merits

PLCs have been gaining popularity on the factory floor and will probably remain predominant for some time to come. Most of this is because of the advantages they offer which are as follow:

(a) **Flexibility:** In the past, each different electronically controlled production machine required its own type of controller. But now one model of a PLC can serve as the controller for any of the machines.

(b) **Implementing Changes and Correcting Errors:** With a wired relay-type panel, any program alterations require time for rewiring of panels and devices. When a PLC program circuit or sequence design is made, the PLC program can be change from a keyboard sequence in a matter of minutes. No rewiring is required for a PLC-controlled system.

(c) **Lower Cost –** Increased technology makes it possible to condense more functions into smaller and less expensive packages. Now, you can purchase a PLC with numerous relays, timers, counters and other function for a few hundred dollars.

(d) **Large Qualities of Contacts:** The PLC has a large quantity of contacts for each coil available in its programming. Time will be taken to procure and install a new relay or relay contact block when a design change is made requiring more contacts.

(e) **Pilot Running:** A PLC programmed circuit can be prerun and evaluated in the officer or lab.

(f) **Visual Observation:** A PLC circuit's operation can be seen during operation directly on a CRT screen. The operation or mis-operation of a circuit can be observed as it happens. Logic paths light up on the screen as they are energized. Troubleshooting can be done more quickly during visual observation.
(g) **Speed of Operation** – Relays can take an unacceptable amount of time to actuate. The operational speed for the PLC logic operation is determined by the scan time, which is a matter of milliseconds.
(h) **Ladder or Boolean Programming Method:** The PLC programming can be accomplished in the ladder mode by an electrician or technician. Alternately, a PLC programmer who works in digital or Boolean control systems can also easily perform PLC programming.
(i) **Reliability and Maintainability:** Solid-state devices are more reliable in general than mechanical system or relays and timers. The PLC is made of solid-state components with very high reliability rates. Consequently, the control system maintenance cost are lower and downtime is minimal.
(j) **Documentation:** An immediate print out of the true PLC circuit is available in minutes if required.
(k) **Security:** A PLC program change cannot be made unless the PLC is properly unlocked and programmed. Relay panels tend to undergo document changes.
(l) **Ease of Changes by Reprogramming:** Since the PLC can be reprogrammed quickly, mixed production processing can be accomplished. For example, if part B comes down the assembly line while part A is still being processed, a program for part B's processing can be reprogrammed into the production machinery in a matter of seconds.
(m) **Simplicity of Ordering Control System Components:** When the PLC arrives, all the counters, relays and other components arrive as one delivery. With the PLC, one more relay is available – provided you ordered a PLC with enough computing power.[6]

1.2.2 PLC Derits

(a) **Fixed Program Applications:** Some programs are single function application. It does not pay to use a PLC that includes multiple programming capabilities if they are not needed. One example is in the use if drum controller/ sequencers.
(b) **Environmental Considerations:** Certain process environment, such as high heat and vibration, interfere with the electronic devices in PLC's which limits their use.
(c) **Fixed-Circuit Operation:** If the circuit in operation is never altered, a fixed control system (such as a mechanical drum) might be less costly than a PLC. The PLC is most effective when periodic changes in operation are made.
(d) **Fail-Safe Operation:** In relay systems, the stop button electrically disconnects the circuit; if the power fails, the system stops. Furthermore the relay system does not automatically restart when power is restored. This, of course, can be programmed into the PLC; however, in some PLC programs, you may have to apply an input voltage to cause a device to stop. These systems are not fail-safe. This disadvantage can be overcome by adding safety relays to a PLC system.[6]

2. APPLICATIONS OF A 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 as follow thus;[7]

- ✓ The batch processes in chemical, cement, food and paper industries which are sequential in nature, requiring time of event based decisions is controlled by PLCs.
- ✓ In large process plants PLCs are being increasingly used for automatic start up and shut down of critical equipment. A PLC ensures that equipment cannot be started unless all the permissive conditions for safe start have seen established. It also monitors the conditions necessary for safe running of the equipment and trips the equipment whenever any abnormality in the system is detected.
- ✓ The PLC can be programmed to function as an energy management system for boiler control for maximum efficiency and safety.
- ✓ In automation of bulk material handling system at ports.
- ✓ In automation for a ship loader.
- ✓ Automation for wagon loaders.
- ✓ For blast furnace charging controls in steel plants.
- ✓ In automation for galvanizing unit.
- ✓ For chemical plants process control automation.
- ✓ In automation of a rock phosphate drying and grinding system.
- ✓ Modernization of boiler and turbo generator set.
- ✓ Process visualization for mining application.
- ✓ Criteria display system for power station.
- ✓ As stored programmed automation unit for the operation of diesel generator sets.
- ✓ In Dairy automation and food processing.
- ✓ For a highly modernized pulp paper factory.
- ✓ In automation system for the printing industry.
- ✓ In automation of container transfer crane.
- ✓ In automation of High-speed elevators.
- ✓ In automation of machine tools and transfer lines.
- ✓ In Mixing operations and automation of packaging plants.
- ✓ In compressed air plants and gas handling plants.
- ✓ In fuel oil processing plants and water classification plants.
- ✓ To control the conveyor/classifying system.[5]

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2.1 Automatic Mixing System

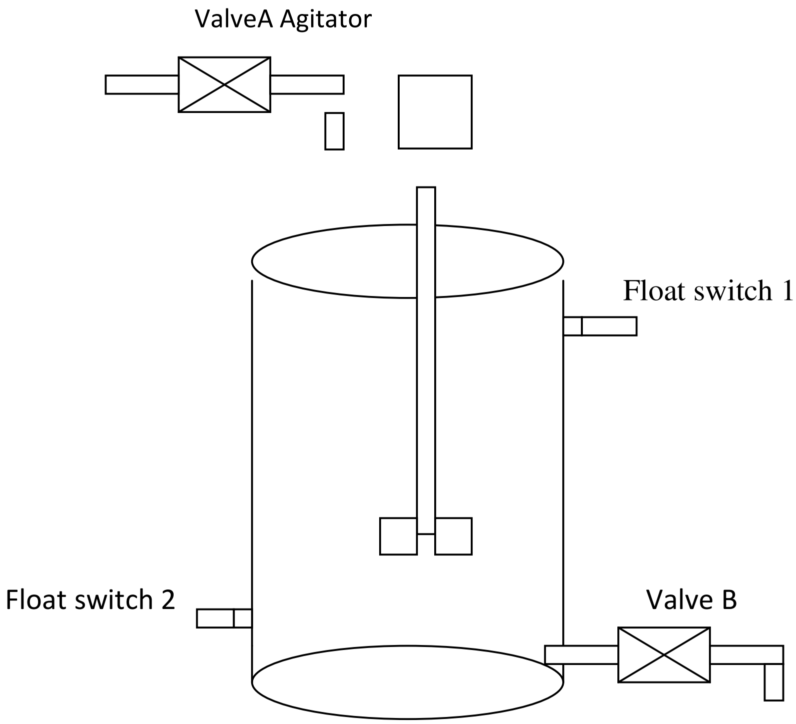

Fig. 2.1: Automatic mixing system

In figure shown, when START button is pressed, solenoid valve A is energized and a batch of liquid is entered in tank. Float switch 1 detects the upper limit of liquid of liquid level and Float switch 2 detects the lower limit of liquid. As, tank begins to fill, Switch 2 closes. When the tank is full, switch 1 shuts off the solenoid valve A and start agitator to mix the liquid. The Agitator mixes the liquid for 30 seconds and shuts off. When the Agitator turn off, solenoid valve B is energized to drain the liquid. After the tank has been emptied, float switch 2 opens and solenoid B shuts off. The Addresses of I/P and O/P are given below.

DEVICE	**ADDRESS**	
	NO	NC
Stop Switch	I 04	I 24
Start Switch	I 05	I 25
Float Switch 1	I 06	I 26
Float Switch 2	I 07	I 27
Valve A	U 00	U 20
Valve B	U 01	U 21
Agitator Motor	U 02	U 22
Control Relay	U 03	U 23

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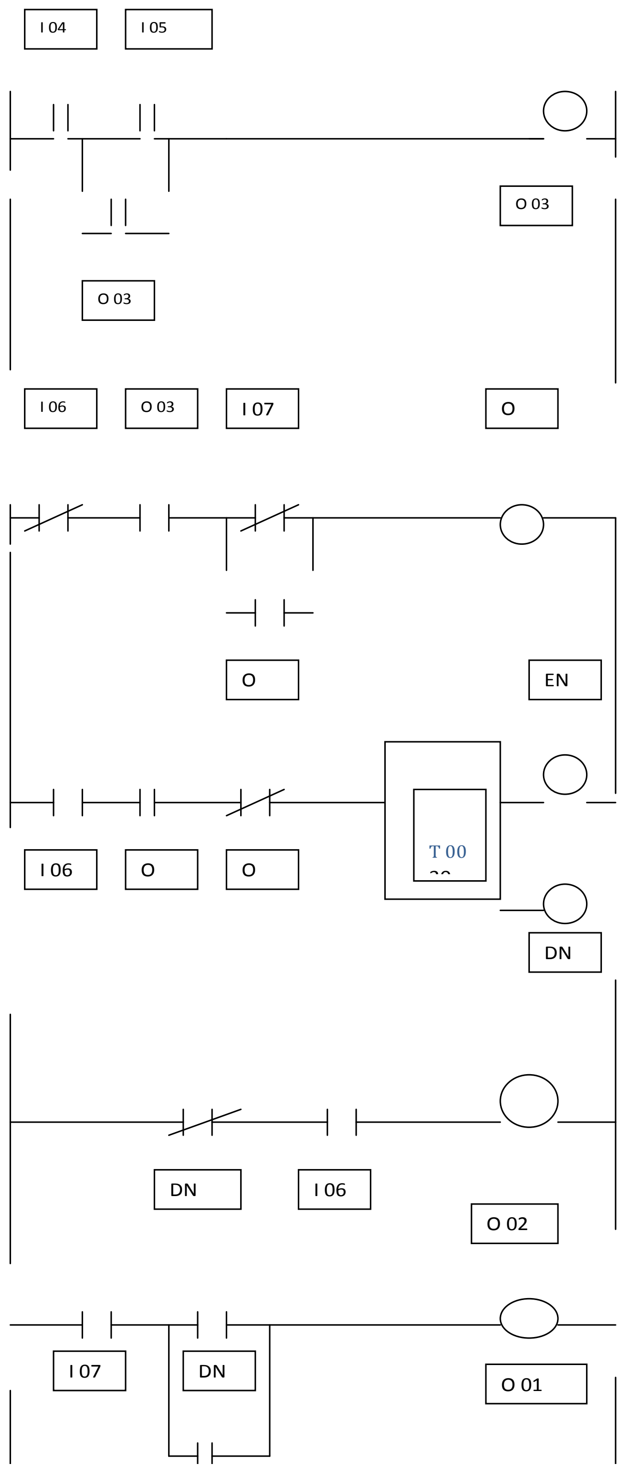

Fig. 2.2: The ladder diagram of above automatic system

2.2 Program in STL language

```
A I 04
A
O I 05
O U 03
= U 03
A I 26
A U 03
A
O I 27
O U 00
= U 00
A I 06
A U 03
A U 21
= T 00 1f
A T 02
A I 06
= U 02
A I 07
A
O T 00
O U 01
= U 01
E
```

2.3 Explanation of Ladder Diagram:

In first rung the stop switch is connected in series with start switch to activate the control relay. The stop switch is normally close type whereas start switch is normally open type. So when the start switch is pressed control relay is activated. The start switch is push to on type so normally on contact of control relay is used to latch. In second rung the NC contact of float switch 1 and NO contact of control relay is in series with valve A. When start switch is pressed and the liquid level is below float switch 1 the valve A is opened and it is closed when level touches the float switch 1.The NC contact of float switch 2 is latched by the NO contact of valve A so valve A does not opened as soon as the level falls below the float switch 1 level and remain close till the tank is fully emptied.

In third rung the normally open contact of float switch 1is connected in series with timer so when liquid level reaches to float switch 1, the timer is started. In fourth rung the NC contact of timer DN bit is connected in series with NO contact of float switch 1 to Agitator motor. When liquid level is at float switch 1and the timer is running the motor is turned on. In fifth rung The NO contact of float switch 2 is connected in series with NO DN bit of timer. So when the liquid level is above the float switch 2 and timer turned off the valve B is opened.

3. DISCUSSION

Control engineering has evolved over time. In the past, human beings were the main method of controlling a system. More recently electricity has been used for control and early electrical control was based on relays. These relays allow power to be switched on and off without a mechanical switch. It is common to use relays to make simple logical control decisions. The development of low cost computer has brought the most recent revolution, the Programmable Logic Controller (PLC).[6]

A programmable logic controller (PLC) is a special form of micro- processor-based controller that uses a programmable memory to store instructions and to implement functions such as logic, sequencing, timing, counting and arithmetic in order to control machines and processes,and are designed to be operated by engineers with perhaps a limited knowledge of computers and computing languages. They are not designed so that only computer programmers can set up or change the programs. Thus, the designers of the PLC have pre-programmed it so that the control program can be entered using a simple, rather intuitive, form of language.[8]

3.1 Input/output Section

The I/O section contains input modules and output modules. Functionally, the input modules are equivalent to the signal converters (i.e. Analog to Digital or high power to low power). All modern PLC input modules use optical devices to accomplish electrically isolated coupling between the input circuit and the processor electronics. Each input device is wired to a particular input terminal on the I/O section. Thus if the switch is closed, 5v dc appears on input terminal, converts this dc voltage to a digital 1 and sends it to the processor via programmable peripheral interface (PPI). Conversely, if the switch is open, no dc voltage appears on input terminal. Input section will respond to this condition by sending a digital 0 to the processor. The other input terminals behave identically.[5]

The processor of a PLC holds and executes the user program. In order to carry out this job, the processor must store the most up-to-date input and output conditions.

(a) Input Image Table

The input conditions are stored in the input image table, which is a portion of the processor's memory. That is, every single input module in the I/O section has assigned to it a particular location within the input image table. That particular location is dedicated solely to the task of keeping track of the latest condition of its input terminal. As mentioned in earlier section, if the input terminal has 5v dc power fed to it by its input device, the location within the input image table contains a binary 1(HI); if the input terminal has no 5v dc power fed to it, the location contains a binary 0(LO). The processor needs to know the latest input conditions because the user program instructions are contingent upon those conditions. In other words, an individual instruction may have one outcome if a particular input is HI and a different outcome if that input is LO.

(b) Output Image Table

The output conditions are stored in the output image table, which is another portion of the processor's memory. The output image table bears the same relation to the output interface of the I/O section that while terminals are analog inputs. You can directly connect any analog input to the processor via these terminals. Analog signal from these terminals is first converted to digital value via programmable peripheral interface (PPI). The I/O section's output modules are functionally the same as the output amplifiers. They receive a low power digital signal from the processor and convert it into a high power signal capable of driving an industrial load. A modern PLC output module is optically isolated, and uses a triac, power transistor or relay as the series connected load controlling device. Terminal 1 to 8 are these type of O/P terminals whereas terminal D/A is Analog output terminal from processor. Each output device is wired to a particular output terminal on the I/O interface. Thus, for example, if output module 1 receives a digital 1 by applying 5v dc to output terminal 1, thereby illuminating LED is extinguished. Besides 5v dc (TTL devices), I/O module are also for interfacing to other industrial levels, including 12v dc. The input image table bears to the input modules. That is, every single output module has assigned to it a particular memory location is dedicated solely to the task of keeping track of the latest condition of its output module. Of course, the output situation differs from the input situation with regard to the direction of information flow is from the output image table to the output modules, while in the input situation the information flow is from the input modules to the input image table. The locations within the input and output image tables are identified by addresses, which refers to unique address of each terminal.

(c) Central Processing Unit

The subsection of the processor that actually performs the program execution will be called the central processing unit (CPU) with reference to input and output image table CPU executes the user program and continuously updates the output image table. The output image table has a dual nature; its first function is to receive immediate information from the CPU and pass if on to the output modules of the I/O section; but secondly, it also must be capable of passing output information "backward" to the CPU, when the user program instruction that the CPU is working on calls for an item of output information. The input image table does not have its dual nature. Its single mission is to acquire information from the input modules and pass that information "forward" to the CPU when the instruction that the CPU is working on calls for an item of input information.

(d) User Program Memory

A particular portion of the processor's memory is used for storing the user program instructions. We will use the name user program memory to refer to this processor subsection. Before a PLC can begin controlling an industrial system, a human user must enter the coded instructions that make up the user program. This procedure called programming the PLC. As the user enters instructions, they are automatically stored at sequential locations within the user program memory. This sequential placement of program instructions is self-regulated by the PLC, with no discretion needed by the human user. The total number of instructions in the user program can range from a half dozen or so, for controlling a simple machine, to several thousand, for controlling a complex machine or process. After the programming procedure is complete, the human user manually switches the PLC out to PROGRAM mode into RUN mode, which causes the CPU to start executing the program from beginning to end repeatedly.

(e) The Complete Scan Cycle

As long as the PLC is left in the RUN mode, the processor executes the user program over and over again. Figure depicts the entire repetitive series of events. Beginning at the top of the circle representing the scan cycle, the first operation is the input scan. During the input scan, the current status of every input module is stored in the input image table, bringing it up to date. Following the input scan, the processor enters its user program execution. Sometimes called "program scan". The program executes with reference to input and output image tables and updates output image table. Throughout the user program execution, the processor continuously keeps its output image table up to date, as stated earlier. However, the output modules themselves are not kept continuously up to date. Instead, the entire output image table is transferred to the output module during the output scan following the program execution.

(f) Data Memory

A PLC is a computer, after all. Therefore, it can perform arithmetic, numeric comparisons, counting, etc. Naturally the numbers and data can change from one scan cycle to the next. Therefore the PLC must have a section of its memory set aside for keeping track of variable data, or numbers, that are involved with the user program. This section of memory we will call data memory. When the CPU is executing an instruction for which a certain data value must be known, that data value is brought in from data memory. When the CPU executes an instruction that provides a numerical result, that result is put out into data memory. Thus, CPU can read from or write to the data memory. Understand that this relationship is different from the relationship between the CPU and the user program memory. When the user program is executing, the CPU can only reads from the user program memory, never write to it. The function of the operating system is to present the user with the equivalent of an extended machine or virtual machine that is easier to program than the underlying hardware. Due to this operating system, PLC is very easy to program. It can be programmed using electrical schemes with familiar relay symbols so that a plant electrician can easily access the PLC. Even though he does not know the assembly language or even if he may not have any familiarity with computers and electronics, he will be able to program the PLC.

The function of PLC Operating system is:

1. Loads the user program from programming device to program memory.
2. To read status of input devices.
3. To execute user program.
4. To form and update input image table.
5. As per the status of output image table controls the output devices.
6. To provide user-friendly functions.

This O.S. makes supervision over entire system, so O.S. Programs are said to running in supervisory mode. When the user completely enters his program in user memory, he transfers control from PROGRAM mode to RUN mode. In RUN mode the control of the whole system is transferred to operating system. Now operating system takes care of the whole system such that the whole system becomes automatic and appears as magic to users.[5]

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4. RECOMMENDATION AND CONCLUSION

The future expansion of PLCs, it is recommend that interfacing of DAC is provided on the PLC board, which can be used to give an analog output. Construct of signal-conditioning circuit so we can directly connect the transducers like load cell, thermocouple, LVDT. Designing stepper motor controller, this can be interfaced with PLC.We can further construct PID controller module which can be switched ON or OFF by this PLC so we can control systems using continuous controller in digital fashion. Conclusively, the PLC offers a compromise between advance control techniques and present day technology. It is extremely difficult to forecast the rate and form of progress of PLCs, but there is strong evidence that development is both rapid and cumulative. Though a PLC is not designed to replace a computer, it is useful and cost effective for medium sized control systems. With the capability of functioning as local controllers in distributed control systems. PLCs will retain their application in large process plants.

A further development of PLCs leads to the development of programmable function controller (PFC) is compatible to PCs and directly controls the desired functions. In Nigeria every process industry is replacing relay control systems by PLCs and will go for PFCs in near future. In the near future every flats and offices may possess PFCs to control room temperature, as elevator controller, maintain water tank levels, as small telephone exchange etc.[5]

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