INTRODUCTION TO AUTOMATION

Like many buzzwords, the meaning of the term "automation" has become blurred with its increasingly popular use, or, more accurately, its misuse!

An automatic mechanism is a self-acting or self-regulating mechanism that controls an object in accordance with a desired behaviour. Machinery and processes that work automatically have many uses in industry.

Main Uses of Automation

- Operations that need to be repeated
- Marketing large quantities of a product
- Dangerous processes or operations, such as working with toxic chemicals or radioactive materials
- Labor saving operations
- Carrying out accurate sequences, such as placing components on printed circuit boards.

An automated process is often a "closed-loop" system. It gains information or signals from monitoring the output of the system. These are then used to 'feedback' and automatically adjust and control input to the system. The feedback principle is very essential to automatic control mechanisms, which enables a designer to endow a machine with the capacity for self-correction. A feedback loop is a mechanical, pneumatic, or electronic that senses or measures a physical quantity such as position, temperature, size, or
speed, compares it with the pre-established standard, and takes whatever preprogrammed action is necessary to maintain the measured quantity within the limits of the acceptable standards. Through feedback devices, machines can start, stop, speedup, slowdown, count, inspect, test, compare, and measure. These operations are commonly applied to a wide variety of production operations that can include milling, boring, bottling and refining.

**Importance of Computer in Automation**

The advent of computer has greatly facilitated the use of feedback loop in manufacturing process. Computers and feedback loops have promoted the development of numerically controlled machines (the motions of which are controlled by punched paper or magnetic tapes) and machining centers (machine tools that can perform several different machining operations).

More recently the introduction of microprocessors and computer combinations have made possible the development of computer aided design and computer aided manufacture (CAD & CAM) technology. A computer is used to monitor and govern the entire operation of the factory, from scheduling each step of production to keep tracking of parts inventory and tools used.

**Equipments sued in Automation:**

- Common automation equipment includes:
- Controlled conveyors
- Robots
- Pick-and-place machines
- Process control equipment
- Automatic test equipment
Common enabling equipment includes:

- Equipment for supplies and services, such as water, air and electricity
- Handling devices
- Jigs and fixtures
- Computers
- Microprocessors
- Programmable controllers

**Automation Specification**

An automation specification is a list of the main features of the automated system or process, which are:

- What action the system should perform
- The number of components or items to be handled in a certain time
- The speed and accuracy of operation
- Where savings can be made, such as time and labour

**Investigating Automation**

Important features to consider are:

- The automation requirements, including the main purpose, the links with other parts of the manufacturing process and the control requirements
- Automation equipment used
- Enabling equipment used
- Operation of the automation process, such as the components handled and the sequence of handling
• Health and safety requirements in terms of working environment, materials, equipment used and the product produced.

**Reasons for Automating**

• Mitigate the effects of labor shortages
• Reduce labor cost
• Increase labor productivity
• Improve product quality
• Improve worker safety
• Reduce or eliminate routine manual and clerical tasks
• Reduce manufacturing lead-time
• Accomplish processes that cannot be done manually
• Reduce unit cost.

**Shortage of labor**

In the U.S., in 1995, the ratio of the number of workers making social security payments to the number of retirees drawing social security checks was 3:1. It was expected to go to 2:1 in 2000. About half of Japanese manufacturing companies have invested in automated systems to cope with labor shortages. Labor growth in Japan is estimated to be 0.4 annually from 1994 to 2000. In 2000, 15% of the work force will be over 65.

**High cost of labor**

In industrialized societies the labor costs have been constantly increasing. Japan's labor costs are 5% more than the U.S. and over 50% higher than the U.K. Germany imports cheap labor to augment domestic labor. Less industrialized countries are not far behind. Taiwan's manufacturing labor cost quadrupled from 1974 to 1984.
while Korea’s manufacturing labor cost doubled from 1979 to 1984, and quadrupled again between 1984 and 1996.

<table>
<thead>
<tr>
<th>Country</th>
<th>1985</th>
<th>1995</th>
</tr>
</thead>
<tbody>
<tr>
<td>Germany</td>
<td>9.6</td>
<td>31.88</td>
</tr>
<tr>
<td>Japan</td>
<td>6.34</td>
<td>23.66</td>
</tr>
<tr>
<td>France</td>
<td>7.52</td>
<td>19.34</td>
</tr>
<tr>
<td>USA</td>
<td>13.01</td>
<td>17.20</td>
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<tr>
<td>UK</td>
<td>6.27</td>
<td>13.17</td>
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<tr>
<td>Malaysia</td>
<td>1.08</td>
<td>1.59</td>
</tr>
<tr>
<td>South Korea</td>
<td>1.23</td>
<td>7.40</td>
</tr>
<tr>
<td>China</td>
<td>0.19</td>
<td>0.25</td>
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<tr>
<td>India</td>
<td>0.35</td>
<td>0.25</td>
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</tbody>
</table>

**Table**: Hourly labor costs in manufacturing for 1985 and 1995 in U.S. dollars

**Increased productivity**

Higher production output per hour of labour input is possible with automation than with manual operations. For example, GM’s collaboration with Toyota in Fremont, California employs 3100 workers in contrast to 5100 at a comparable GM plant. Productivity is the single most important factor in determining a nation’s standard of living. If the value of output/hour goes up, the overall income levels go up. (Artificial increases in wages lead to inflation, so productivity of human resources should govern employee wages).

**Competition**

The ultimate goal of a company is to increase profits. However, there are other measures that are harder to measure. Automation may result in lower prices, superior products, better labour relations,
and a better company image. Not automating (maintaining status quo) may allow hungrier competition to steal market share and sales. (E.g., Honda could defend against Yamaha's assault on the motorcycle market by being able to introduce or replace 113 models in 18 months).

**Safety**

Automation allows the employee to assume a supervisory role instead of being directly involved in the manufacturing task. For example, die casting is hot and dangerous and the work pieces are often very heavy. In fact, the first industrial robot was used by General Motors in 1961 for the automation of die casting 9. Welding, spray painting and other operations can be a health hazard. (Machines can also do these jobs more precisely and achieve better quality products.)

**Reducing manufacturing lead time**

Automation allows the manufacturer to respond quickly to the consumers needs. Toyota and Honda are able to introduce a new model (preliminary design to manufactured car) between 13-18 months. This figure is 21 months for Detroit and over 24 months for European automobile companies.

Second, flexible automation also companies to handle frequent design modifications. For example, in the first 18 months after the introduction of new compression brakes in Cummins diesel engines, there were 14 design changes.

Automation is also allowing organizations to move from the traditional "mass production model" to mass customization. Toyota uses its highly skilled and flexible work force to make individually
customized products (more models, colors, options etc.). Levis Strauss has started to manufacture individually tailored jeans. While Japan dominates the market for commodity memory chips, U.S. producers such as National Semiconductor II are leaders in customized chips (each chip can cost as much as a million dollars). U.S. labor Secretary R. Reich writes about the transformation from high-volume production to high-value production.

**Lower costs**

In addition to cutting labor costs, automation may decrease the scrap rate and thus reduce the cost of raw materials. It also enables just-in-time manufacturing which in turn allows the manufacturer to reduce the in-process inventory. It is possible to improve the quality of the product at lower cost.

**PROGRAMMABLE LOGIC CONTROLLERS**

A Programming Logic Controller (PLC) is a microprocessor-based system designed to perform logical decision making for Industrial Control Applications. A PLC is a digitally operated electronic equipment which uses programmable memory for its internal storage of instructions for implementing specific functions such as logic, sequencing, timing, counting and arithmetic operations through input/output modules for automation of various types of machine processes.

**History of PLC's**

Development began in 1968, after a request from GENERAL MOTORS. To reduce the cost of rewiring, General Motors called for a solid state system that had the flexibility of a computer, yet could be programmed and maintained by the plant engineers and
technicians. It also had to withstand the dirty air, vibrations, electrical noise, temperature etc.

The first PLCs were installed in 1969. They quickly became a success, as they were more reliable than relay based systems especially due to the ruggedness of the solid state as compared with moving parts and electromagnetic relays. They took less space, provided materials, installation, supported flexible reprogramming, trouble shooting and labor cost saving. The programming language was based on the ladder diagram and electronic symbols used by electricians and plant personnel. No matter what the application, use of PLC helps increase competitiveness.

Introduction

Now a days food processing industries are coming up with good quality of products due to automated plants, which are well equipped with PLC’s (Programmable Logic Controllers) at every stage.

Basically PLC (Programmable Logic Controller) is a device—more precisely a system— which can control logical or sequential operation of events/device along with the associated inter locking conditions applicable for start/stop of that device. Thus in a process if we have in all twenty drives which run the whole process, then there is a specific sequence in which this process/drive must start or stop. Previously the starting and stopping was done by relays, the relay logic panel. Then followed the discrete gates and the latest trend is PLC — the programmable logic controller — using microprocessor or micro computer. The earliest PLC was developed in 1968 by consulting engineering firm called Bedford Associated
and the first PLC was developed as a dedicated computer control system for the general Motors Hydramatic divisions. Working of the PLC can be understood with the help of Ladder - Diagram technique.

Parle Biscuits Ltd. Bahadurgarh, is one of the leading concerns in biscuit manufacturing. They are producing three brands under their name i.e. Monnaco, Parle-G, Krackjack. Initially they started in late seventies with fully mechanical set up where large manpower was required. High power consumption was in demand by plant. Then in mid eighties they converted the plant into semi automated plant by replacing mechanical panels with electronics panels but they too were bulky. In mid nineties, they have emerged with fully automated plant by replacing bulky electronics panel with sophisticated and light weighted PLC panels at every stage of plant right from autoweighting of maida & sugar to packaging of biscuits in packets and putting packets into boxes.

Theoretically we have studied PLC in detail with the help of literature available in journals and books, but that is only one side of the coin. Another one is when we actually put the things at the industry, we have to deal with many environmental parameters i.e. humidity, temperature, vibration, dust etc. Confronting with all this, we have to take certain precautions which are enlisted further in the table. Apart from this, we came across problems like interchanging of voltages, non-availability of experts, improper training imparted to engineers, surge voltages, mishandling of devices and many others which are tabulated with their causes and remedies. All the details tabulated below are being collected after having intensive
discussions with engineers of Parle Biscuits and experts from PLC manufacturing companies. This effort has been taken up with full sincerity and authenticity. No such work has been published so far in the literature available related to PLC’s.

PLC is the heart of PLC panel and a great amount of precaution is taken while collecting the details. PLC single handedly controls many processes simultaneously which reduces the requirement of manpower and supply power consumptions. It also increases the accuracy and precision in bringing out the products. Therefore, now a days it is the necessity of every process industry to be facilitated with PLC’s. Also there will be reduction in the time for the completion of product as well as hygiene and sanitation of plant will be maintained which is at top priority for any process industry.

Many companies are active in manufacturing PLC’s. At Parle Biscuits Ltd. we have got PLC’s of different makes form ALLEN BRADLEY, TELEMECANIQUE, SIEMENS, B&R Ltd. PLC is the very versatile device and it has got very small failure which reduces the brake down and improves the quality and quantity of product in the given stipulated period. Under the name of above mentioned companies we came out with good quality PLC’s.

WHY USE A PLC?

This question / topic has been a very debatable issue. Today one generally accepted rule is that PLCS became economically viable in control systems that need three four relays. They offer lucrative benefits are stated after the table provided on the next page.
PROBLEMS, THEIR CAUSES AND REMEDIES OF PLC'S WHEN OPERATING AT INDUSTRIAL LEVEL:

<table>
<thead>
<tr>
<th>Problem</th>
<th>Reasons</th>
<th>Remedial Actions</th>
</tr>
</thead>
<tbody>
<tr>
<td>1) PLC cards burnt off.</td>
<td>i) Possibility of putting A.C. card into D.C. card slot or vice versa.</td>
<td>i) Supply specifications must be checked properly before connecting the PLC.</td>
</tr>
<tr>
<td>a) communication card failure</td>
<td>ii) A.C. supply provided to D.C. Cards.</td>
<td>ii) Repairmen should be trained properly before allowing him to handle the PLC.</td>
</tr>
<tr>
<td>b) Digital I/P &amp; O/P card failure</td>
<td>iii) High intensity supply is provided to low supply requiring cards.</td>
<td></td>
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<tr>
<td>b) Analog I/P &amp; O/P Card</td>
<td>iv) Negligence of repairman/engineer.</td>
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<tr>
<td>2) Internal Short circuiting in PLC circuit</td>
<td>v) Untrained repairman /Engineer.</td>
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<tr>
<td>i) Drilling at some places in panel after the installation of card.</td>
<td>i) PLC card should be covered properly while drilling.</td>
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<tr>
<td>3) Loosening of PLC card connections with panel slots.</td>
<td>i) Vibrations produced when mechanical machines are operating at high speed.</td>
<td>i) Proper suspensions i.e. springs or rubber pads must be provided below the panel.</td>
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<td></td>
<td>ii) There should be some provision that PLC panel can be placed away from the vibratory environment.</td>
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<tr>
<td>Problem</td>
<td>Reasons</td>
<td>Remedial Actions</td>
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<tr>
<td>4) Nuisance tripping</td>
<td>i) High ambient temperature</td>
<td>i) Panel A.C. must be provided</td>
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<td></td>
<td>ii) Humidity during the monsoon whether.</td>
<td></td>
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<tr>
<td>5) Faculty cards at the time of installation or maintenance.</td>
<td>i) Improper handling of cards.</td>
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<td></td>
<td>ii) Due to body static charge.</td>
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<td></td>
<td>iii) Untrained repairmen.</td>
<td></td>
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<td></td>
<td>iv) Due to welding in running condition.</td>
<td></td>
</tr>
<tr>
<td>6) Abnormal behaviour of PLC.</td>
<td>i) Surges in Power supply</td>
<td>i) Handle the card with high degree of delicacy &amp; as per specifications provided in manual.</td>
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<tr>
<td></td>
<td>ii) Dusty Environment.</td>
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<td>iii) Enters in stop mode.</td>
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<td></td>
<td></td>
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</tr>
<tr>
<td></td>
<td>i) Put filters and surge suppressors at input supply</td>
<td></td>
</tr>
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<td></td>
<td>ii) Panel should be dust free.</td>
<td></td>
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<tr>
<td></td>
<td>iii) It can be placed at some distance from the dusty environment.</td>
<td></td>
</tr>
<tr>
<td></td>
<td>iv) Reset the PLC to be activated again.</td>
<td></td>
</tr>
<tr>
<td>Problem</td>
<td>Reasons</td>
<td>Remedial Actions</td>
</tr>
<tr>
<td>-------------------------------------</td>
<td>----------------------------------------------</td>
<td>-----------------------------------------------------</td>
</tr>
<tr>
<td>7) Overall software corrupted.</td>
<td>i) Surges in power supply</td>
<td>i) Filters and surge suppressors are being installed at Input supply.</td>
</tr>
<tr>
<td></td>
<td>ii) Communication cables crosses A.C. supply cables.</td>
<td>ii) Communication cables are isolated form A.C. supply</td>
</tr>
<tr>
<td></td>
<td>iii) Wrong handling of RESET switch.</td>
<td>iii) Repairman must be trained properly before handling a specific PLC.</td>
</tr>
<tr>
<td></td>
<td>iv) Some removes back up battery by mistake.</td>
<td>iv) Back up battery must be replaced before it expires.</td>
</tr>
<tr>
<td></td>
<td>V) Expiry of Back up battery.</td>
<td>v) FAT (Factory analysis test) must be there so as to avoid any fault in the wires.</td>
</tr>
<tr>
<td></td>
<td>vi) Wring i.e. connecting wrong wire at wrong place.</td>
<td></td>
</tr>
<tr>
<td>8) Indicator fails.</td>
<td>i) LED’s are faulty</td>
<td>i) LED must be checked before being on.</td>
</tr>
<tr>
<td></td>
<td>ii) Due to more supply LED below off.</td>
<td>ii) Supply checks should be provided.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>iii) LED should be replaced.</td>
</tr>
</tbody>
</table>

1. **COST SAVING** : Due to reduced wiring and associate wiring errors, it has become a boon for the manufacturers as well as the customers especially those belonging to the small segment.

2. **RELIABILITY** : It allows the transfer and download of a program from one PLC to the other. This in turn reduces programming time, minimizes debugging and increases reliability. It reduces wiring errors as only wiring required is for power, inputs and outputs.
3. **FLEXIBILITY**: Modifications can be done by both the OEMs (ORIGINAL EQUIPMENT MANUFACTURERS) and the End-users by just a few keystrokes.

4. **ADVANCED FUNCTIONS**: They can perform a wide variety of control tasks, from a single, repetitive action to complex data manipulation. Standardizing on PLCs opens many doors for designers, and simplifies the job for maintenance personnel.

5. **COMMUNICATIONS**: Communicating with operator interfaces other PLCs or Computer facilitates data collection and information exchange.

6. **SPEED**: In complex processes where time factor is very important, PLCs quick response capability is very important. eg. Packaging Industry.

7. **DIAGNOSTICS**: The troubleshooting capability of programming devices and the diagnostic resident in the PLC allow users to easily trace and correct Software and Hardware problems.

**BASIC ARCHITECTURE OF A PLC:**

![BASIC ARCHITECTURE OF A PLC](image)

Fig. 7.1
A PLC system comprises of:

- INPUTS
- OUTPUTS
- CENTRAL PROCESSING UNIT
- MEMORY FOR PROGRAM AND DATA STORAGE
- POWER SUPPLY
- PROGRAMMING DEVICES
- OPERATOR INTERFACES

All PLC's from micro to very large, use these same basic components and are structured in the similar fashion as shown below.

**INPUTS**

The input screw terminals on a PLC form the interface which field connects devices to the PLC. Inputs include items such as pushbuttons, thumbwheel switches, limit switches, selector switches, proximity sensors and photoelectric sensors. These are all discrete devices that provide an On or Off status to the PLC.

The electrical signals that field devices send to the PLC are typically unfiltered 120V ac or 24V dc. The input circuitry on the PLC takes this field voltage and "conditions" it to usable by the PLC. Conditioning is necessary because the internal components of a PLC operate on 5V dc, and this minimizes the possibility of damage by shielding them from voltage spikes. To electrically isolate the internal components from the input terminals, PLCs employ an optical isolator, which uses light to couple signals from one electrical device to another.
The PLC's input circuitry also “filters” field voltage signals to qualify them as valid, such as a signal from a sensor, or not valid, such as high-frequency electrical “noise” or static. Input filters determine the validity of a signal by its duration; they “wait” to confirm that a signal is a reference from an input device rather than electrical noise. A typical filter time is 8ms, but some PLCs have adjustable input filter response times. A longer response time provides better filtering of electrical noise. A shorter response time helps in applications that require high-speed operation (e.g., interrupts or counting).

**OUTPUTS**

The outputs connected to the output terminals of the PLC are devices like solenoids, relays, contractor, motor starters, indicator lights, values and alarms. Output circuits operate in a manner similar to input circuits: signals from the CPU pass through an isolation barrier before energizing output circuits. PLCs use a variety of output circuits to energize their output terminals: relays, transistors and triacs.

- **Relays** are for either AC/DC power. Traditional PLC electromagnetic relays typically handle current up to a few amperes. Relays can better withstand voltage spikes and they have an air gap between their contacts, which eliminates the possibility of current leakage. However, they are comparatively slow when subject to wear overtime.

- **Transistors** switch dc power, are silent and have no moving parts to wear out. They are fast and can reduce response time but only carry loads of 0.5 amps or less. Special type of
transistors such as FETs can handle more power, typically up to 1 amp.

- Triacs strictly switch ac power. Like transistors, triac outputs are silent, have no moving parts to wear, are fast and carry loads of 0.5 amps or less.

CENTRAL PROCESSING UNIT (CPU)
The CPU made up of a microprocessor and a memory system forms the primary component of the PLC. The CPU reads the inputs, executes logics as dictated by the application program, performs the calculations and controls the output accordingly.

PLC uses work with two areas of the CPU, program files and data files.

**Program files** store a users application program, subroutine files and error files.

**Data files** store data associated with the program such as I/O status, timer counters, preset and accumulated values and other stored constants or variables. Together these two areas are called the application or user memory.

Also within the CPU is an executive program or system memory that directs and performs operation activities such as executing the user program and co-ordination input scans and output updates. System memory, which is programmed by the manufacturer, cannot be accessed by the user.

**TYPES OF MEMORY**
Programmable Logic Controllers have programmable memory that allows users to develop and modify the control programs. Memory is
a physical space inside the CPU where the program and data files are stored and manipulated.

**Memory types fall in two categories:**
**Volatile of Non Volatile.**

**Volatile memory** can be easily altered or erased and it can be written to and written from however without proper back up, a power loss can cause a loss of programmed contents. The best-known form of Volatile memory is RANDOM ACCESS MEMORY (RAM). RAM is relatively fast and offers an easy means to create and store users application programs. If normal power is disrupted, micro PLC's with RAM memory use battery/capacitor backups to prevent program losses.

**Non-Volatile memory** retains its programmed contents without battery or capacitor backups even if power is lost. The EEPROM is a non volatile memory that has the same flexibility as RAM and is programmed through application software which runs on a PC or through a micro PLC's Hand Held Programmers (HHP's)

**DATA, MEMORY AND ADDRESSING**
Memory is a physical space where as Data is information stored in that space. The CPU operates like a computer; it manipulates Data using binary digits or bits. A bit is a discreet location within a silicon chip that either has a voltage present read as, a value of 1 (ON) or not present, read as a value of 0 (OFF). Thus Data is a pattern of electrical charges that represent a numerical value.

**OPERATING CYCLE**
All the components of the PLC system come into play during the operating cycle, which consists of operations performed sequentially and repeatedly. The major elements of an operating cycle are
THE INPUT SCAN: During the input scan, the PLC examines the external input device for a voltage present or absent that is ON/OFF state. The status of the inputs is temporarily stored in an “input image” memory file.

PROGRAM SCAN: During the program scan, the PLC scans the instructions in the ladder logic program, uses the input status from the input image file and determines if an output will or will not be energized. The resulting status of the output is written in the “output image” memory file.

OUTPUT SCAN: Based on the data in the output image file, the PLC energizes or de-energizes the output circuits, controlling external devices.

POWER SUPPLIES

The Power Supply provides power to the controller’s internal electronics, converts the incoming voltage to a usable form and protects the PLC components from voltage spikes. These power Supplies are designed to maintain normal operation even if the voltage varies from 10 to 15 percent. Sometimes a voltage transformer is also installed between the PLC and the primary power source. A PLC can operate for several milli seconds without the power before the power, supply signals can no longer provide adequate dc power to the system.

Until recently, all micro PLCs operate on 24 V dc. however several micro PLC manufacturers now offer products that operate either on 120 V ac, 220 V ac or 24 V dc.
PROGRAMMING DEVICES
When entering a program into a PLC the two devices most commonly used are:

- Personal Computer (PC)
- Hand Held Programmer (HHP)

The PC is used to run PLC Programming Software which allows the users to create, edit, document, store and troubleshoot ladder diagrams and generate printed reports. The HHP is used as a troubleshooting tool because it is compact and has its own memory to store programs.

OPERATOR INTERFACES
To communicate with the PLC, to enter data or monitor and control machine status, traditional operator interfaces include push buttons, thumb wheel switches, pilot lights and LED numeric displays. To improve the interface between the operator and the PLC a new generation of electronic operator interface devices or peripherals can be connected. These are not programming devices but graphic or alphanumeric displays and control panels that consolidate all the functions of traditional operator interface devices into a single panel. These interfaces can output data and display message about machine status in descriptive text ("motor 1 ON"), display parts count and track alarms. They can also be used for data input by providing better and more easily conveyed information; these instructions decrease the need for operator training on machine operation and reduce system, component and installation cost. These products communicate with the PLC through an RS 232 Communications Port. This opens up input, output points that can be used for
sensors and output devices and enables a PLC to control a more complex machine or process.

RELIABILITY DESIGN

A principle of design must be that it should be inherently reliable, in the expected environments and for its expected life and take into account the expected production processes. This requires that the design in addition to having an understanding and taking into account of the usual design features such as stress, weight, appearance etc. must also fully appreciate the range of expected environmental conditions throughout the life of the product and the production methods which will be used in the manufacture. Therefore it is necessary to adopt a more disciplined approach to design with a view to ensuring that the high demands of the modern market for reliability are met.

The objective is to design a given product/system meets the target failure rate (or target reliability) under the specified environmental conditions. The assumption is made that all components and elements are operating in the useful region where failure rate is constant with time.

Causes of unreliability:

- Design mistake.
- Manufacturing defects.
- Maintenance neglected.
- Exceeding design limits.
- Environmental factors.

Designing for reliability:
• Design as simple as possible. Greater the number of components, the greater the chance of failure.
• Derating.
• Design with fail safety in mind.
• Redundancy.
• Item projected from extremes of environmental conditions will have increased reliability.
• Maintainability and serviceability.
• Optimum level of reliability.
• Trade off of decrease in weight for the decrease in reliability.
• The greater the degree of specification the greater inherent reliability of the design.

RELIABILITY TESTING

Reliability testing is done to ensure that the product will operate without failure during its expected life cycle since reliability is a function of time and variability, reliability tests must be performed over suitably long period of time to ensure that important failure modes particularly wear out failure are generated. Comprehensive reliability testing leads to lower total development costs, reduced cost of warranty and support and reduction in other direct and indirect cost of failure.

Reliability tests:

There are four areas of testing:

• **Environmental stress screening.**

  These tests are conducted at lower level of the product to identify early failures due to weak parts, workmanship defects and other reasons for non conformance.
- **Reliability development / growth tests:**
  There tests are performed before the final release of the design with a view to improving product reliability through identification, analysis corrections of failures and verification of the corrective actions.

- **Reliability qualification tests:**
  These tests are conducted on a product which is representative of the approved production configuration. The test provide assurance that the production articles will confirm to the reliability requirements.

- **Production reliability acceptance tests:**
  There tests provide periodic evaluation of reliability of production hardware, particularly when any changes have been made in design, tooling processes, parts or other characteristics.

**Life testing:**

Life testing is used to obtain failure data for reliability estimation methods. In life testing, a sample of components from a hypothesized populations of such components is placed under test using the environment in which the components are expected to function and their corresponding times to failures are received.

In general two major types of tests are conducted: the first with replacement of failed components and the second without replacement of fail components. In the test with replacement as soon as a component fails, it is replaced by a new identical one. In the test without replacement, a component is not replaced when it fails, and the test continues with the remaining component.
Due to long life of certain component, it is sometimes necessary to terminate the test and perform the reliability analysis based on the observed data up to the point of termination. There are two types of possible life test with terminations: the first is time terminated and the second is failure terminated. In the time terminated life test $n$ units are placed under the test and the test is terminated after a predetermined number of clock hours have elapsed. The number of components failed during the test time and the corresponding time to failure of each components are recovered. In the failure terminated life tests $n$ units are placed under test and the test is terminated when a predetermined number of components failures have occurred. The time to failure of each failed components and the time that the last failure occurred are recovered. For each type of tests there are two possibilities: with replacement or without replacement.

**Accelerated testing:**

Accelerated testing is a common form of securing reliability test data at reduced testing cost. In this form of testing the products are made to perform at abnormally high levels of stress and/or environments in order to make them fail sooner. Earlier failures means less tests equipments, lower testing costs and earlier assurance. Extrapolation is then used to convert the short life under severe conditions into the expected life under normal conditions. Accelerated testing can introduce new failure modes which do not occur during normal product used.
Sequential testing:

The sequential probability ratio test have been devised to establish in the shortest possible time and at minimum cost, whether or not the reliability of a type of component or of a system is equal to or better than a specified minimum. The method enables to make one of three decisions as each failures occurs, accept, reject or continue testing. Hence two values of mean life $\lambda_1$ and $\lambda_2$ are established. $\lambda_1$ is some minimum acceptable value and $\lambda_2$ is some chosen acceptable value. After r failures have occurred the probability of r failures is computed occurring for a mean life of $\lambda$.

In the case of Poisson distribution, the probability of r failures in time t for an equipment whose times to failures are exponentially distributed is

$$P_r = \frac{(t/\lambda)^r e^{-t/\lambda}}{r!}$$

Where $\lambda$ is the chosen mean life. Having computed this for $\lambda_1$ and $\lambda_2$ take the $P_{\lambda_1}/P_{\lambda_2}$ and compare this against two selected positive constants A and B, which are based on previously agreed on risks – the consumers risk $\beta$, and producers, risk $\alpha$.

$$A = 1 - \beta/\alpha, \quad B = \beta/1-\alpha$$

At each failure, accept if $P_{\lambda_1}/P_{\lambda_2} \leq \beta$,

Reject if $P_{\lambda_1}/P_{\lambda_2} \geq A$,

continue testing if $\beta < P_{\lambda_1}/P_{\lambda_2} < A$.

Reliability centered maintenance:

It is a systematic process used to determine what has to be accomplished to ensure that any physical facility is able to
continuously meet its designed functions in its current operating context.

RCM leads to maintenance programmes that focus PM on specific failure modes likely to occur. The organization gets benefit from RCM if its breakdown is greater than 25% of maintenance workload.

Goals and principles of RCM

GOALS:
- To develop design associated priorities that can facilitate PM.
- Together information useful for improving the design of items with proven unsatisfactory, inherent reliability.
- To develop PM related tasks that can reinstate reliability and safety to their inherent levels in the event of the equipment or system deterioration.
- To achieve this goal when the total cost is minimal.

PRINCIPLES:
- RCM is system/equipment focused.
- Safety and economic derive RCM
- RCM is function oriented.
- Design limitations are acknowledged by RCM.
- RCM is reliability centered.
- An unsatisfactory condition is defined as a failure by RCM.
- RCM is a living system.
- Three type of maintenance tasks along with run to failure are acknowledged by RCM.
- RCM tasks must be effective.
- RCM uses a logic tree to screen maintenance tasks
- RCM tasks must be applicable.
Related questions:
Any RCM process should ensure that all the following questions are answered effectively as per their sequence

- What are the functions and associated expected levels of the facility performance in its current operating context?
- How might it fail to meet its assigned functions?
- What are the reasons for each functional failure or failure mode?
- What is the effect of each failure?
- How does each failure matter?
- What remedial measures should be taken to prevent or predict each failure?
- What measures should be taken in the event of not finding suitable proactive tasks?

RCM PROCESS:

- Identify important items with respect to maintenance.
- Obtain appropriate failure data
- Develop fault tree analysis data
- Apply decision logic to critical failure modes
- Classify maintenance requirements
- Implement RCM decisions
- Apply sustaining engineering on the basis of field experience.


RCM COMPONENTS:

**REACTIVE MAINTENANCE PRIORITY CLASSIFICATIONS**

<table>
<thead>
<tr>
<th>Priority Description</th>
<th>Priority Level</th>
<th>Criteria based on system/equipment failure consequences</th>
</tr>
</thead>
<tbody>
<tr>
<td>Emergency</td>
<td>I</td>
<td>Serious and immediate impact on mission&lt;br&gt;Safety of life/property is under threat</td>
</tr>
<tr>
<td>Urgent</td>
<td>II</td>
<td>Serious and an impending impact on mission&lt;br&gt;Continuity of facility operation is threatened</td>
</tr>
<tr>
<td>Priority</td>
<td>III</td>
<td>Significant and advance effect on project is imminent&lt;br&gt;Degradation in quality of mission support</td>
</tr>
<tr>
<td>Routine</td>
<td>IV</td>
<td>Insignificant effect on mission&lt;br&gt;Existence of redundancy</td>
</tr>
<tr>
<td>Discretionary</td>
<td>V</td>
<td>Resources are available&lt;br&gt;Impact on mission is negligible</td>
</tr>
<tr>
<td>Differed</td>
<td>VI</td>
<td>Unavailability of resources&lt;br&gt;Negligible impact on mission</td>
</tr>
</tbody>
</table>

Table 7.2

Fig. 7.2